Engineering Policy Ballot

Effective: October 1, 2025

Level 2

Level two revisions require the approval of the **Assistant Chief Engineer** and the **Federal Highway Administration** only. The Senior Management Team is encouraged to review the content and provide comment to the appropriate director. For all other parties, these revisions are posted for information only.

ENGINEERING POLICY BALLOT

Effective: October 1, 2025

Issue 1: Revises Sec 1018 to include Type IL in accordance with AASHTO M240 and updates sampling language. Removes auto-sampling references from EPG 1018

Approval: **Level 2 – Assistant Chief Engineer**

Sponsor: Robert Marshall – CM

Summary: Adds Type IL cement as the reference cement for testing fly ash replacing Type I which is no longer supplied. Also, added Type IL where needed to replace Type I. Added clauses to the specifications that needed to be revised that were outdated and were more general in nature.

Publication: Missouri Standard Specification: Sec 1018
Engineering Policy Guide: 1018.5

Issue 2: Sec 403.13.1 Paving Widths revised to uneven lanes which is more consistent with Sec 401 and 402

Approval: **Level 2 – Assistant Chief Engineer**

Sponsor: Jason Blomberg – CM

Summary: Sec 403 language currently requires the full width of pavement to be completed as soon as practical or the next operating day unless otherwise approved. This change brings Sec 403 in alignment with Sec 401 and 402 by modifying the length of time before required placement of adjacent lane. Uneven pavement conditions for any section of pavement can be no longer than 7 days.

Publication: Missouri Standard Specification: Sec 403

Issue 3: Hybrid polymer concrete for partial depth pavement repair

Approval: **Level 2 – Assistant Chief Engineer**

Sponsor: Jason Blomberg – CM

Summary: New product for Class A partial depth pavement repair for concrete pavement.

Publication: Job Special Provision: new JSP

Issue 4: TM 93 - CaO, MgO, and Al2O3 testing by instrumental analysis

Approval: **Level 2 – Assistant Chief Engineer**

Sponsor: Robert Marshall – CM

Summary: CaO, MgO, and Al2O3 shall be tested by instrumental analysis rather than analytical methods to avoid swayed results from other elements present in analytical methods.

Publication: Engineering Policy Guide: 106.3.2.93 TM-93

Issue 5: Sec 1061 Revision to address issues with wire durability on signal/lighting projects

Approval: **Level 2 – Assistant Chief Engineer**

Sponsor: Gretchen Hanks – DE

Summary: Revises to Sec 1061-Electrical Conductors to require the use of more durable wire currently being specified by JSP in some districts.

Publication: Missouri Standard Specification: Sec 1061

Issue 6: Revising Power Outage at Signalized Intersections requirements

Approval: **Level 2 – Assistant Chief Engineer**

Sponsor: Joseph V. Mulnik – TS

Summary: Removing the requirement of district power outage plans for signalized intersections from EPG 902.5.43.

Publication: Engineering Policy Guide: 902.5.43

Issue 7: Torque and Angle Fixed Spline Bolts

Approval: **Level 2 – Assistant Chief Engineer**

Sponsor: Darren Kemna – BR

Summary: Adding guidance for the installation of ASTM F3148 TNA Fixed Spline bolts.

Publication: Missouri Standard Specification: Sec 712, Sec 1080
Engineering Policy Guide: 712.1.5 thru 712.3.3, 751.50, 1080

Issue 8: Conical pile points and reinforcing steel pay item for Cast-In-Place (CIP) concrete pile

Approval: **Level 2 – Assistant Chief Engineer**

Sponsor: Darren Kemna – BR

Summary: Clarify conical pile points to require ASTM A148, Grade 90-60 and not allow the grade 35 shoes for CIP correlating with recent changes requiring modified Grade 3 shells with a 50 ksi yield strength. Pay item clarified for CIP reinforcing steel.

Publication: Missouri Standard Specification: Sec 702
Engineering Policy Guide: 751.50

Issue 9: System L Coating Specification

Approval: **Level 2 – Assistant Chief Engineer**

Sponsor: Darren Kemna – BR

Summary: Provide an inorganic ethyl silicate topcoat option for inorganic zinc primers on structural steel. Other miscellaneous coating issues are addressed.

Publication: Missouri Standard Specification: Sec 1045, Sec 1081
Engineering Policy Guide: 751.2.9.2, 751.6.1, 751.6.2.11, 751.6.2.12, 751.14.5.8, 751.50, 1045

Issue 10: MSE wall setback distance from bridge abutments

Approval: **Level 2 – Assistant Chief Engineer**

Sponsor: Suresh Patel – BR

Summary: Clarifying clear space requirement between MSE wall and front face of the abutment beam (setback distance). Additional reasoning provided and increased minimum setback.

Publication: Engineering Policy Guide: 751.25.2.1, 751.50

Issue 11: Seismic details for bridge widening

Approval: **Level 2 – Assistant Chief Engineer**

Sponsor: Suresh Patel – BR

Summary: EPG and Bridge Special Provisions updated to clarify seismic details for bridge widening (one side, two sides, and FRP wrap).

Publication: Engineering Policy Guide: 751.9.1, 751.40.3.2, 751.50

Issue 12: Optional procedure for bridge column buckling design

Approval: **Level 2 – Assistant Chief Engineer**

Sponsor: Darren Kemna – BR

Summary: Implement findings of research project TR202203 in EPG.

Publication: Engineering Policy Guide: 751.31.2.4

Issue 13: Prestressed Girder Stress Limits for Bridges

Approval: **Level 2 – Assistant Chief Engineer**

Sponsor: Darren Kemna – BR

Summary: Provides EPG guidance for prestressed girder stress limits.

Publication: Engineering Policy Guide: 751.21.2, 751.22.2.3

SECTION 1018

FLY ASH FOR CONCRETE

1018.1 Scope. This specification covers fly ash for use in ~~Portland cement~~ concrete.

1018.2 General. Only fly ash from sources qualified in accordance with these specifications will be permitted. The mixing of different classes and sources of fly ash will not be permitted. All fly ash shall be in accordance with AASHTO M 295, Class C, F or ~~F~~N, except as herein specified.

1018.2.1 Class C fly ash shall meet either (a) or (b) of the following requirements:

(a) The 7-day Strength Activity Index with ~~Portland~~ Type IL cement shall be ~~at~~ a minimum of 85 percent of the control.

(b) The Calcium oxide content shall be 23 percent, minimum.

1018.2.1.1 All Class C fly ash shall have a minimum Strength Activity Index with ~~Portland~~ Type IL cement of 85 percent of the control at 28 days.

1018.2.2 The percent each of silicon dioxide (SiO_2), aluminum oxide (Al_2O_3) and iron oxide (Fe_2O_3) shall be reported in addition to the total of the three.

1018.2.3 Loss on Ignition shall not exceed 1.5 percent unless supplie~~s~~rs provide test data verifying performance and durability ~~in~~of fly ash concrete applications for sources exceeding this requirement.

1018.2.4 The term “manufacturer”, as used in this specification, will be the actual manufacturer of the fly ash. The term, “marketing entity”, as used in this specification, will be the supplier or broker of the fly ash. The marketing entity shall be responsible to be in accordance with these specifications.

1018.2.5 Cement used for testing fly ash shall be a Type IL in accordance with AASHTO M~~85~~240.

1018.2.6 All marketing entities, terminals, and independent testing laboratories shall be qualified prior to acceptance of any material.

UNCHANGED SPECS – INTENTIONALLY NOT SHOWN

1018.4 Marketing Entity Qualification. In order to become qualified, a written request shall be sent by the marketing entity to Construction and Materials, along with a copy of the marketing entity’s QC plan and the following information. The power plant and terminals may be inspected to verify the information and to establish personal contact with the QC personnel.

1018.4.1. The following information shall be included in the request for qualification:

(a) An outline of the QC program from the coal yard to the point where the product is relinquished to the purchaser. The QC program shall cover all tests required by the specification, and shall include the testing frequency for each test. The name of the testing laboratory shall also be included.

(b) A copy of the testing laboratory's most recent Cement and Concrete Reference Laboratory (CCRL) inspection report and the latest CCRL proficiency sample report. The CCRL inspection shall cover all tests required by the specification. Documentation showing satisfactory resolution of all inspection deficiencies shall be included.

(c) Complete name and address of the fly ash source and owner. If located in an area without precise address identification, a complete map description shall be furnished.

(d) Complete name and address or map location of the coal mine. If more than one source of coal is used, all sources shall be listed.

(e) Type of coal used.

(f) Class of fly ash produced and number of units producing fly ash meeting the specified requirements herein.

(g) A description of production procedures including, but not limited to, any additives mixed with the coal during production, any additive or dust suppressant used to collect the fly ash, ash collection methods, production capacity in tons (Mg) per day, and the proportions and proportioning procedures of any blended coals.

(h) Description of storage facilities, including capacities and set-aside capabilities.

(i) A copy of a typical bill of lading in accordance with the certification statement.

(j) A split sample of the class of fly ash proposed for use, MoDOT will request where the sample shall be obtained for approval.~~obtained from the autosampler over a minimum of one production day.~~ The marketing entity's test results for the split sample shall also be submitted.

UNCHANGED SPECS – INTENTIONALLY NOT SHOWN

1018.6.3 Shipping. Fly ash shall be continually sampled and tested ~~via autosamplers~~ at a location, frequency and duration acceptable to MoDOT, and may be continuously shipped direct from a marketing entity or generating station silo.

UNCHANGED SPECS – INTENTIONALLY NOT SHOWN

1018.5 Laboratory Procedures for Sec 1018

1018.5.1 Sample Preparation

Prior to testing, the sample should be thoroughly mixed, passed through a No.20 [850 mm] sieve, and brought to room temperature. All foreign matter and lumps that do not pulverize easily in the fingers must be discarded.

1018.5.2 Procedure

Chemical analysis is to be conducted according to ASTM C114 and MoDOT Test Methods T46 and T91. Original test data and calculations are to be recorded in Laboratory workbooks. Test results are to be recorded through AWP and retained on file in the Laboratory.

Physical tests on the following are to be conducted in accordance with ASTM C311.

(a) Fineness, 325 (45 mm) sieve analysis ASTM C430

(b) Pozzolanic Activity Index (7 day) ASTM C311

(c) Water requirement ASTM C311

(d) Soundness, autoclave ASTM C311

(e) Specific Gravity ASTM C311

Original test data and calculations are to be recorded in Laboratory workbooks. Test results are to be recorded through AWP and retained on file in the Laboratory.

1018.5.3 Source Acceptance

Samples are to be taken by the manufacturer in accordance with ASTM C311 from the conveyor, after exiting the precipitator collector and prior to entry into the designated storage silo, or where designated by the engineer.

Ash, that is manually sampled and tested every 400 tons, is to be held until the required tests have been run and the results are properly certified and are available for pick up by MoDOT personnel prior to shipment.

Ash, that is continually sampled and tested ~~via auto samplers~~ at a frequency and duration acceptable to the engineer, can be continuously shipped direct from a generating station silo, provided the following minimum criteria are met:

a. The storage silo has a minimum capacity of two days production or 1000 tons, whichever is the largest.

b. The storage silo is full, and certified test results on the entire contents are available prior to the first shipment.

c. The ash quantity in the silo is never less than 400 tons.

d. A continual inventory of the quantity of ash in silos is maintained within one shift of being correct.

e. The engineer has free access to station facilities and records necessary to conduct inspection and sampling.

f. All ash conveyance lines to the designated silo or silos will be sampled after precipitator collector and prior to entry into the designated silo(s)~~, or by an auto sampler~~ where designated by the engineer.

~~g. Each precipitator bank line shall have its own auto sampler placed per paragraph (f) above, if it does not join a common line with an auto sampler.~~

~~h. The allowance of one auto sampler in a common line serving multiple precipitator banks will depend on the placement of the auto sampler, tons of ash generated per day, the number of hoppers in each bank and the number of banks. This will be at the discretion of the engineer.~~

i. The generating station personnel handle and expedite all documents required to ship by MoDOT Certification.

1018.5.4 Plant Inspection

Qualified fly ash manufacturers and terminals shipping material by certification to Department projects shall be inspected on a regular basis by a representative of the Laboratory. This inspection shall include a review of plant facilities for producing a quality product; plant testing procedures; frequency of tests; plant records of daily test results and shipping information; company certification procedures of silos, bins, and/or shipments; and a discussion of items of mutual interest between the plant and the Department. The Laboratory representative shall coordinate test results and test procedures between the Laboratory and the respective plant laboratory, and investigate associated problems.

All silo or bin certifications and results of complete physical and chemical tests received in the Laboratory are to be checked for specification compliance and to determine if the required certifications have been furnished.

1018.5.5 Sample Record

The sample record shall be completed in AASHTOWARE Project (AWP) in accordance with AWP MA Sample Record, General, and shall indicate acceptance, qualified acceptance, or rejection. Appropriate remarks, as described in EPG 106.20 Reporting, are to be included in the remarks to clarify conditions of acceptance or rejections. Test results shall be reported on the appropriate templates under the Tests tab.

SECTION 403

ASPHALTIC CONCRETE PAVEMENT

UNCHANGED SPECS – INTENTIONALLY NOT SHOWN

403.13.1 Uneven Lanes~~Paving Widths~~. ~~The following shall apply for roadways constructed under traffic. For pavements having a width of 16 to 24 feet, inclusive, the asphaltic concrete pavement shall be laid in lanes approximately one half the full width of the completed pavement, and the full width shall be completed as soon as practical. Unless otherwise permitted, a single lane of any course shall not be constructed to a length that cannot be completed to full width of the pavement the succeeding operating day. For pavements greater than 24 feet wide, single lane width construction shall be limited to one day's production and completion to full width shall be accomplished as soon as practical.~~ For roadways constructed under traffic, u~~U~~neven pavement lanes shall not be left in place for ~~no~~ more than seven days, unless approved by the engineer.~~ Removal of pavement to be in accordance with this specification shall be at the contractor's expense.~~

UNCHANGED SPECS – INTENTIONALLY NOT SHOWN

Hybrid Polymer Concrete for Use in Partial Depth Pavement Repairs JSP

1.0 Description. This work shall consist of removal, furnishing, and placing hybrid polymer concrete material to repair existing concrete pavement by performing partial depth concrete pavement repairs as specified in the plans or as approved by the engineer. All work shall be in accordance with Section 613 except as modified herein.

1.1 Acceptable Manufacturer Systems. The chosen HPC system shall meet the performance requirements as stated in this provision and shall be FasTrac CE700 HPC or approved equal.

2.0 Materials.

2.1 Resin Binder. The HPC Resin binder shall be a 100 percent solid two-component, thermosetting hybrid system that is moisture insensitive and shall comply with the following requirements:

Resin Binder		
Property	**Requirement**	**Test Method**
Viscosity*	750 Centipoise, minimum	ASTM C881 / AASHTO M 235
Flash Point	>200° F	ASTM D3278
VOC Content	<10 g/L	EPA24
Styrene Content	0%, maximum	ASTM D2369
Gel Time	10 minutes, minimum	C881 / ASTM M 235
Tensile Strength	2000 - 2500 psi at 7 Days	ASTM D638
Tensile Elongation	50% minimum at 7 Days	ASTM D638
Tensile Bond Strength to Concrete	250 psi or 100% Substrate Failure	ASTM C1583 (ACI 503R)
Water Absorption	0.5% @24 hours, maximum	ASTM D570
Type D Hardness	60-80	ASTM D2240
Thermal Compatibility	Pass	ASTM C884
Chloride Ion Permeability	<10.0 Coulombs	AASHTO T277

*Spindle and speed selection based upon ASTM D2556.

2.2 Mixed Aggregates.

2.2.1 Crushed Particles. Aggregate retained on the No. 8 sieve shall have a maximum of 45 percent crushed particles as determined by AASHTO T 335.

2.2.2 Moisture Content. Moisture content shall not be more than one half of the weighted average as determined by AASHTO T 255 at the time of mixing with the resin.

2.2.3 Aggregate Gradation.

Gradation Requirements	
Sieve Size	**Percent Passing by Weight**
1/2"	100
3/8"	98-100
No. 4	77-100
No. 8	60-82
No. 16	34-56
No. 30	5-25
No. 50	0-15
No. 100	0-7
No. 200	0-3

2.3 Surface Aggregates. Only light-colored aggregate (e.g. flint rock or similar) that meets the requirements of Sec 1039 shall be used on this job. No dark colored aggregate will be allowed (e.g. coal slag).

2.3.1 All aggregates shall be furnished in appropriate packaging that is clearly labeled and protects the aggregate from any contaminates on the jobsite and from exposure to rain or other moisture.

2.4 Delivery of Materials. All materials shall be delivered in their original containers bearing the manufacturer's label, specifying date of manufacturing, batch number, trade name and quantity. Each shipment shall be accompanied by a Material Safety Data Sheet (MSDS).

2.5 Storage of Materials. The material shall be stored to prevent damage by the elements and to ensure the preservation of their quality and fitness for the work. The containers shall be stored in a manner that will not allow leakage or spillage from one material to contact the containers or materials of the other. The storage space shall keep the materials clean and dry and shall contain a high-low thermometer. The temperatures of the storage space shall not fall below nor rise above that recommended by the manufacturer. Every precaution shall be taken to avoid contact with flame.

2.6 Training. The contractor shall arrange to have the material supplier furnish technical service related to application of material and health and safety training for personnel who are to handle the materials. The installer shall be certified by the HPC system supplier.

2.7 Technical Support. The engineer may require the material’s supplier to have a representative onsite during the initial surface preparation and initial placement of the material. The material representative shall provide consultation as Quality Control of the installation of the product, but the engineer will have final decision-making authority in all matters.

3.0 Mix and Application Procedure. The contractor shall prepare and submit all applicable mixing and application procedures to the engineer for approval prior to the preconstruction meeting. All equipment and materials used in the mixing and application procedure shall be in accordance with the manufacturer's requirements.

4.0 Construction.

4.1.1 Surface Preparation. Removal of the existing patched, spalled, delaminated or otherwise deteriorated concrete surface shall be limited to 1/3 (one third) of the pavement

thickness or 4 inches, whichever is less. Removal of concrete shall be accomplished with light jack hammers and/or a mill head designed for concrete milling. All loose materials, including milled or broken concrete or asphalt, crack seal materials, oil, sand, dust, grit or other contaminants, shall be completely removed. Exposed faces of the concrete shall be cleaned with compressed air at a minimum of 100 psi. Removal of material shall be in accordance with Sec 202.2.

4.1.2 If the manufacturer requires priming, all surfaces of the repair area shall be primed using a primer and procedure recommended and approved by the manufacturer. Any costs related to primer shall be included in the unit cost. No direct payment will be made for the priming of the repair areas.

4.1.3 Partially exposed reinforcing steel mesh shall be removed or sandblasted clean before placing patch materials. If sandblasting is used, all surfaces shall be cleaned of loose sandblasting grit with compressed air.

4.2 Placement. The hybrid polymer concrete shall not be placed when weather or surface conditions are such that the material cannot be properly handled, placed and cured per manufacturer's recommendations within the specified requirements of traffic control.

4.2.1 Mixing Equipment. The concrete shall be volumetrically mixed at the job site by a continuous mixer in accordance with Sec 501. Small quantities that can be placed without a volumetric mixer shall be mixed according to the manufacturer's requirements and as approved by the engineer.

4.2.1.1 Batching Information. The continuous mixer shall be equipped with a metering device that automatically measures and records the aggregate volumes and corresponding resin volumes. The volumes shall be recorded at no greater than five-minute intervals along with the time and date of each recording. A printout of the recordings shall be furnished to the engineer at the end of each shift. Readout gages shall be visible to the engineer at all times.

4.2.1.2 Mixture Consistency. The concrete discharged from the mixer shall be uniform in composition and consistency. Mixing capability shall be such that initial and final finishing operations can proceed at a steady pace.

4.2.2 Finishing Equipment. Finishing equipment shall be capable of consolidating the hybrid polymer concrete and striking off the hybrid polymer concrete to the final grade, thickness and cross-sections as shown in the contract documents.

4.2.3 Contamination. The contractor shall prevent any cleaning chemicals from reaching the overlay system components during the mixing operation.

4.3 Placement of Surface Aggregate.

4.3.1 Broadcast Aggregate Application. Dry aggregate shall be applied in such a manner as to cover the overlay completely within 5 minutes of application. The dry aggregate shall be placed in a manner such that the level of the overlay is not disturbed.

4.3.2 Wet spots shall be covered with the aggregate prior to the gelling of the Resin Binder.

4.3.3 After the curing period, all loose aggregate shall be removed by brooming or vacuuming. Any loose aggregate reclaimed for reuse as broadcast aggregate shall be approved by the engineer. At a minimum the reclaimed aggregate shall be screened and verified to be clean, uncontaminated and dry. All reclaimed aggregate must be in conformance with the requirements in Section 2.0 Materials.

4.4 Curing. Traffic and construction equipment will not be permitted on the repair area until the hybrid polymer overlay has adequately cooled and gained strength as recommended by the manufacturer.

4.5 Repair areas in the roadway and shoulders shall be swept clean of all loose debris before opening to traffic.

5.0 Additional or Reduced Work. If additional work is necessary beyond what is specified in the work order or the required repair is not as extensive as originally viewed, the contractor shall contact the engineer for authorization to proceed with the additional or reduced work. The contractor shall note that this authorization to proceed with additional or reduced work may change which unit bid items are used to calculate final payment depending on final repair quantities. Any work performed without authorization of the engineer shall be at the contractor's expense.

6.0 Method of Measurement. Measurement shall be made to the nearest cubic yard based on the actual material used with an acceptable form of package documentation.

7.0 Basis of Payment. Payment for the above-described work, including all material, equipment, labor and any other incidental work necessary to complete this item, will be considered completely covered by the contract unit price for Item 613-99.07, Pavement Repair using Hybrid Polymer Concrete, per cubic yard.

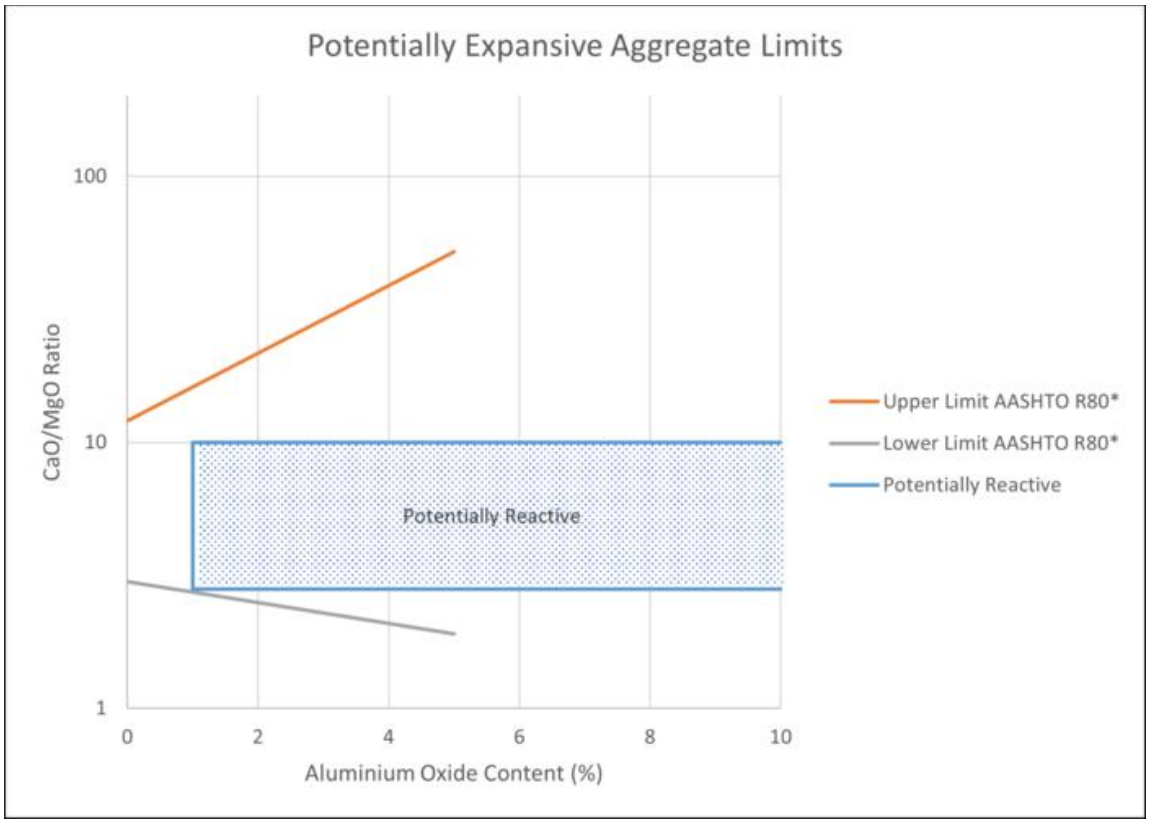
106.3.2.93 TM-93, Alkali Carbonate Reactivity Screening

This test method establishes the procedures for identifying potential alkali carbonate reactivity (expansion) and acceptance of aggregate used in concrete pavements and masonry. This test method applies to new quarries, new ledges (and combinations of ledges), existing quarries and ledges.

106.3.2.93.1 Means of Evaluating Aggregate Alkali Carbonate Reactivity

1. Chemical Analysis

The chemical analysis of aggregate reactivity is an objective, quantifiable and repeatable test. MoDOT will perform the chemical analysis per the process identified in ASTM C 25 for determining the aggregate composition. The analysis determines the calcium oxide (CaO), magnesium oxide (MgO), and aluminum oxide (Al_2O_3) content of the aggregate. The chemical compositions are then plotted on a chart with the CaO/MgO ratio on the y-axis and Al_2O_3 percentage on the x-axis per Fig. 2 in AASHTO R 80. Aggregates are considered potentially reactive if the Al_2O_3 content is greater than or equal to 1.0% and the CaO/MgO ratio is either greater than or equal to 3.0 or less than or equal to 10.0 (see chart below). See flow charts in 106.3.2.93.2 for approval hierarchy. CaO, MgO and Al2O3 shall be analyzed by instrumental analysis only.



* MoDOT's upper and lower limits of potentially reactive (shaded area) aggregates.

2. Petrographic Examination

A petrographic examination is another means of determining alkali carbonate reactivity. The sample aggregate for petrographic analysis will be obtained at the same time as the source sample. MoDOT personnel shall be present at the time of sample. The petrographic sample shall be placed in an approved tamper-evident container (provided by the quarry) for shipment to petrographer. Per ASTM C 295, a petrographic examination is to be performed by a petrographer with at least 5 years of experience in petrographic examinations of concrete aggregate including, but not limited to, identification of minerals in aggregate, classification of rock types, and categorizing physical and chemical properties of rocks and minerals. The petrographer will have completed

college level course work in mineralogy, petrography, or optical mineralogy. MoDOT does not accept on-the-job training by a non-degreed petrographer as qualified to perform petrographical examinations. MoDOT may request petrographer's qualifications in addition to the petrographic report. The procedures in C 295 shall be used to perform the petrographic examination. The petrographic examination report to MoDOT shall include at a minimum:

- Quarry name and ledge name; all ledges if used in combination
- MoDOT District quarry resides
- Date sample was obtained; date petrographic analysis was completed
- Name of petrographer and company/organization affiliated
- Lithographic descriptions with photographs of the sample(s) examined
- Microphotographs of aggregate indicating carbonate particles and/or other reactive materials
- Results of the examination
- All conclusions related to the examination

See flow charts in EPG 106.3.2.93.2 for the approval hierarchy. See EPG 106.3.2.93.3 for petrographic examination submittals. No direct payment will be made by the Commission for shipping the petrographic analysis sample to petrographer, or for the petrographic analysis performed by the petrographer.

3. Concrete Prism/Beam Test

ASTM C 1105 is yet another means for determining the potential expansion of alkali carbonate reactivity in concrete aggregate. MoDOT will perform this test per C 1105 at its Central Laboratory. Concrete specimen expansion will be measured at 3, 6, 9, and 12 months. The test specimens will be considered alkali carbonate reactive (expansive) if the specimens expand greater than 0.015% at 3 months, 0.025% at 6 months, or 0.030% at 12 months. See flow chart in EPG 106.3.2.93.2 for the approval hierarchy.

106.3.2.93.2 Approval Process for Potential Alkali Carbonate Reactive Aggregate

1. Process for New Ledges and New Quarries

The flowchart shown in Figure 1 shows the process for determining alkali carbonate reactivity (expansiveness) in new ledges and quarries. It is important to note TM-93 is only for determining whether or not aggregate is potentially expansive. All other requirements of Sec. 1005 shall be met for the ledge(s) to be approved for use in pavement or masonry concrete.

Should ASTM C 1105 test method need to be performed on the aggregate, the quarry will be notified by District personnel that this test method requires 12 months to complete, and during those 12 months, the aggregate cannot be approved for use in pavement or masonry concrete. The aggregate however, can be considered for other uses based on meeting required specifications.

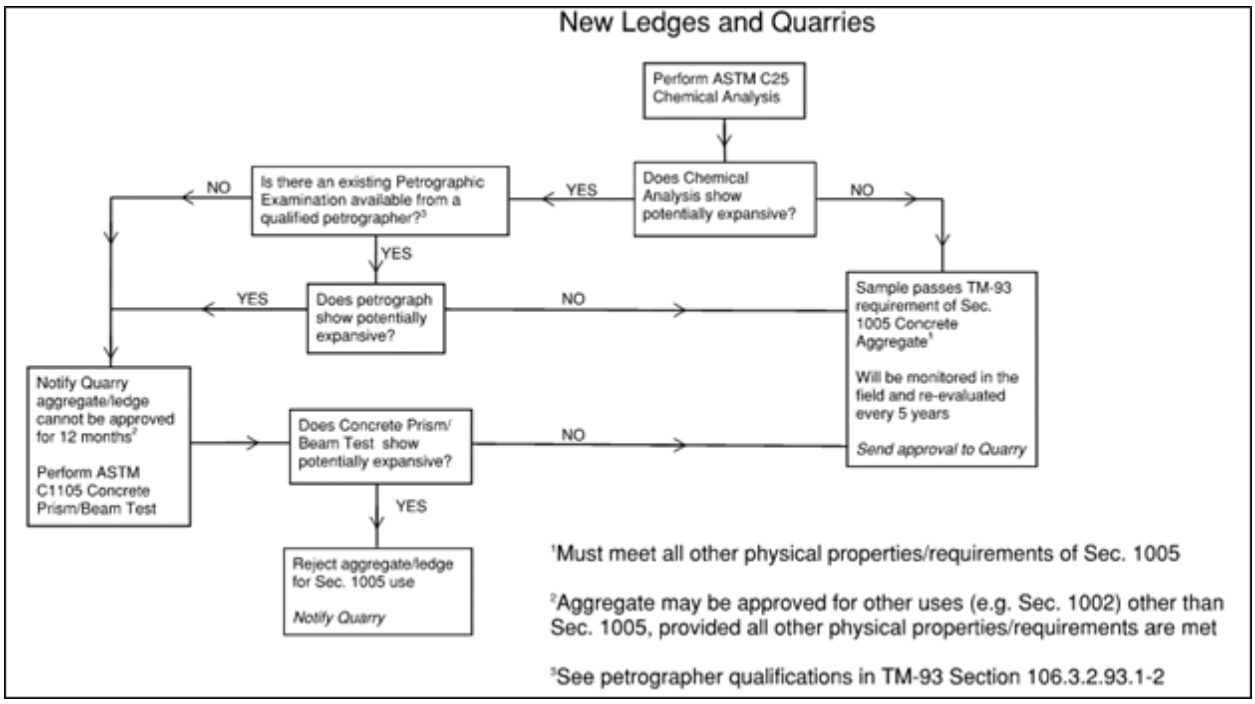


Figure 1. Process for determining alkali carbonate reactivity for new ledges and quarries.

2. Process for Existing Ledges and Existing Quarries

The flowchart shown in Figure 2 shows the process for determining alkali carbonate reactivity (expansiveness) in existing ledges and quarries. It is important to note TM-93 is only for determining whether or not aggregate is potentially expansive. All other requirements of Sec. 1005 shall be met before the ledge(s) are approved for use in pavement or masonry concrete.

Should ASTM C 1105 test method need to be performed on the aggregate, the quarry will be notified by District personnel that this test method requires 12 months to complete, and during those 12 months, the aggregate cannot be approved for use in pavement or masonry concrete. The aggregate however, can be considered for other uses based on meeting required specifications.

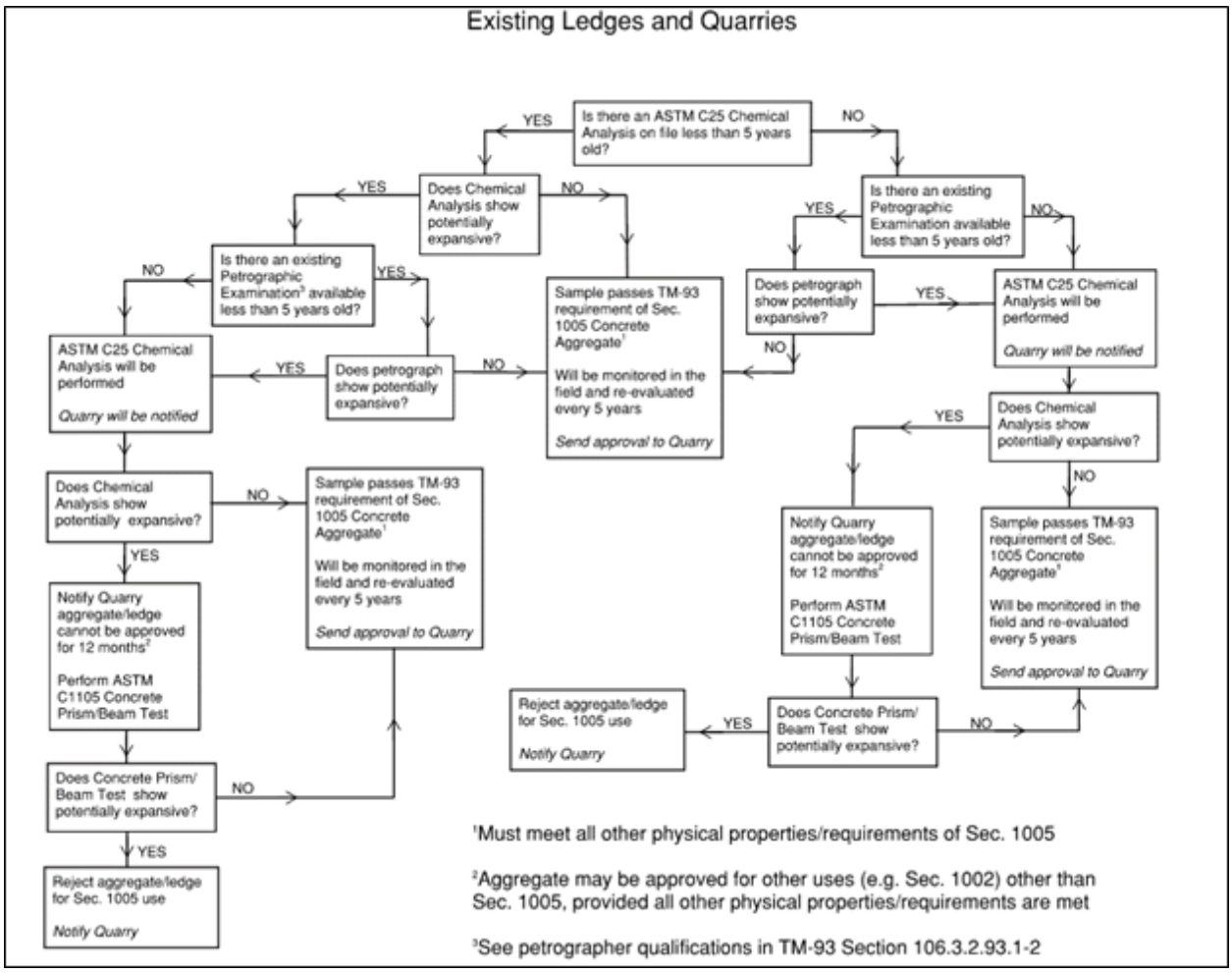


Figure 2. Process for determining alkali carbonate reactivity for existing ledges and quarries.

106.3.2.93.3 Submitting Petrographic Examinations Reports to MoDOT

1. Petrographic Examination Reports

Petrographic examination reports can be used in the process to determine the alkali carbonate reactivity (expansiveness) of aggregate. See petrographer requirements in Section 109.3.2.93.1. When a quarry obtains a petrographic examination report, the report shall be submitted to the District Construction and Materials Department of the district the quarry resides. The submittal can be made electronically or can be an original hard copy mailed/delivered to the district. Hard copy reports will be scanned/digitized for easier file storage. Regardless of whether or not the petrographic examination report shows the aggregate is potentially expansive, MoDOT will retain the report. The district will forward the report to Central Office Construction and Materials Division for document retention. This will allow time to prepare for ASTM C 1105 testing if necessary.

All petrographic reports will be digitally stored by Central Office Construction and Materials Division.

SECTION 1061

ELECTRICAL CONDUCTORS

1061.1 General. This specification covers electrical conductors and associated material for use on highway construction projects. Contractor furnished equipment that will become the property of the Commission shall be of new stock unless stated otherwise in the contract documents. Electrical conductors and associated equipment shall be in accordance with applicable requirements of ICEA, IMSA, NEMA, EIA, NEC, NFPA and regulations of the National Board of Fire Underwriters and shall meet the approval of the engineer.

1061.2 Conductors. Except as noted, all conductors shall be soft drawn, Class B or C stranded copper wire in accordance with ANSI/NEMA WC70/ICEA ~~A~~S-95-658. Solid conductors may be used only for grounding where connected to a ground rod.

1061.3 High Voltage Power Cable. The voltage rating for high voltage power cable supplying primary electrical power shall be 5 KV for primary voltages less than 5,000 volts, and 15 KV for voltages of 5,000 volts and greater. The specific type of cable shall be as recommended and approved by the utility company or municipality supplying power.

1061.4 Low Voltage Power Cable. Low voltage power cable shall be 600-volt, single conductor cable with a temperature rating of 90° C in wet and dry environments and ~~thermoplastic or~~ thermosetting cross-linked polyethylene (XLP) insulated. All cable shall be plainly marked on the outside with the manufacturer's name and identification in accordance with industry practice. Insulation type shall be ~~THHN/THWN-2 or~~XHHW-2. Cable used for service entrances shall be USE-2 rated. Average thickness of insulation shall be no less than specified in the following table, with a minimum thickness of 90 percent thereof.

~~Size (AWG or kcmil)~~	~~Thickness, Mils THHN/THWN-2)~~
~~14-12~~	~~15~~
~~10~~	~~20~~
~~8-6~~	~~30~~
~~4-2~~	~~40~~
~~1-4/0~~	~~50~~
~~250-500~~	~~60~~
~~501-1000~~	~~70~~
Size (AWG or kcmil)	**Thickness, Mils ~~THHN/~~(XHHW-2)**
14-10	30
8-2	45
1-4/0	55
213-500	65
501-1000	80

1061.5 Cable-Conduit. Cable-conduit shall consist of one to four low voltage power cables with an insulated sized electrical neutral and a bare safety ground, factory installed in black

polyethylene conduit intended for direct burial. The conduit shall be plainly marked on the outside with manufacturer's name and identification in accordance with industry practice and shall be in accordance with ASTM D 3485. Cable-conduit shall be accompanied by the manufacturer's certification stating the conduit is in accordance with the requirements of this specification.

1061.6 Pole and Bracket Cable. Pole and bracket cable located in the lighting or signal pole that supplies electrical power to highway lighting shall consist of two single conductors. Wire size shall be No. 10 AWG in accordance with the requirements of low voltage power cable. Insulation type shall be ~~THHN/THWN-2 or~~ XHHW-2. Average insulation shall be in accordance with Sec 1061.4.

1061.7 Multi-Conductor Cable. Multi-conductor cable for traffic signals shall be No. 16 AWG, rated at 600 volts. The cable shall be in accordance with IMSA Specification No. 19-1 or No. 20-1.

1061.8 Induction Loop Detector Cable. Induction loop detector cable shall be single-conductor No. 14 AWG wire, with Type XHHW insulation, marked as such, rated at 600 volts. The cable shall be in accordance with IMSA Specification No. 51-7.

1061.9 Loop Detector Lead-In Cable. Lead-in cable used between the loop detector and the controller shall be two-conductor, twisted, shielded No. 14 AWG wire rated at 600 volts. The cable shall be in accordance with IMSA Specification No. 50-2.

1061.10 Certification. All cables and conductors shall be accompanied by certification from the supplier indicating: (1) the supplier is familiar with the requirements of these specifications and, (2) cable furnished was from a lot manufactured by (manufacturer's name) whose test results are in accordance with these specifications.

902.5.43 Power Outages at Signalized Intersections

~~**Standard.** Each district shall develop a power outage plan for signalized intersections that includes information about the installation, use, and recovery of Temporary Stop Signs (TSS) and the installation of battery backup systems. This subarticle provides information for these items.~~

902.5.43.1 Temporary Stop Signs at Signalized Intersections

Support. Temporary Stop Signs (TSS) refer to stop signs that meet the MUTCD stop sign design requirements for regulatory signs and are temporarily installed at signalized intersections where the traffic signals cannot function due to damage and/or power outage. These temporary placements include but are not limited to roll-up stop signs, temporary mounts on the signal vertical upright, or stop signs mounted on other crash worthy devices.

Standard. If used, such signs shall remain at the intersection until power at the non-functioning signalized intersection has been restored (see EPG 902.5.43.1.4 Recovery).

902.5.43.1.1 Conditions For Use

Guidance. TSS may be erected at locations where a signalized intersection is non-functioning. A non-functioning signalized intersection is defined as an intersection that is equipped with a traffic signal that is damaged and/or without power which cannot display proper indications to control traffic.

After verifying that the signal is non-functioning, Districts should contact the appropriate utility company to notify them of the power outage, if applicable, and to determine if power will be restored in a reasonable amount of time (at the District's discretion). If used, the TSS should be deployed as soon as practical depending on location of the signalized intersection and the stored TSS. Districts should also request police assistance for traffic control if they are not already present at the site or aware of the power outage. Outside of normal business hours, it might be necessary for the electrician or maintenance personnel to directly contact the highway patrol or local police and the power company. When a signalized intersection is non-functioning, then TSS may be installed when one of the following conditions is met:

- When the traffic signal is both damaged and without power, or
- When the traffic signal is without power and restoration of power using an alternate power source is not possible.

Standard. When TSS are utilized at a signalized intersection that is non-functioning, the District shall decide whether the power shall be disconnected or whether the signal should be switched to flash to avoid conflicts when power is restored. If switched to flash, the flash shall be red-red since TSS will be installed on all approaches, if used, at a signalized intersection without power (dark signals are to be treated like a 4-way stop according to the Missouri Driver's Guide). The TSS shall not be displayed at the same time as any signal indication is displayed other than a flashing red.

A request shall be made of the nearest maintenance building, emergency responder, or external emergency responder (whomever stores the TSS) to bring stop signs to the intersection. Personnel or emergency responders instructed in signal operation shall disconnect the power or switch the signal to flash operation (external emergency responders will do this in the signal

cabinet police door) before placing the TSS. Without this change in operation, the traffic signal could return to steady (stop-and-go) mode within seconds after the signal is repaired or power is restored, which would cause conflicts between the signal and the TSS (conflicting green or yellow indications with a stop sign for the same approach). The signal shall be visible to traffic on all approaches and all these approaches will flash upon restoration of power (see EPG 902.5.43.2 for more information regarding Startup from Dark).

Guidance. When law enforcement is present at a non-functioning signalized intersection to direct traffic, then the TSS that have been placed should be covered or removed to avoid conflicts (the law enforcements authority supersedes the TSS).

Option. If it has been determined that the power outage will last for an extended amount of time (at the district's discretion) the signal heads may be covered to reduce the confusion of approaching motorists.

Guidance. If signal heads are covered, the appropriate enforcement agency should be advised and asked to occasionally monitor the intersection. Also, the power company should be advised and asked to notify proper personnel when the power is restored.

902.5.43.1.2 Location and Placement

Standard. The signalized intersection locations for installation of TSS shall meet the conditions of use in EPG 902.5.43.1.1 and shall be at the discretion of the district. ~~Each District shall develop a list of critical signalized intersections to establish a priority for TSS installation. The TSS prioritized installation list developed by each district shall be in each district's Power Outage Plan.~~

Guidance. The installation of TSS ~~should begin at the identified critical intersections and~~ should be prioritized as follows (as applicable to each district):

1. Signals with railroad preemption

2. Signals with a speed limit greater than 50 mph

3. Signals with a high accident rate

4. Intersections difficult to flag or require multiple flaggers (non-routine roadway configurations/geometry, SPUIs, multi-lane approaches, etc.)

5. Signals with high volumes (freeway type off-ramps, major roadways, etc.)

6. Signals with frequent power outages

7. Signals located at schools.

~~As battery backup systems are installed (see EPG 902.5.43.3 Battery Backup Systems at Signalized Intersections) at signalized intersections, districts should re-evaluate their list of prioritized intersections for the installation of TSS.~~

Standard. When used, TSS shall be placed in a location where they are visible to all lanes on all roadways. On two-way roadways, stop signs shall be erected on the right-hand side of all approaches. On divided highways, stop signs shall be erected on both the right and, if possible, on the left-hand side or at location for best visibility of all approaches.

Guidance. If the power outage is widespread, additional personnel should be requested to help with the placement of the signs.

902.5.43.1.3 Storage and Distribution

~~**Guidance.** Each District should store enough TSS to be deployed at the critical signalized intersections identified in the District Power Outage Plan.~~

Standard. TSS shall be distributed by the district to the district's maintenance personnel or emergency responders or external emergency responders on an as-needed basis. It shall be the responsibility of the district to develop a means of distribution.

902.5.43.1.4 Recovery

Standard. TSS shall remain at the intersection until power at the non-functioning signalized intersection has been restored. Power will remain disconnected or the signal will flash until TSS are removed. Immediately following TSS removal, personnel or emergency responders instructed in signal operation shall restore signal operation in accordance with the procedures set forth in EPG 902.5.43.2 Steady (stop-and-go) Mode for transition to steady (stop-and-go) mode.

The recovery of the TSS shall be accomplished by using the district's maintenance personnel or emergency responders or external emergency responders by either of the following:

- Complete removal from each intersection.
- Stockpiling outside of the intersection to avoid conflicts with the signalized intersection (stockpiled signs shall not be faced towards the traveling public and stored not to damage sheeting) and stored in a location to not become a roadside hazard.

~~A detailed recovery plan for each intersection with TSS shall be developed in the district's Power Outage Plan.~~

902.5.43.2 Start up from Dark at Signalized Intersections

Standard. When a signalized intersection has been damaged and/or is without power the district shall have either disconnected the power or switched the signal to flash to avoid conflicts when power is restored. If switched to flash, the flash shall be red-red since TSS will be installed on all approaches, if used, at a signalized intersection without power (dark signals are to be treated like a 4-way stop according to the Missouri Drive's Guide). If TSS are in place, the power shall remain disconnected or the signal shall operate in flash mode until TSS are removed and personnel or emergency responders instructed in signal operation restore signal operation.

Steady (stop-and-go) Mode

Standard. When power is reconnected or when the signal is switched from flash to steady (stop-and-go) mode, the controllers shall be programmed for startup from flash. The signal shall flash red-red for 7 seconds and then change to steady red clearance for 6 seconds followed by beginning of major-street green interval or if there is no common major-street green interval, at the beginning of the green interval for the major traffic movement on the major street.

902.5.43.3 Battery Backup Systems at Signalized Intersections

902.5.43.3.1 Installation/Placement

~~**Standard.** Each district shall develop a list of critical signalized intersections to establish a priority for the installation of Battery Backup Systems (BBS) as part of the district's Power Outage Plan.~~

Guidance. The installation of Battery Backup Systems (BBS) ~~should begin at the identified critical intersections and~~ should be prioritized as follows (as applicable to each district):

1. Signals with railroad preemption
2. Signals with a speed limit greater than 50 mph
3. Signals with a high accident rate
4. Intersections difficult to flag or require multiple flaggers (non-routine roadway configurations/geometry, SPUIs, multi-lane approaches, etc.)
5. Signals with high volumes (freeway type off-ramps, major roadways, etc.)
6. Signals with frequent power outages
7. Signals located at schools.

~~Each district's prioritized installation list for BBS should be based on their traffic conditions and needs. The prioritized TSS installation list will need to be reevaluated as BBS are installed.~~

902.5.43.3.2 Duration

Standard. BBS shall be capable of operating at a minimum of 2 hours in steady (stop-and-go) mode and a minimum of 2 hours in flash operation.

Guidance. Any signalized intersection with BBS should have a generator socket for extended operation.

SECTION 712

STRUCTURAL STEEL CONSTRUCTION

UNCHANGED SPECS – INTENTIONALLY NOT SHOWN

712.7 High-Strength Bolt Installation.

712.7.1 Bolted Parts. The slope of surfaces of bolted parts in contact with the bolt head and nut shall not exceed one in 20 with respect to a plane normal to the bolt axis. All bolted parts, including underhead bearing areas and joint surfaces within the grip of the bolt, shall fit solidly together when assembled in the snug tight condition, and shall not be separated by gaskets or any other interposed compressible material. When assembled, all joint surfaces, including those adjacent to the bolt heads, nuts or washers, shall be free of scale, dirt, burrs, other foreign material and other defects that would prevent solid seating of the parts. Contact surfaces within friction-type joints shall be free of oil and paint, except in accordance with Sec 1081.10.3.10, lacquer, rust inhibitor and galvanizing. All bolts, nuts and washers shall be free of rust, burrs, dirt, other foreign material and other defects that would prevent proper tensioning. All galvanized nuts used with ~~for coated high strength bolts~~ heavy hex bolts shall be properly lubricated with a visible water-soluble lubricant in accordance with ASTM A563 S2 or S3. All nuts for uncoated ~~high strength~~ bolts shall be properly lubricated with a water-soluble lubricant in accordance with ASTM A563 S1 ~~that is oily to the touch~~.

712.7.2 Snug Tightness of Connections. Regardless of the method of final tightening used to install the fasteners, the joint and all fasteners shall first be brought to the snug tight condition. Snug tight will be defined as the tightness where all faying surfaces of the joint are in firm contact as attained by a few impacts of an impact wrench or the full effort of a person using an ordinary spud wrench. When using the Combined Method of pre-tensioning, snug tight shall be further defined as the application of the installation tool to achieve the snug tight condition, using the tool output as demonstrated during preinstallation verification testing. Following the initial snug tightening of the fitting-up bolts, the remaining holes shall be filled with high strength bolts and tightened to a snug tight condition. All final bolts completing the connection shall be high strength and required nominal diameter. Snug tightening shall progress systematically from the most rigid part of the connection to the free edges. Bolts shall be retightened in a similar manner as necessary until all bolts are simultaneously snug tight, and the section is fully compacted with the bolted parts of the joint in full contact. For Type 3 and Type 1 bolts that will be field coated, if a connection is not completely tightened within five days of snug tightening, the contractor shall remove three bolts of a given connection and conduct rotational capacity testing in accordance with Sec 1080 to verify nut lubrication. For bolted field splices, the amount of bolts specified for bolt removal shall apply to each element of the splice (top flange, web and bottom flange). If the rotational capacity test is unacceptable, all bolts shall be removed, inspected, relubricated and may then be reinstalled. For galvanized bolts, the above condition shall be met as well as the threads of the bolts and nuts shall be inspected for galling prior to final tensioning. Any bolts or nuts with threads that are galled shall be removed and replaced.

712.7.3 Bolt Tension. Each fastener shall be tightened to provide, when all fasteners in the joint are tight, at least the minimum bolt tension shown below for the size and grade of fastener used. Threaded bolts shall be tightened by methods described in Secs 712.7.5, 712.7.6, ~~or~~ 712.7.7 or 712.7.8. If required because of bolt entering and wrench operation clearances,

tightening may be done by turning the bolt while the nut is prevented from rotating. On non-parallel abutting surfaces where bevel washers will not be required, the nut shall be torqued against the non-sloping surface. Nuts shall be placed on the inside face of exterior girders, the top of girder flanges or in other situations the least exposed position, except if inaccessible for turning, on a sloping surface or otherwise approved by the engineer. Impact wrenches, if used, shall be of adequate capacity and sufficiently supplied with air to perform the required tightening of each bolt in approximately 10 seconds for bolts up to and including 1 ¼-inch diameter and within approximately 15 seconds for larger bolts. Bolts or nuts, once tensioned and subsequently loosened (turned), shall not be used as permanent bolts or nuts. Bolt tension calibration devices shall be calibrated and certified as to accuracy by a private testing lab within one year before usage, or at any time the tensioning process indicates that the calibration is in error.

Bolt Tension			
English			
Bolt Size (in.)	**Minimum Initial Bolt Tension[a] (lb x 1000)**	**Minimum Final Bolt Tension (lb x 1000)**	
	ASTM F3148 Grade 144	ASTM F3125 -Grade A325	ASTM F3125 Grade 144 and Grade A490 ASTM F3148 Grade 144
1/2	7	12	15
5/8	11	19	24
3/4	16	28	35
7/8	22	39	49
1	29	51	64
1 1/8	36	64	80
1 1/4	46	81	102
1 3/8	55	97	121
1 1/2	66	118	148

[a]Applies to preinstallation verification testing when using the Combined Method of Pre-tensioning

712.7.4 Washers. All fasteners shall have a hardened washer under the nut or bolt head, whichever is turned in tightening. All heavy hex head fasteners over all oversized or slotted holes shall also have a hardened washer under the non-turned element. Round heads meeting the minimum dimensional requirements of ASTM F3148 do not require a washer under the head for oversized or short slotted holes. Where an outer face of the bolted parts has a slope of more than one in 20 with respect to a plane normal to the bolt axis, a smooth beveled washer shall be used to compensate for the lack of parallelism. Direct tension indicators (DTI) washers will not be permitted.

712.7.5 Calibrated Wrench Method. When calibrated wrenches are used to provide the bolt tension specified in Sec 712.7.3, the wrench setting shall be such as to induce a bolt tension 5 to 10 percent in excess of the specified value. Wrenches shall be calibrated at least once each working day by tightening in a device capable of indicating actual bolt tension no less than three typical bolts of each diameter from the bolts to be installed. Power wrenches shall be adjusted to stall or cut out at the selected tension. If manual torque wrenches are used, the torque indication corresponding to the selected tension shall be noted and used in the installation of all bolts of the tested lot. Nuts shall be in tightening motion when torque is measured. After the joint has been brought to a snug tight condition, all bolts in the joint shall be tightened by progressing systematically from the most rigid part of the joint to the free edges. When using

calibrated wrenches to install several bolts in a single joint, the wrench shall be returned to "touch up" bolts previously tightened, which may have been loosened by the tightening of subsequent bolts, until all are tightened to the selected tension. During tightening, there shall be no rotation of the part not turned by the wrench.

712.7.6 Turn-~~o~~Of-Nut Method. When the turn-of-nut method is used to provide the bolt tension, there shall first be enough bolts brought to a snug tight condition as defined in Sec 712.7.2 to ensure that the parts of the joint are brought into full contact with each other. Following this initial operation, bolts shall be placed in any remaining holes in the connection and brought to snug tightness. All bolts in the joint shall then be tightened additionally by the applicable nut rotation specified below, with tightening progressing systematically from the most rigid part of the joint to the free edges. During this operation, there shall be no rotation of the part not turned by the wrench.

Nut[a] Rotation from Snug Tight Condition			
Disposition of Outer Faces of Bolted Parts			
Bolt length measured from underside of head to extreme end of point	**Bolt faces normal to bolt axis**	**One face normal to bolt axis and other face sloped not more than 1:20 (bevel washer not used)**	**Both faces sloped not more than 1:20 from normal to bolt axis (bevel washers not used)**
Up to and including 4 diameters	1/3 turn	1/2 turn	2/3 turn
Over 4 diameters but not exceeding 8 diameters	1/2 turn	2/3 turn	5/6 turn
Over 8 diameters but not exceeding 12 diameters	2/3 turn	5/6 turn	1 turn

[a]Nut rotation shall be relative to bolts, regardless of the element (nut or bolt) being turned. For all required nut rotations, the tolerance will be minus 0 degrees and plus 60 degrees (1/6 turn).

712.7.7 ~~Load Indicating~~Twist Off Tension Control Bolt Method. Tightening by this method will be permitted, provided it can be demonstrated by the following procedure that the bolt has been tightened, at a minimum, to 1.05 times the bolt tension indicated in Sec 712.7.3. Three bolts of a representative length and of the same grade, diameter and condition as those under inspection shall be placed individually in a calibration device capable of indicating bolt tension. There shall be a washer under the part turned in tightening each bolt. Each bolt specified shall be tightened in the calibration device until the spline drive has sheared off. When this method is used to provide the bolt tension, all bolts in the joint shall be tightened in stages to prevent or minimize slackening of the installed bolts. The first stage shall be to tighten all bolts to a snug tight condition at which point all of the faying surfaces of the joint shall be firmly in contact. The final stage of tightening to full tension shall be accomplished by progressing systematically from the most rigid part of the joint to the free edges.

712.7.8 Combined Method. ASTM F3148 fixed spline bolts shall be installed by this method unless otherwise approved by the engineer. Preinstallation Verification Testing and Installation of the combined method installation shall be in accordance with ASTM F3148 Appendix X2 and X3. Inspection shall be in accordance with Sec 712.7.13.

712.7.9~~8~~ Bolt Length. When snug tight, the beginning of the bolt threads shall be even with or project slightly beyond the nut. When properly tensioned, the bolt projections beyond the nut shall be as such to prevent the nut from engaging the thread runout.

712.7.10~~9~~ Bolt Tension Calibration Device. A Skidmore-Wilhelm Calibrator or an acceptable equivalent tension measuring device will be required at each job site during erection. Periodic testing, at least once each working day when the calibrated wrench method is used, shall be

performed to assure compliance with the installation test procedures required for the tightening method used, and to perform pre-installation job site rotational-capacity testing. Bolts too short for the Skidmore-Wilhelm Calibrator short bolt setup shall have pre-installation job site rotational-capacity testing done according to ASTM F3125 Annex A2, Method 2 Short Bolt Test Procedure or ASTM F3148 Annex A1, Method 2 Short Bolt Test Procedure, as applicable. Bolt tension calibration devices shall be calibrated and certified as to accuracy by a private testing laboratory within one year before usage or at any time the accuracy is questionable.

712.7.110 Rotational-Capacity Testing. The rotational-capacity test shall be performed on three (3) bolts of each rotational-capacity lot prior to the start of bolt installation in accordance with Sec 1080.2.5.4 except ASTM F3148 Grade 144 fixed spline bolts shall have pre-installation verification testing performed on three (3) bolt assemblies of each lot in accordance with ASTM F3148 Appendix X2 in lieu of rotational-capacity testing. Hardened steel washers shall be part of the test, regardless if washers will not be required as part of the installation procedure. Bolt, nut, and washer when required, combinations as installed shall be only from the established and tested rotational-capacity lot.

712.7.121 Weathered Bolts. Weathered or rusted bolts or nuts not in accordance with Secs 712.7.1, 712.7.3 and 712.7.110 shall be cleaned and relubricated prior to installation. Recleaned or relubricated bolt, nut and washer assemblies shall be retested in accordance with Sec 712.7.110 prior to installation. Relubrication shall be performed by or at the direction of the manufacturer for ASTM F3148 Grade 144 and ASTM F3125 Grade 144 bolts, Grade F1852 (A325TC) and F2280 (A490TC) twist-off tension control bolts.

712.7.132 Inspection. The engineer will observe the installation and tightening of bolt assemblies to determine that the selected tightening procedure is properly used, and will determine that all bolt assemblies are tightened. The following verification inspection will be used:

(a) Either the engineer, or the contractor in the presence of the engineer, will use an inspecting torque wrench and bolt tension calibration device furnished by the contractor.

(b) Three bolt assemblies of a representative length, and of the same grade, diameter and condition as those under inspection will be placed individually in a calibration device capable of indicating bolt tension. There will be a washer under the part turned in tightening each bolt. Each bolt specified will be tightened in the device, using the measuring torque wrench, to the minimum tension specified in Sec 712.7.3. –Of the three values obtained, the highest value will be taken as the job inspecting torque to be used in the manner specified in Sec 712.7.132. The inspecting torque will be re-established at intervals of no more than 30 calendar days or at any time appreciable changes are encountered.

(c) Bolts represented by the sample prescribed in Sec 712.7.132 that have been tightened in the structure will be inspected by applying, in the tightening direction, the inspecting wrench and the wrench's job inspecting torque to 10 percent of the bolts, but no less than two bolts, selected at random in each connection. If no nut or bolt head is turned by this application of the job inspecting torque, the connection will be accepted as properly tightened. If any nut or bolt head is turned by the application of the job inspecting torque, this torque shall be applied to all bolts in the connection. All bolts whose nut or head was turned by the job inspecting torque shall be tightened and re-inspected.

(d) Calibrated wrench tightening will be verified during actual installation in the assembled steel work. The wrench settingadjustment selected by the calibration process shall not produce a bolt or nut rotation from snug tight greater than permitted in Sec 712.7.6.

UNCHANGED SPECS – INTENTIONALLY NOT SHOWN

SECTION 1080

STRUCTURAL STEEL FABRICATION

1080.1 Scope. This specification covers the fabrication and inspection of bridges and structures made of structural steel and miscellaneous metals.

1080.2 Material. Except as amended by Sec 1080.2.4, all material shall be in accordance with Division 1000, Material Details, and specifically as follows:

Item	Section / Specification
Shear Connectors	1037
Paint for Structural Steel	1045
Coating of Structural Steel	1081
Structural Carbon Steel	AASHTO M 270, Grade 36 ASTM A709, Grade 36
Structural Low Alloy Steel	AASHTO M 270, Grade 50 ASTM A709, Grade 50 AASHTO M 270, Grade 50W ASTM A709, Grade 50W
Quenched and Tempered Alloy Steel	AASHTO M 270, Grade HPS 50W ASTM A709, Grade HPS 50W AASHTO M 270, Grade HPS 70W ASTM A709, Grade HPS 70W ASTM A709, Grade 100/100W
Carbon Steel Bolts and Nuts	ASTM A307
High Strength Bolts, Nuts and Washers	ASTM F3125 Grade A 325 Type 1 ASTM F3125 Grade A325 Type 3 ASTM F3125 Grade 144 Type 1 ASTM F3125 Grade 144 Type 3 ASTM F3125 Grade A490 Type 1 (Plain only) ASTM F3125 Grade A490 Type 3 ASTM F3148 Grade 144 Type 1 ASTM F3148 Grade 144 Type 3 ASTM F436 ASTM A563 AASHTO M 292
Cold Finished Carbon Steel Shafting	AASHTO M 169
Carbon Steel Forgings	AASHTO M 102 Class F
Alloy Steel Forgings	AASHTO M 102 Class G
Gray Iron Castings	AASHTO M 105 Class 50
Malleable Iron Castings	ASTM A47
Carbon Steel Castings	AASHTO M 103 Grade 485-275
Galvanized Coatings	AASHTO M 111 AASHTO M 232 Class C ASTM B695 Class 55
Lead for Bearing Pads	ASTM B29
Identification of Metals	ASTM A6

UNCHANGED SPECS – INTENTIONALLY NOT SHOWN

1080.2.5 High Strength Fastener Assemblies. In addition to the requirements of Sec 712.2, high strength bolts, nuts and washers shall meet the following requirements. The contractor shall furnish a manufacturer's ~~certification~~ certified test report showing the results ~~of tests performed~~. Identification in accordance with the appropriate AASHTO/ASTM specifications shall be maintained by container markings which shall match identifying numbers on the certifications and be traceable to the certified mill test reports. High strength fastener assemblies shall be galvanized unless specifically indicated otherwise by the contract documents. When high strength bolts are used with weathering steel, the fasteners shall be Type 3, including fasteners located in areas of the structure to be partially coated, expansion device supports, slab drain brackets and similar items. High strength fasteners in partially coated areas of weathering steel and slab drain baskets attached to weathering steel shall be coated in accordance with Sec 1080.4.5.1. ASTM F3125 Grade A490 bolts shall be installed plain (also referred to as uncoated or black), tensioned and then cleaned and coated with the coating system as specified on the plans. The cleaning and the zinc coating shall not be applied by any process, which can cause hydrogen embrittlement. All certification testing requirements and mill test reports referenced in the following sections shall be in accordance with Sec 106.

1080.2.5.1 Bolts. All bolts shall be in accordance with ASTM F3125 Grade A325 except when ASTM F3125 Grade 144 or A490 bolts or ASTM F3148 assemblies are specified on the plans. If the contractor elects to use twist-off tension control~~load indicator~~ bolts, ASTM F3125 Grade F1852 (A325TC) or ASTM F3125 Grade F2280 (A490TC), ~~,~~ only a hex head will be permitted. The type of head used shall be consistent throughout the entire structure, unless otherwise approved by the engineer.

1080.2.5.1.1 Proof Load Tests. Proof load tests in accordance with ASTM F606 Method 1 shall be performed. Minimum test frequency shall be in accordance with ASTM F3125 or ASTM F3148 ~~Grade A325~~.

1080.2.5.1.2 Wedge Tests. Wedge tests on full size bolts, in accordance with ASTM F606, paragraph 3.5 shall be performed. If bolts are to be galvanized, tests shall be performed after galvanizing. Minimum test frequency shall be in accordance with ASTM F3125 or ASTM F3148. ~~Grade A325. Weathering steel and nuts shall be grade C3 or DH3.~~

1080.2.5.2 Nuts. All nuts shall be in accordance with AASHTO M 292 as applicable or ASTM A563, except as follows.

1080.2.5.2.1 Nut Grades. Ungalvanized nuts shall be grades ~~2,~~ C, D or C3 with a minimum Rockwell hardness of 89 HRB or Brinell hardness 180 HB or heat ~~-~~treated grades ~~2H,~~ DH or DH3. Nuts that are to be galvanized shall be heat ~~-~~treated grade~~s~~ ~~2H,~~ DH or DH3. Weathering steel nuts shall be grade C3 or DH3 for use with ASTM F3125 Grade A325 Type 3 and grade DH3 for use with ASTM F3125 Grade 144 Type 3, A490 Type 3 or ASTM F3148 Grade 144 Type 3.

1080.2.5.2.2 Overtapping. Nuts to be galvanized shall be tapped oversize the minimum amount required for proper assembly. The amount of overtap in the nut shall be such that the nut will assemble freely on the bolt in the coated condition and shall be in accordance with the mechanical requirements and the rotational-capacity test requirements of ASTM A563. The overtapping requirements of ASTM A563 will apply, except these limits shall be considered maximum values instead of the minimum, as currently shown.

1080.2.5.2.3 Nut Lubrication. All galvanized nuts~~, including ASTM A194 nuts,~~ shall meet the supplementary requirements of ASTM A563. Galvanized nuts used with heavy hex bolts shall be properly lubricated with a visible water-soluble lubricant in accordance with ASTM

A563 S2 or S3. All nuts for uncoated bolts shall be properly lubricated with a water-soluble lubricant in accordance with ASTM A563 S1.~~a lubricant containing a dye of any color that contrasts with the color of the galvanizing.~~

1080.2.5.2.4 Proof Load Tests. Proof load tests in accordance with ASTM F606 shall be performed. Minimum test frequency shall be in accordance with ASTM A563 or AASHTO M 292. If nuts are to be galvanized, tests shall be performed after lubricating.

1080.2.5.3 Washers. All washers shall be in accordance with ASTM F436. Hardness testing shall be performed on galvanized washers. The coating shall be removed prior to taking hardness measurements. Washers for weathering steel shall be Type 3. Direct tension indicators (DTI) washers will not be permitted.

1080.2.5.4 Rotational-Capacity Tests. Rotational-capacity tests shall be performed on all bolt, nut and washer assemblies by the manufacturer or distributor prior to shipping. Washers shall be part of the test, regardless if they are required as part of the installation procedure or not. Tests shall be conducted after galvanizing when galvanizing is required.

1080.2.5.4.1 Test Methods. Except as modified herein, the rotational-capacity test shall be performed in accordance with ASTM F3125 or ASTM F3148, as applicable.~~Grade A325.~~

1080.2.5.4.2 Test Lots. Each combination of bolt production lot, nut lot and washer lot shall be tested as an assembly. Where washers are not required as part of the installation procedures, washers need not be included in the lot identification. A rotational-capacity lot number shall be assigned to each combination of lots tested. The minimum frequency of testing shall be two (2) assemblies per rotational-capacity lot.

1080.2.5.4.3 Testing Device. The bolt, nut and washer assembly shall be assembled in a Skidmore-Wilhelm Calibrator or an acceptable equivalent device.

1080.2.5.4.4 Minimum Rotation. The minimum rotation, from a snug tight condition, 10 percent of the specified proof load, shall be as follows:

Minimum Bolt Rotation		
	Rotation	
Bolt Length	**ASTM F3125 Grade A325 and Grade 144 ASTM-F3148 Grade 144**	**ASTM F3125 Grade A490**
≤ 4 Diameters	240° (2/3 turn)	240° (2/3 turn)
> 4 Diameters and ≤ 8 Diameters	360° (1 turn)	300° (5/6 turn)
> 8 Diameters	420° (1 1/6 turn)	360° (1 turn)

1080.2.5.4.5 Required Tension. The tension reached at the above rotation shall be equal to or greater than 1.15 times the required installation tension. The installation tension and the tension for the turn test for ASTM F3125 Grade A325, 144 and ~~ASTM F3125 Grade~~ A490 and ASTM F3148 Grade 144 bolts shall be as follows:

Required Bolt Tensions									
Diameter, in.	**1/2**	**5/8**	**3/4**	**7/8**	**1.00**	**1-1/8**	**1-1/4**	**1-3/8**	**1-1/2**
ASTM F3125 Grade A325									
Req. Installation Tension, kips	12	19	28	39	51	64	81	97	118
Turn Test Tension, kips	14	22	32	45	59	74	94	112	136

ASTM F3125 Grade 144 or A490 or ASTM F3148 Grade 144									
Req. Installation Tension, kips	15	24	35	49	64	80	102	121	148
Turn Test Tension, kips	17	28	40	56	74	92	117	139	170

UNCHANGED SPECS – INTENTIONALLY NOT SHOWN

1080.2.10 Steel Stamping. Any metal die stamping of match marks and erection marks in structural steel members shall be limited to a position in the end 1 1/2 inches of flange plates and flange splice plates, the middle third of web plates and the outside edge of the middle third of web splice plates. Metal die stamping at other locations or for other purposes may be approved by the engineer provided low stress dies are used. Low stress dies will be defined as those manufactured to produce impressions that are rounded at the bottom rather than sharp edged. Metal die stamping on pin plates and hanger plates will not be permitted. Plasma etching will not be permitted.

UNCHANGED SPECS – INTENTIONALLY NOT SHOWN

1080.3.1.5 Office Space. A suitable office area shall be provided for exclusive use by the engineer. The office may be enclosed or semi-enclosed as available at the location of QA inspection, but shall be suitable for use as determined by the engineer. The floor space shall be at least 120 square feet unless otherwise approved by the engineer, weatherproof, secure, insulated and lighted. The office space shall be adequately ventilated, heated and air conditioned. Electric outlets with 110-120 volt, 60 Hz current and a telephone with outside line, inter-plant and ~~dial-up computer capabilities~~ Wi-Fi or Ethernet connection to the internet shall be provided. Office furniture consisting of a desk, a minimum of 30 x 60 inches with drawers, a swivel desk chair with arms and a storage/filing cabinet with lock hardware and key shall be provided. All office furniture will be subject to approval by the engineer. Should any furniture become unsatisfactory, the furniture shall be promptly repaired or replaced to the satisfaction of the engineer. Accessible parking shall be provided near the office any time the shop is in operation on MoDOT projects. No direct payment will be made for furnishing and maintaining an acceptable office area for QA inspection.

UNCHANGED SPECS – INTENTIONALLY NOT SHOWN

1080.3.3.2 Holes. Holes for connections of main members shall be subpunched or subdrilled and reamed while assembled in the shop or may be drilled from the solid with main members and each splice plate fully assembled in their final erected positions. Holes for floor beams and framed stringer connections shall be drilled or reamed to a steel template of sufficient thickness to center the drill accurately and all members to be secured through the same group of holes shall be drilled or reamed from the same template. Holes may be punched full size in secondary members such as lateral, longitudinal and sway bracing, lacing bars, stay plates and diaphragms. Stacking of web splice plates during drilling or reaming operations on straight girders will be permitted. Thermal cutting of holes will not be permitted.

UNCHANGED SPECS – INTENTIONALLY NOT SHOWN

1080.3.3.10 Pin Holes. Pin holes shall be bored true to size, smooth and straight, at right angles to the axis of the member and parallel with each other. The boring shall be done after the member is assembled and welded. The center-to-center distance of pin holes shall be correct within 1/32 inch for an individual component or member. The diameter of bored/milled pin holes shall not exceed that of the pin by more than 1/50 inch for pins 4 inches or less in diameter or no more than 1/32 inch for pins larger than 4 inches in diameter.

UNCHANGED SPECS – INTENTIONALLY NOT SHOWN

712.1.5 High Strength Bolts (Sec 712.7)

Bolts, nuts, and washers must meet applicable requirements of AASHTO as noted in Sec 1080.2. ASTM F3125 Grade A325 bolts shall be used on bridge connections unless other types of bolts are specified in the contract. To facilitate easy identification of high strength bolts, the following figure shows some of the typical bolt markings required by the ASTM specification.

<table>
<tr><th>Bolt/Nut</th><th colspan="2">Type 1 (Plain or Galvanized)</th><th colspan="2">Type 3 (Weathering)</th></tr>
<tr><td>ASTM F3125 Grade A325</td><td colspan="2"> 

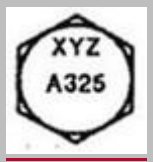
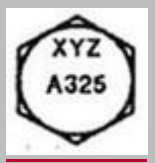
Three radial lines 120° Apart are optional</td><td colspan="2"> 
</td></tr>
<tr><td>ASTM F3125 Grade A490</td><td colspan="2"> 
</td><td colspan="2"> 
</td></tr>
<tr><td rowspan="3">ASTM A563 Nuts</td><td>Type 1
Plain</td><td>Type 1
Galvanized</td><td colspan="2">Type 3
Plain</td></tr>
<tr><td> 

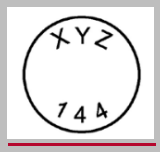
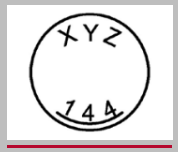
Arcs Indicate Grade C (Grade A325 bolt)</td><td></td><td colspan="2"></td></tr>
<tr><td> 

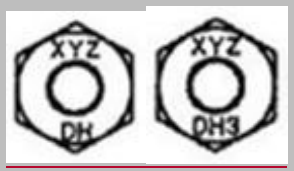
Arcs with “3” Indicate Grade C3 (Grade A325 bolt)</td><td></td><td colspan="2"> 

Arcs with “3” Indicate Grade C3 (Grade A325 bolt)</td></tr>
</table>

	 ~~Grade D (Grade A325 bolt)~~			
	 ~~Grade DH (Grade A325 bolt and Grade A490 bolt)~~	 ~~Grade DH (Grade A325 bolt)~~	 ~~Grade DH3 (Grade A325 bolt)~~	 ~~Grade DH3 (Grade A490 bolt)~~
	 ~~Grade DH3 (Grade A325bolt and Grade A490 bolt)~~			

Bolt	Type 1 Plain	Type 1 Galvanized	Type 3 (Weathering)
ASTM F3125 Grade A325	 Three radial lines 120° Apart are optional		
ASTM F3125 Grade 144			

Bolt	Type 1 Plain	Type 1 Galvanized	Type 3 (Weathering)
ASTM F3125 Grade A490		n/a	
ASTM F3148 Grade 144			

Nuts	Type 1 Plain	Type 1 Galvanized	Type 3 (Weathering)
ASTM A563	 Arcs Indicate Grade C (Grade A325 bolt)	n/a	 Arcs with "3" Indicate Grade C3 (Grade A325 bolt)
	 Grade D (Grade A325 bolt)	n/a	n/a
	 Grade DH (Grade A325, Grade 144 or, Grade A490 bolt)	 Grade DH or DH3 (Grade A325 or Grade 144 bolt)	 Grade DH3 (Grade A325, Grade 144 and Grade A490 bolt)

(Reprinted and modified from 2020 Research Council on Structural Connections (RCSC) ~~AISC Steel Construction Manual, 15th Ed., Table 2.1 and~~ Figure C-2.1).

Note: XYZ represents the manufacturer's identification mark.

~~A permissible alternate type of nut may be furnished. Such nuts would be marked with the symbol 2 or 2H and the manufacturer's symbol.~~

Bolts tightened by the calibrated wrench or turn-of-nut method should be checked following the procedures outlined in the Standard Specifications.

The sides of bolt heads and nuts tightened with an impact wrench will appear slightly peened. This will indicate that the wrench has been applied to the fastener.

712.1.5.1 Bolted Parts

Sec 712.7.1 covers cleaning of parts to be bolted. Bolts, nuts, and washers will normally be received with a light residual coating of lubricant. This coating is not considered detrimental to friction type connections and need not be removed. If bolts are received with a heavy coating of preservative, it must be removed. A light residual coating of lubricant may be applied or allowed to remain in the bolt threads, but not to such an extent as to run down between the washer and bolted parts and into the interfaces between parts being assembled.

712.1.5.2 Bolt Tension

A washer is required under nut or bolt head, whichever is turned in tightening, to prevent galling between nut or bolt head and the surface against which the head or nut would turn in tightening, and to minimize irregularities in the torque-tension ratio where bolts are tightened by calibrated wrench method. Washers are also required under finished nuts and the heads of regular semi-finished hexagon bolts against the possibility of some reduction in bearing area due to field reaming. When oversized holes are used as permitted by the contract, a washer shall be placed under both the bolt head and the nut. Washers are not required under the round head of ASTM F3148 Grade 144 TNA fixed spline bolts.

Standard Specifications require that bolt torque and impact wrenches be calibrated by means of a device capable of measuring actual tension produced by a given wrench effort applied to a representative sample. Current specifications require power wrenches to be set to induce a bolt tension 5 percent to 10 percent in excess of specified values but the Special Provisions for the project should be checked for a possible revision to this requirement.

The contractor is required to furnish a device capable of indicating actual bolt tension for the calibration of wrenches or load indicating device. A certification indicating recent calibration of the device should accompany it. It is recommended that the certification of calibration be within the past year but if the device is being used with satisfactory results, the period may be extended. More frequent calibration may be necessary if the device receives heavy use over an extended period.

The contractor shall ~~will generally~~ use ~~either the calibrated wrench method or the turn-of-nut method for~~ one of the tightening methods ~~bolts~~ as outlined in Sec 712.7 or as directed by the engineer or contract documents. ASTM F3148 Grade 144 TNA fixed spline bolts shall use combined method for tightening bolts as outlined in Sec 712.7. The sides of bolt heads or nuts tightened with an impact wrench will appear slightly peened. This will usually indicate that the wrench has been applied to the fastener. If the wrench damages the galvanized coating, the contractor shall repair the coating by an acceptable method.

712.1.5.3 Rotational-Capacity Testing and Installation of ~~ASTM F3125 Grade A325~~ Type 3 Bolts

Type 3 (weathering steel) bolts behave quite differently than the galvanized bolts used in most MoDOT structures and require additional care to test and install properly.

The contractor **must** keep bolts stored in sealed kegs out of the elements until ready for use. Storage in a warehouse, shed, shipping container or other weatherproof building is best. The lubricant used on Type 3 bolts dissipates quickly, allowing rust to begin. Kegs should not be opened until absolutely necessary and promptly resealed whenever work stops.

If bolts fail the rotational-capacity test, preinstallation tension test or fails in torsion during installation, insufficient lubrication is the most likely cause. Relubrication of Grade A325 bolts is allowed. Several different waxes and lubricants are suggested by FHWA, including Castrol 140 Stick Wax (which has been successfully field tested by MoDOT), Castrol Safety-Film 639, MacDermid Torque'N Tension Control Fluid, beeswax, etc. Relubrication shall be performed by or at the direction of the manufacturer for ASTM F3148 Grade 144 bolts and ASTM F3125 Grade 144 bolts, Grade F1852 (A325TC) and F2280 (A490TC) twist-off tension control bolts.

Galling of the washer may occur, especially with longer bolts. This can be reduced by lubricating the contact area of the bolt face at the washer with an approved lubricant. If this face is lubricated for testing, it must also be lubricated during bolt installation.

Failure of the bolts due to galling of the washer can also be prevented by turning the nut in one continuous motion during testing. For larger diameter bolts, this can be a problem. Torque multipliers amplify this effect. If many larger diameter bolts will be tested, ask the contractor to purchase an electric gear reduction wrench with reaction arm. The Skidmore will need to have a reaction kit installed. This wrench will produce better results and save time spent performing tests (and, therefore, lower costs).

For long bolts, (L>8d), use proper spacer bushings on the back of the Skidmore to avoid excessive use of spacers between the washer and front plate of the Skidmore. Stacking spacers can cause bending of long bolts, which will cause inaccurate results, false failures and potential damage to the Skidmore. Consult the Skidmore user manual for maximum allowable spacer lengths.

712.1.5.4 Bolt Testing and Verification

Bridges are designed so that many of the steel-to-steel connections that are made in the field are slip-critical connections. Slip-critical means that once the bolt is tightened, the bolt and the pieces of steel (or plies) will not move. It relies on the bolt to clamp down on the steel and create so much force between the steel plates that they will not move at all. Should they slip and move it would be a critical issue for the bridge.

When it comes to bolt design, the bolt is being tensioned in order to establish the clamping force needed. The tightening of the nut on the bolt is what produces the needed tension. Bridge Designers will design each of these joints based on established minimums for each bolt size. So, for example, a Bridge Designer will assume that an ASTM F3125 Grade A325 7/8” diameter bolt will be able to supply 39,000 pounds of clamping force. This means that the contractor in the field must ensure that they are tightening each bolt to this tension.

In order to verify that the bolts are installed correctly in the field, it is essential that contractors and inspectors understand the requirements of bolted connections, and the specifications that govern them. For this work, Sec 712 Structural Steel Connection and Sec 1080 Structural Steel Fabrication will primarily be consulted.

The general steps are:

- Step 1, Determine Bolt Type
- Step 2, Inspection Type Selection
- Step 3, Rotational Capacity Test
- Step 4, Installation
- Step 5, Bolt Verification

712.1.5.4.1 Step 1, Determine Bolt Type

The first step is to review the contractor’s submittals to see what kind of bolts they will be using. You can also look at the bolts in the field to check for the bolt type. Table 712.1.5.4.1 shows what is on the hex head of the bolt, and how the markings can show what type of bolt it is.

~~Table 712.1.5.4.1~~

~~Bolt/Nut~~	~~Type 1 (Plain or Galvanized)~~	~~Type 3 (Weathering)~~
~~ASTM F3125 Grade A325~~	 ~~Three radial lines 120° Apart are optional~~	

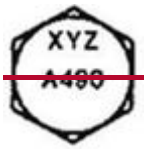
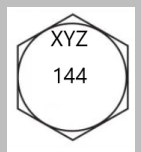
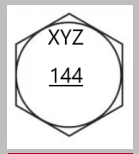
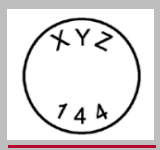
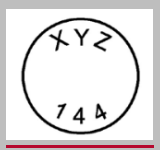
~~ASTM F3125 Grade A490~~		

Table 712.1.5.4.1

Bolt	Type 1 Plain	Type 1 Galvanized	Type 3 (Weathering)
ASTM F3125 Grade A325	 Three radial lines 120° Apart are optional		
ASTM F3125 Grade 144			
ASTM F3125 Grade A490		n/a	
ASTM F3148 Grade 144			

Below is a reproduction~~section from~~ of ASTM F3125 Section 9 and ~~from~~ASTM F3148 Section 8 that governs the testing requirements for these types of high-strength bolts. The text shown is a portion of the test method that deals with lot control and mimics the numbering used in both specifications (e.g., 8.1 = 1, 8.1.1 = 1.1, etc.). It is an expectation of the standard that not only are all high-strength bolts produced meeting the material properties specified, but the manufacturer also must produce these bolts with a specific tracking procedure that reduces groups of bolts into lots. The lots are a set of bolts that are represented by material tests to prove they meet requirements. Each of these sets of bolts are tracked with ~~paperwork~~ test reports ~~and~~ tied to lot identification numbers. Not only are the bolts produced this way, but also all the nuts and washers have specific lots assigned. When a bolt, nut, and washer are put together and sold together, they are referred to as an assembly, and these

assemblies are further tracked by assembly lots. Once one piece of the assembly changes, the properties or behavior of the bolt could potentially have been changed.

Testing and Lot Control

1. *Testing Responsibility:*

1.1 Each lot shall be tested by the responsible party prior to shipment in accordance with the lot control and identification quality assurance plan in 2 through 5.

4. A lot shall be a quantity of uniquely identified bolts of the same nominal size and length produced consecutively at the initial operation from a single mill heat of material and processed at one time, by the same process, in the same manner so that statistical sampling is valid.

5. Fastener tension testing and rotational capacity testing require that the responsible party maintain assembly lot traceability. A unique assembly lot number shall be created for each change in assembly component lot number, such as nuts or washers.

9 | Testing and Lot Control

9.1 Testing Responsibility:

9.1.1 Each lot shall be tested by the manufacturer prior to shipment in accordance with the lot control and identification quality assurance plan in Sections 9.2 through 9.5.

9.4 A lot shall be a quantity of uniquely identified structural bolts of the same nominal size and length ~~produced consecutively at the initial operation from a single mill heat of material and processed at one~~ time, by the same process, in the same manner so that statistical sampling is valid.

9.5 Additional testing for fastener assemblies, such as assembly tension testing and rotational capacity testing also require that the manufacturer or responsible party maintain assembly lot traceability. A unique assembly or rotational capacity lot number shall be created for each change in assembly component lot number, such as nuts or washers.

Figure 712.1.5.4.1.1, ~~and~~ 712.1.5.4.1.2 and 712.1.5.4.1.3 ~~below are of bolt heads to~~ show different types of bolt heads~~.~~ ~~and~~ Figure 712.1.5.4.1.4~~3~~ shows a copy of a common ~~shipping form~~ certified material test report that provides testing verification of the bolts. ~~and~~ Figure 712.1.5.4.1.5 shows a copy of a common Test Report for a Torque and Angle (TNA) fixed spline bolt assembly.

Figure 712.1.5.4.1.1, A325/144/A490 will be stamped on the head of the bolt.

Figure 712.1.5.4.1.2,

A325TC/A490TC Twist-off Tension Control Bolt

These bolts will follow requirements of ASTM Grade F1852 (A325TC) or Grade 2280 (A490TC). ~~listed on bolt. They will list Standard Number and then TC.~~

Figure 712.1.5.4.1.3, 144 TNA Fixed Spline Bolt
These fixed spline bolts will follow the requirements of ASTM F3148 Grade 144 with TNA (Torque & Angle) ~~also~~ listed on the bolt head.

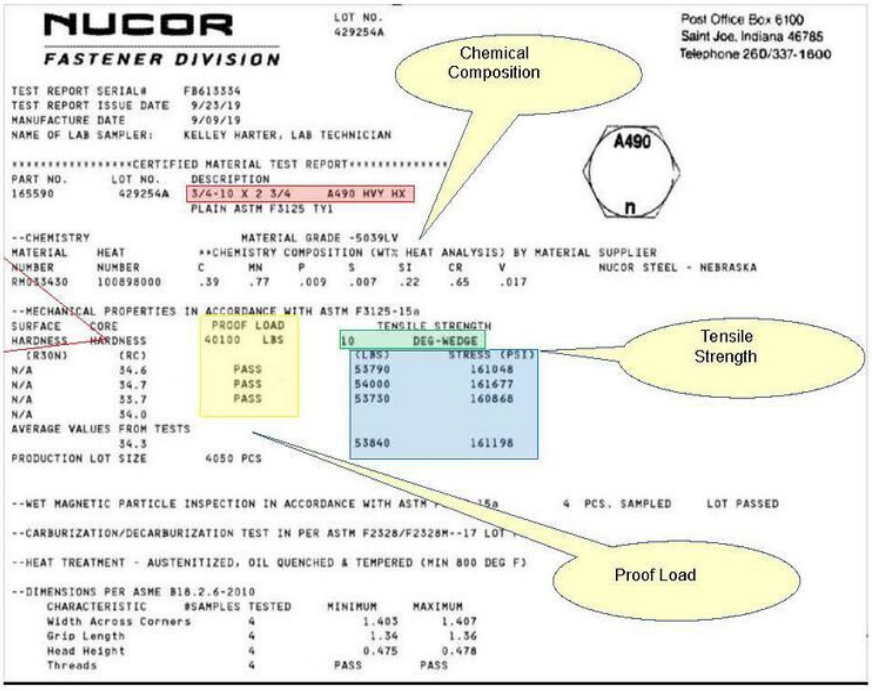


Figure 712.1.5.4.1.~~43~~, Copy of a Common Certified Material Test Report~~Shipping Paperwork~~

Unytite, Inc. One Unytite Drive Peru, IL 61354	**Test Report** **Torque-and-Angle Fixed-Spline Structural Bolting Assembly**	Customer: PO Number: Quantity:	

Set Number: 41302-10896560

Description: 1-8 x 3 F3148 TNA® 144 Type 1 Assembly Mech. Galvanized (S1)

Date Tested	Temperature (f)	Performed By	Test Method	Sample Plan
12/6/2024	70	Nicholas Trump	ASTM F3148-17a(2024)	ASTM F1470 Table 3 Sample Size C & D

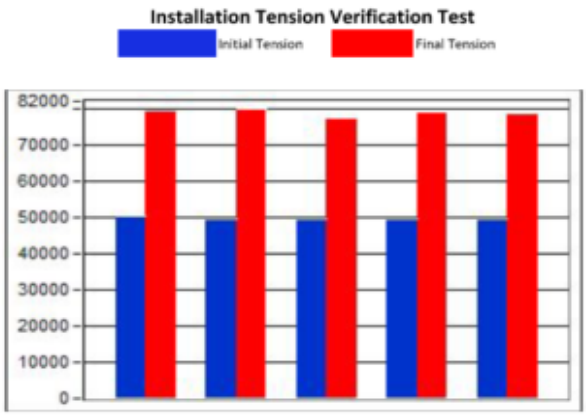
Test Equipment	Serial Number	Calibration Date
Tension Measuring System	HT-4000 / HT-1033 (V065384)	7/30/2024
Torque Measuring System	HT-4000 / HT-1033 (200760)	7/30/2024

Component Data	Size	Grade	Type	Finish	Lot No.
Bolt	1-8 x 3	144	1	Mech. Galvanized	41302-10896560
Nut	1-8	A563 DH	1	Mech. Galvanized	41367-5806273802
Washer	1	F436	1	Mech. Galvanized	0924-384

Qualification Test Results - *Sample Size C*	Criteria	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Minimum Initial Tension (lbs)	29,000	29,355	29,166	29,544	29,049	29,373
Torque Required at Minimum Initial Tension (ft/lbs)	n/a	290	296	304	289	297
Additional Rotation Angle Required From Minimum Initial Tension to Exceed the Minimum Final Tension	n/a	71	68	73	69	70

Installation Verification Test Results - *Sample Size C*	Criteria	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Initial Tension Torque Setting (ft/lbs)	500	500	500	500	500	500
Minimum Initial Tension (lbs)	29,000	50,279	49,415	49,703	49,451	49,523
Rotation from Initial Tension	90	90	90	90	90	90
Minimum Final Tension (lbs)	67,000	79,437	79,869	77,520	78,906	78,627

Rotational Capacity Test Results - *Sample Size D*	Criteria	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Initial Tension (lbs)	6,000	6,000	6,000	6,000	6,000	6,000
Minimum Installation Tension (lbs)	64,000	64,309	64,156	64,165	64,129	64,102
Maximum Allowable Torque (ft/lbs)	1,333	641	649	659	666	655
Degrees of Rotation	240	241	241	241	242	242
Minimum Tension at Full Rotation (lbs)	74,000	81,344	81,749	77,871	80,850	79,635



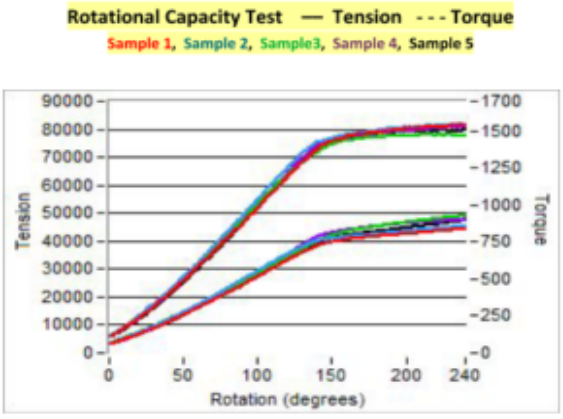


Figure 712.1.5.4.1.5, Copy of Test Report for TNA Fixed Spline Structural Bolting Assembly

712.1.5.4.2 Step 2, Inspection Type Selection

The second step is to determine the inspection type. The information below shows how to proceed once it is determined what type of bolt is being used in the field. The bolt type and verification method available will dictate the options and the requirements needed to follow for inspection in the field.

Prior to going into the field, determine the bolt type and the inspection method that will be used. This will allow you to know the equipment needed and discuss test procedures with the contractor. For some test methods, the contractor will provide the calibrated equipment to check the bolts.

712.1.5.4.2.1 Bolt Type

The first step is to find out what type of bolt you are using in the field. The bolt type will dictate how much information is needed for the Rotational Capacity Testing.

712.1.5.4.2.2 A325/144/A490 Hex Head Bolt

The use of A325/144/A490 hex head bolts will come with standard nuts, bolts, and washers. These will be tightened in the field using air tools and torque wrenches.

Rotational Capacity Testing is based on Table 712.1.5.4.3.1, Long Bolts, or 712.1.5.4.3.2, Short Bolts. Bolt checks will need to address questions shown in the table used.

Bolt inspection acceptance by the calibrated wrench method will be made using Sec 712.7.5 and Sec 712.7.132(c).

Bolt inspection acceptance by the turn-of-nut method will be made using Sec 712.7.6 and Sec 712.7.132(c).

712.1.5.4.2.3 A325TC/A490TC Twist-off Tension Control Bolt

The use of A325TC/A490TC bolts will come with nuts, bolts and washers. These will be tightened in the field using a specialized tool designed to tighten the nut and hold the spline of the bolt till the spline twists off.

Rotational Capacity Testing is based on Table 712.1.5.4.3.3. Bolt checks will need to address questions shown in the table.

Bolt inspection acceptance by load indicating the twist off tension control bolt method will be made using Sec 712.7.7 and Sec 712.7.132(c).

712.1.5.4.2.4 144 TNA Fixed Spline Bolt

The use of 144 TNA fixed spline bolts will come with nuts, bolts and washers. These will be tightened in the field using a specialized tool designed to tighten the nut and the hold the spline of the bolt.

Test Report for a Torque and Angle (TNA) fixed spline bolt assembly shall be included from the supplier with Rotational Capacity Test results for initial acceptance.

Bolt inspection acceptance by the combined method will be made using Sec 712.7.8 and Sec 712.7.13(c).

712.1.5.4.3 Step 3, Rotational Capacity

The third step is to verify that the bolts on the jobsite are going to perform as intended by the design team. Each of these bolts must achieve a specific tension that will be confirmed using the Rotational Capacity (RoCap) Testing except ASTM F3148 Grade 144 TNA fixed spline bolts shall have Pre-Installation Verification Testing performed in accordance with ASTM F3148 Appendix X2 in lieu of RoCap Testing. This RoCap tTesting is described in Sec 712.7 and Sec 1080.2.5.4.

The goal of the Rotational Capacity or Pre-Installation Verification test is to verify that the bolts will perform as intended. The main component that is being tested is that the bolts can be brought to the correct tension. This must be accomplished without applying too much torque to the bolts and field installed bolts will be turned to the correct rotation meeting or exceeding the design tension for the fastener. For the bolts to work correctly, it is critical for the threads to be clean and there must be plenty of lubricant on the bolts and nuts. There is a chance that the protective coatings and lubricants will be washed away anytime the bolts, nuts, and washers are allowed to sit out in the elements. In addition, there is a chance that rust could develop from water being on the bolts, and carelessness could lead to physical damage of the bolts. Any of these issues could cause the bolts and the nuts to not interact as designed. It may take more torque to achieve the needed tension in the bolts or the installed fasteners cannot be checked accordingly with a torque wrench.

The bolt manufacturer may provide documentation to show that a Rotational Capacity Test (RoCap) Test has been performed. For all bolts except F3148 Grade 144 TNA fixed spline bolts, The tThe inspector and contractor will still have to perform Rotational Capacity Tests in the field even if this the RoCap Test Report paperwork is provided. except for, Supplier Test Report for F3148 Grade 144 TNA fixed spline bolt assemblies shall include the RoCap tTesting and the Pre-Installation Verification Testing for initial acceptance. According to Sec 712.7.110, “rotational capacity test shall be performed on 3 bolts of each rotational-capacity lot prior to the start of bolt installation. except ASTM F3148 Grade 144 TNA fixed spline bolts shall have Pre-Installation Verification Testing performed on 3 bolts assemblies of each lot in accordance with ASTM F3148 Appendix X2”. All bolt

assemblies provided shall be a part of a rotational capacity or Pre-Installation Verification lot, which means that all bolt assembly lots used on MoDOT jobs shall be tested on the jobsite prior to incorporation. The first time a new lot of bolts is opened, plan on performing the required test. Also, the ~~Rotation Capacity~~ RoCap Test or Pre-installation Verification Test should be run any time questions or issues arise when ~~torqueing~~torquing a bolt to achieve design tension, or bolt hardware conditions change.

The RoCap or Pre-Installation Verification test should only be run once per lot, unless one of the following conditions occur:

1. Bolts arrive on the jobsite for the first time

   All bolt assembly lots must be tested once they are on the jobsite. If conditions do not change, then the one test should suffice.

2. Bolt, washer, or nut lots have been interchanged

   It is important when the ~~Rotational Capacity~~RoCap or Pre-Installation Verification ~~t~~Test is run that lot numbers for all the individual pieces (bolts, nuts, and washers) remain the same. Once any of these lots change, the ~~Rotational Capacity~~RoCap or Pre-Installation Verification ~~t~~Test must be run again.

3. Bolt lubrication appears to have been compromised

   Once a ~~Rotation Capacity~~RoCap or Pre-Installation Verification ~~t~~Test has been run, another one will not have to be run, unless the bolt condition changes. One aspect that is a factor is bolt lubrication. If the bolt is left in the wind and rain, the lubrication likely will be compromised. Once it is noticed that a bolt lubrication has changed, the ~~Rotation Capacity~~RoCap or Pre-Installation Verification ~~t~~Test must be run again.

4. Bolts appear rusty or damaged

   Rust is the far extreme of a lack of lubrication. Not only has the lubrication gone away, but the protective coating is gone, and the bolt has been allowed to rust. They will need to be cleaned, re-lubricated and tested again for Ro~~tation~~ Cap~~acity~~ or Pre-Installation Verification.

There is not a way to test tension once the bolt has been tightened. The ~~Rotational Capacity~~RoCap or Pre-Installation Verification Test is a way to verify not only that the bolts are in good condition, but also that they have not been impacted by field conditions. The test will require two components. One component is to visually inspect the bolts and record the results on the form provided in eProjects. The second component is to run tests on the three bolts in the field using a Skidmore-Wilhelm Bolt tension measuring device and a torque wrench. Both the Skidmore and torque wrench must have a calibration performed on it within the previous year from the manufacturer or a test lab. There must be a sticker on it, as well as all supporting documentation to show it has been calibrated.

RoCap Test Form Long Bolts are shown in Table 712.1.5.4.3.1 and Table 712.1.5.4.3.3~~,~~. RoCap Test Form Short Bolts are shown in Table 712.1.5.4.3.2. ~~and~~ Pre-Installation Verification Test Form for TNA ~~B~~fixed spline bolts are shown in Table 712.1.5.4.3.4. These forms will assist in obtaining all the required information for the testing methods allowed by MoDOT.

Table 712.1.5.4.3.1 and Table 712.1.5.4.3.2 ~~is~~ are to be used when the Calibrated Wrench (Sec 712.7.5) or Turn-Of-Nut (Sec 712.7.6) Methods are used. Table 712.1.5.4.3.4 is to be used when Combined Method (Sec 712.7.8) is used for TNA fixed spline bolts. By running the calculations in the spec book to verify the bolts, the values needed for the equipment in the field will also be determined. The entire test will need to be completed to verify that the bolt is good for use in the field.

Calibrated Wrench – The values from Table 712.1.5.4.3.1 and Table 712.1.5.4.3.2 that will be needed are the recorded Torque Values.

Turn-Of-Nut – When using the Turn-Of-Nut Method, the Ro~~tation~~ Cap~~acity~~ Test provides a check that the turn requirements of Sec 712.7.6 will generate the minimum tension required. Verify that the amount the

nut has turned going to the minimum bolt tension is less than the specified nut rotation in Sec 712.7.6 Nut Rotation from Snug Tight Condition table.

Combined Method – When using the Combined Method, the Supplier Test Report for F3148 Grade 144 TNA fixed spline bolt assemblies shall include the RoCap Testing and the Pre-Installation Verification Testing for initial acceptance. In lieu of RoCap testing, Pre-Installation Verification Testing of the assembly shall be performed in accordance with Sec 712.7.8 (ASTM F3148 Appendix X2).

The RoCap test for Calibrated Wrench and Turn-Of-Nut Methods is split based on long and short hex head bolts. Long bolts are those bolts that can fit into the Skidmore-Wilhelm Bolt Tension Measuring Device or the Skidmore-Wilhelm short bolt setup. Short bolts are those that are too short to fit into the short bolt setup tension measuring device.

Table 712.1.5.4.3.1 provides info about how to run the test, and the information to be recorded.

Rotation Capacity Testing Steps for Calibrated Wrench Method (Sec 712.7.5) and Turn-Of-Nut Method (Sec 712.7.6)

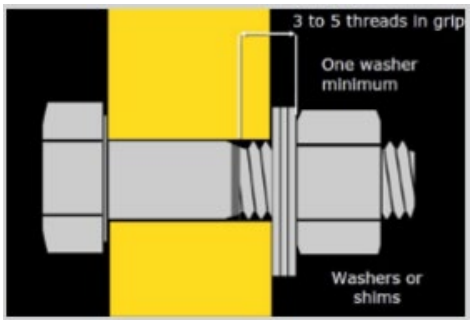
Table 712.1.5.4.3.1

Job Site Rotational Capacity Test (RoCap Test) – A325, 144 & A490 Long Hex Head Bolts

	Part 1								Part 2		
Test No.	Sec 712.7.3 Minimum Final Bolt Tension (P)	Less Than	Bolt Tension Gauge Reading (P)	Sec 1080.2.5.4.6 Maximum Allowable Torque (T)	Greater Than	Torque Gauge Reading	Actual Nut Rotation (turn)	Sec 7121.7.6 Nut Rotation (turn) Less than actual(Y/N)	Sec 1080.2.5.4 Required Rotation (turn) Tension Gauge Reading	Equal or Greater Than	Sec 1080.2.5.4.5 Required Turn Test Tension
1		<			>					>=	
2		<			>					>=	
3		<			>					>=	
R1		<			>					>=	
R2		<			>					>=	
R3		<			>					>=	
Torque Formula (T=0.25P x Dia./12), T in ft-lbs, P in lbs, Bolt Dia. in inches											

Long Bolt Test

1. Measure the ratio of diameter/length of the bolt.
2. Place the bolt into the Skidmore and set it to snug tight (10% of installation tension in Sec 712.7.3 Bolt Tension Table). This is to be done with a spud wrench. The contractor should add washers until three to five threads are in the grip, if less than 3 threads, the test will fail. Mark reference rotation marks on the fastener assembly element turned and on face plate of Skidmore. (Mark starting point on bolt end, nut and calibrator face with straight line.) Note that some short bolts may require the short bolt setup for the Skidmore.



3. Turn the fastener with the wrench to be used for the daily testing in the field to the installation minimum tension in Sec 712.7.3 Bolt Tension Table. Stop and record the torque at that moment from the torque wrench and record the tension on the Skidmore. Verify the recorded torque does not exceed the maximum allowable torque (refer to Sec 1080.2.5.4.6 formula). Verify that the amount the nut has turned going to the minimum bolt tension is less than the specified nut rotation in Sec 712.7.6 Nut Rotation from Snug Tight Condition table.

4. Further turn the bolt according to Sec 1080.2.5.4.4. This rotation is measured from the initial match mark made in step 2. Record the tension achieved and then compare the tension at this point to the Turn Test Tension in Sec 1080.2.5.4.5 Required Bolt Tensions Table. The tension must be equal or greater than Turn Test Tension.
5. Remove the bolt and inspect for damage and record it on our form. Turn the nut by hand on the bolt threads to the position it was in during the test. Not being able to turn the nut by hand is thread failure.
6. Repeat the process 2 additional times for each type of bolt assembly (Total of 3 tests per assembly lot).
7. Once the 3 tension and torque values have been obtained from Step 3, use the higher of the 3 numbers.

Table 712.1.5.4.3.2 provides info about how to run the short bolt test for those bolts that are too short to fit into the Skidmore-Wilhelm short bolt setup tension measuring device and the information to be recorded.

Rotation Capacity Testing Steps for Calibrated Wrench Method (Sec 712.7.5) and Turn-Of-Nut Method (Sec 712.7.6)

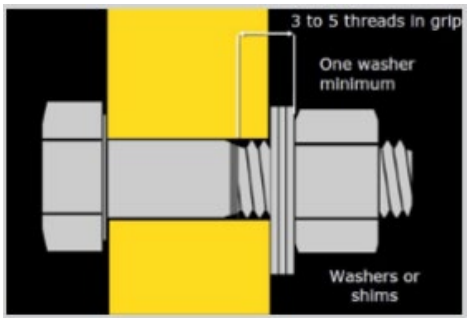
Table 712.1.5.4.3.2
Job Site Rotational Capacity Test (RoCap Test) – A325, 144 & A490 Short Hex Head Bolts

Test No.	Sec 1080.2.5.4.5 Turn Test Tension (P)	20% of Max. Turn Test Torque (T)	Maximum Calculated Turn Test Torque	Greater Than	Torque Gauge Reading at End of First Rotation	Visual Inspection of nut and bolt after Second Rotation (Acceptable/Not Acceptable)
1				>		
2				>		
3				>		
R1				>		
R2				>		
R3				>		
20% Torque Formula (T = 0.20T), T in ft-lbs.						
Torque Formula (T=0.25P x Dia./12), T in ft-lbs., P in lbs., Bolt Dia. In inches						
First Rotation	[L<= 4D, 1/3 turn (120°)], [4D< L<8D, 1/2 turn (180°)]					
Second Rotation	A325 & 144 [L<= 4D, 1/3 turn (120°)], [4D< L<8D, 1/2 turn (180°)] A490 [L<= 4D, 1/4 turn (90°)], [4D< L<8D, 1/3 turn (120°)]					

Short Bolt Test

1. Measure the ratio of diameter/length of the bolt and refer to Sec 712.7.6 on the installation rotation.

2. Place the bolt into the steel plate. The contractor should add washers until three to five threads are in the grip, if less than 3 threads the test will fail. Set it to snug tight (Not exceed 20% of maximum torque at first rotation). Maximum torque at first rotation is equal to Turn Test Tension, Sec 1080.2.5.4.5 and applying that tension to the torque formula in Sec 1080.2.5.4.6. This is to be done with a measuring torque wrench.



3. Mark reference rotation marks on the fastener assembly element turned and on face of steel plate. (Mark starting point on bolt end, nut and steel plate face with straight line.)
4. Turn the fastener with the torque wrench to be used for the daily testing in the field to the rotation shown in Sec 712.7.6 Nut Rotation from Snug Tight Condition Table. Once the first target rotation has been reached, stop and record the torque at that moment from the torque wrench. Verify the recorded torque does not exceed the maximum torque. Maximum torque at first rotation is turn test tension, Sec 1080.2.5.4.5 with torque formula Sec 1080.2.5.4.6, as shown in step 2.
5. Further turn the bolt further according to Sec 1080.2.5.4.4. This rotation is measured from the initial match mark made in step 3. Assemblies that strip or fracture prior to this rotation fail the test.
6. Remove the bolt and inspect for damage and record it on our form. Turn the nut by hand on the bolt threads to the position it was in during the test. Not being able to turn the nut by hand is thread failure.
7. Repeat the process 2 additional times for each type of bolt assembly (Total of 3 tests per assembly lot).
8. Once the 3 torque values have been obtained from Step 3, use the higher of the 3 torque numbers.

Rotation Capacity Testing Steps For ~~Load Indicating~~Twist Off Tension Control Bolt Method (Sec 712.7.7)

The ~~Load Indicating~~Twist Off Tension Control Bolt Method is less common. The bolt is designed to automatically verify that the bolts are not overtightened. The Rotational Capacity test in the field is to verify that the threads are not binding due to rust and dirt. This binding will give a false reading and cause the bolt spline to shear off prior to the design tension being achieved. Also due to the consistency of the bolt, there will not be a need to tighten the bolt to 1.15 times the Minimum Target Tension. The spline of the bolts will snap off within 5-10% of the designed tension of the fastener and exceed the Minimum Target Tension when properly lubricated.

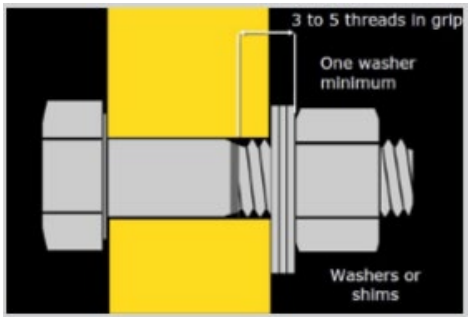
Table 712.1.5.4.3.3 provides info about how to run the test, and the information to be recorded.

Table 712.1.5.4.3.3

Rotation Capacity Testing Steps for ~~Load Indicating~~Twist Off Tension Control Bolt Method (Section 712.7.7)

Job Site Rotational Capacity Test – A325TC/A490TC Bolts				
Test No.	**Sec 712.7.3 1.05xMinimum Final Bolt Tension (P)**	**Less Than**	**Bolt Tension Gauge Reading (P)**	**Inspection Torque Calculated Value**
1		<		
2		<		
3		<		
R1		<		
R2		<		
R3		<		
(Inspection Torque formula = 0.95 x 0.25 x Gauged Tension Reading x Bolt Dia. / 12; Bolt Dia. in inches)				

1. Measure the ratio of diameter/length of the bolt.
2. Place the bolt into the Skidmore and set it to snug tight (10% of installation tension). This is to be done with a spud wrench. The contractor should add washers until only three threads are showing.
3. Place the specialty tool used on the end of the bolt and tighten until the spline of the bolt snaps off.
4. Record the tension value on the Skidmore once the bolt has snapped.
5. Verify that the recorded value is greater than 1.05 times the Minimum Target Tension from Sec 712.7.3.
6. Remove the bolt and inspect for damage.
7. Repeat the process 2 additional times for each type of bolt assembly (Total of 3 tests per assembly lot).
8. Once the 3 torque values have been calculated, use the higher of the 3 torque numbers.



It is most important to verify plies were in contact when bolts were snugged and that a fastener was not subsequently loosened when accompanying splice bolts were tightened and compacted the splice faying surfaces into contact after other fasteners had been already tightened.

Pre-Installation Verification Testing Steps for Torque & Angle (TNA) Fixed Spline Bolts - Combined Method (Sec 712.7.8)

The Pre-Installation Verification Test for Combined Method uses the Skidmore-Wilhelm Bolt Tension Measuring Device or the Skidmore-Wilhelm short bolt setup.

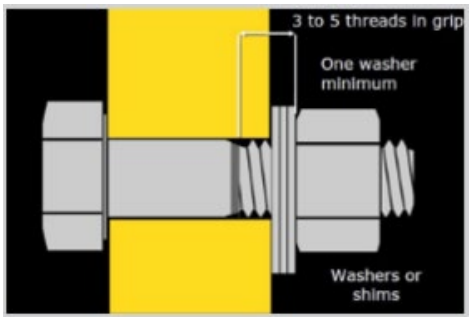
Table 712.1.5.4.3.4 provides info about how to run the test, and the information to be recorded.

Table 712.1.5.4.3.4

Pre-Installation Testing Steps for 144 TNA Fixed Spline Bolts - Combined Method (Section 712.7.8)

Job Site Pre-Installation Verification Test – 144 TNA Fixed Spline Bolts								
Combined Method (Sec 712.7.8)								
TEST No.	Part 1				Part 2			
	Initial Tension Torque Setting (T, ft-lbs)	Sec 712.7.3 Minimum Initial Bolt Tension (P, lbs)	Less Than	Bolt Tension Gauge Reading (P, lbs)	[a]Rotation from Initial Tension (1/x Turn)	Sec 712.7.3 Minimum Final Bolt Tension (P, lbs)	Less Than	Bolt Tension Gauge Reading (P, lbs)
1			=<				=<	
2			=<				=<	
3			=<				=<	
R1			=<				=<	
R2			=<				=<	
R3			=<				=<	
[a]Up to 4D = 90° (1/4 turn), >4D to 8D = 120° (1/3 turn), Bolt Length/Bolt Dia. (Length and Diameter in inches), >8D Consult the supplier								
Looking at the Manufacturer/Supplier Test Report for TNA Fixed Spline Structural Bolting Assembly, record the highest torque value obtained on the samples on the Rotational Capacity Tests:								

1. Measure the ratio of diameter/length of the bolt.



2. Place the bolt into the Skidmore. The contractor should add washers until three to five threads are in the grip, if less than 3 threads, the test will fail. Record the torque of the specialized tool capable of engaging the nut and bolt spline.
3. Tighten the assembly using the specialized tool on snug tightening setting. Record the bolt tension shown on the gauge at the end of tightening. Verify the recorded tension does exceed the minimum in bolt tension (refer to Sec 712.7.3 table).
4.Mark reference rotation marks on the fastener assembly element turned and on face plate of Skidmore. (Mark starting point on bolt end, nut and calibrator face with straight line.) Note that some short bolts may require the short bolt setup for the Skidmore.
5. Tighten the assembly using the specialized tool on angle tightening setting with angle setting dial set to the correct degree of nut rotation. Record the bolt tension shown on the gauge at the end of tightening. Verify the recorded tension does exceed the minimum final bolt tension (refer to Sec 712.7.3 table). Verify that the amount the nut has turned is the specified nut rotation.
6. Remove the bolt and inspect for damage and record it on our form. Turn the nut by hand on the bolt threads to the position it was in during the test. Not being able to turn the nut by hand is thread failure.
7. Repeat the process 2 additional times for each type of bolt assembly (Total of 3 tests per assembly lot).
8. Look at the manufacturer or supplier Test Report for the TNA Fixed Spline Structural Bolting Assembly to obtain the higher torque value obtained on the samples tested on the Rotational Capacity Test.

712.1.5.4.4 Step 4, Installation

The next step is to ensure the proper process is used in the assembly of structural steel. It is important that the contractor is placing temporary bolts, drift pins and permanent bolts in the correct pattern. Read Sec 712.5 for additional requirements when fitting-up the structural steel.

The order in which bolts are tightened is important. If not done correctly, the plates will not be sandwiched tightly, and gaps will be introduced. Due to these being slip-critical connections, the joints need to experience 100% contact between all the plies. The contractor will need to start tightening the joints in the center of the plate, and then work radially out from the center to the extents of the joint.

Once the bolts are tightened by the contractor using one of the ~~three~~ four approved methods, MoDOT will be responsible to check a portion of the bolts. We will review 10% of the bolts, or two per lot, whichever is greater. If bolt issues are discovered, more bolts may need to be reviewed. The following steps are generally what is seen in the field. There may be differences per contractor, but MoDOT's roles and requirements should be the same across the state.

Contractor/QC: The contractor will be installing the bolts through various methods. It can be expected to see Turn-Of-Nut Method, ~~or~~ Calibrated Wrench Method (Torque Wrench) or Combined Method. You could also see the contractor using Stall Out guns that are designed to stop spinning the bolts once a certain torque is reached. Sometimes air impact guns are used and have the air pressure adjusted to stop gun at torque desired using a Skidmore to verify they are exceeding the design tension of the fastener(s). This tool would be considered the Calibrated Wrench. This is an acceptable method, provided they do not change any conditions. They should run the Ro~~tation~~ Cap~~acity~~ Test with the equipment to be used. Once they change any part of the setup (add or remove an air hose, add an additional gun or item ran off of air hose supply, change air pressure, etc.), they will need to rerun the Ro~~tation~~ Cap~~acity~~ Test. If the contractor is using the Turn-Of-Nut Method or Combined Method, then they are not required to use a torque wrench on the nuts as well.

MoDOT/QA: Inspectors will have different checks based upon the type of verification used by the contractor.

If the contractor is using the Calibrated Wrench Method (Torque Wrench or Stall Out Gun) to check every bolt, MoDOT will use a torque wrench and will follow the Calibrated Wrench Method.

If the contractor is using the Turn-Of-Nut Method, MoDOT will follow two steps. We will visually watch the contractor install and snug tighten the fastener assembly, ensuring the plies are in contact. Bolts may be required to be snug tightened more than once as plies are pulled together with later bolts. ~~after doing so and~~ Once all bolts are snug tight and ensuring the plies are in contact, verify ~~ensure~~ that they are match marking the nut, bolt, and plies correctly. Then watch as they turn the nut (or bolt) to make sure ~~it is generating~~ the correct degree of rotation between the bolt and nut has been used.~~number of turns.~~ The unturned element should be restrained from turning during installation. A visual check of all the nuts (or bolts) turned so far can be quickly done to make sure they are marked, and that the marks are turned the correct amount. As a double check, the inspector will also take a torque wrench to check bolt torque on 10% of the bolts. If bolt issues are discovered, more bolts may need to be checked. Even if the contractor did not use a torque wrench to check the bolts, MoDOT inspectors will still use a torque wrench and record findings.

If the contractor is using the Combined Method, MoDOT will follow two steps. We will visually watch the contractor install and snug tighten the fastener assembly with specialized tool on snug tightening setting. Bolts may be required to be snug tightened more than once as plies are pulled together with later bolts. Once all bolts are snug tight and ensuring the plies are in contact, ensure that they are marking the nut, bolt, and plies correctly. Then watch as they tighten the fastener assembly with specialized tool on angle tightening setting with angle setting dial set to the correct degree of nut rotation. A visual check of all the nuts turned so far can be quickly done to make sure they are marked, and that the marks are turned the correct amount. As a double check, the inspector will also take a torque wrench to check bolt torque on 10% of the bolts. If bolt issues are discovered, more bolts may need to be checked. Even if the contractor did not use a torque wrench to check the bolts, MoDOT inspectors will still use a torque wrench and record findings.

~~EPG 712.1.5.4.5 Step 5 details the three verification procedures.~~

712.1.5.4.5 Step 5, Bolt Verification

712.1.5.4.5.1 Calibrated Wrench Method, Sec 712.7.5

The first option listed in the specification book is the Calibrated Wrench Method. This method will use a calibrated wrench to check that the torque delivered to the bolt is the minimum torque needed to induce the needed minimum tension, as shown in Sec 712.7.3. In order to do this, information must be available from the Rotational Capacity Test completed for each lot.

Sec 712.7.5 states that when the calibrated wrench is used, it needs to be set 5-10% over the torque gauge value from Column 4 of the Rotational Capacity Test. Take the maximum Torque Gauge Reading from the Rotational Capacity Test and multiply by 1.05. This new value will be the one set onto the calibrated wrench.

Day-to-Day Verification

Each day the inspector will need to verify the installed bolts are correctly tensioned. Most of the time, MoDOT inspectors will use the contractor's equipment for the verification. The important thing is that the contractor is verifying the calibrated wrench daily. This will mean that the contractor will need to have the Skidmore on site each day to verify that the wrench is generating the correct tension at the torque it is reading. MoDOT inspectors will pick 10% of the bolts to also check bolt torque. The torque value ~~they~~ MoDOT inspectors are checking is the maximum torque gauge reading generated from Step 3 of the Rotation Capacity Test.

712.1.5.4.5.2 Turn-Of-Nut Method, Sec 712.7.6

The second option listed in the specification book is the Turn-Of-Nut Method. This method uses the fact that the nuts must be turned to the rotation specified in Sec 712.7.6 to induce the needed minimum tension, as shown in Sec 712.7.3. In order to do this, verification will be needed from the Ro~~tational~~ Cap~~acity~~ Test completed for each lot.

When the Ro~~tational~~ Cap~~acity~~ Test is run, in Step 3 is to verify the bolt rotation is less than that specified in Sec 712.7.6. Once this is verified, all the bolts can be tightened to the rotation needed and that will confirm that the needed tension has been achieved. This is provided that all the plies are in contact when snug tightened.

Example

On a project you are installing 7/8” diameter bolts that are 4” long. The RoCap test was performed on the bolt assemblies. When the bolts were tensioned during RoCap, they were tensioned to 39,050 lb. From the formula in Sec 1080.2.5.4.6, the maximum torque is to be 712 lb-ft. The bolt was torqued to 701 lb-ft, so it passes the RoCap test. During the test, the inspector also noted that the bolt nut turned 2 flats (or 1/3 of a turn). Sec 712.7.6 Nut Rotation from Snug Tight Condition table says that this bolt is to be turned 1/2 turn for Turn-Of-Nut in the field. Since the bolt achieved the minimum tension in 1/3 turn, we know that the turning it to 1/2 turn will achieve a higher tension value. If the RoCap test shows a higher turn value needed than the Sec 712.7.6 table, then further discussions should be had with the contractor about next steps before any bolts are installed in the field.

Day-to-Day Verification

For the day-to-day verifications, MoDOT inspectors will visually verify that the Turn-Of-Nut Method is completed correctly. They will review marks made by the contractor and make sure that there is a general comfort level with how the contractor is doing the work. In addition to this, MoDOT inspectors will pick 10% of the bolts to also check bolt torque. The torque value ~~they~~ MoDOT inspectors are checking is the maximum torque gauge reading generated from Step 3 of the Ro~~tation~~ Cap~~acity~~ Test.

The photograph to the right shows what the markings will look like when the Turn-Of-Nut Method is used. In order to perform the test, three marks are made: one on the nut, one on the bolt, and one on the steel plate underneath. To begin with, mark the nut at a corner, and follow that line all the way through to the steel. Notice the left side bolts are all starting in the same position. The right-side bolts have been rotated 1/3 of a turn, or two flats of the hex head. Notice how the bolt and the steel still line up, and only the nut has moved. Marking the bolt and steel ensures that the bolt does not move during tightening. The nut will show how much it has moved. Marking the hex head accordingly is a semi-permanent record that the test was run. This also provides the inspector with the necessary information to quickly verify tightness, but a random check of 10% of bolts with a torque wrench by the QA inspector shall still occur. The inspector will not have to tighten the bolts themselves but can witness the ironworker who is tightening some of the bolts to ensure they are following the proper procedure of the Turn-Of-Nut Method.

712.1.5.4.5.3 ~~Load Indicating~~Twist Off Tension Control Bolt Method, Sec 712.7.7

The third option listed in the specification book is the ~~Load Indicating~~Twist Off Tension Control Bolt Method. This method uses the fact that the bolts have been specially designed to shear off once a specific torque has been reached in the bolt. This torque has been correlated to the needed minimum tension as shown in Sec 712.7.3. In order to do this, the verification must be available from the Rotational Capacity Test completed for each lot.

When the Ro~~tational~~ Cap~~acity~~ Test is run, there is one piece of information needed. The Tension Gauge Reading when the spline shears off. Since the spline shears off, and the ~~drill~~ tool cannot provide any more compactive effort, there is generally not a concern about overtightening the bolt provided that the bolt hardware is clean and well lubricated. Once the bolt shears off, the tension achieved is the final tension. The Ro~~tation~~ Cap~~acity~~ Test will verify that the final tension is at or above the minimum bolt tension required in Sec 712.7.3.

Day-to-Day Verification

Since the ~~machine~~ specialty tool will shear the bolt off at the specified tension, the biggest piece to verify is done during the Ro~~tational~~ Cap~~acity~~ Test. Once that is done, the inspector just needs to ensure that the contractor is following the correct tightening procedure shown in Sec 712.7.7. Ensure that all plies are in contract when snug tight and that bolt hardware is clean and well lubricated. The QA Inspector should also perform checks of at least 10% of the fastener assemblies with a torque wrench to verify the fastener is tight using the Inspection Torque value (0.95 x 0.25 x highest gauged tension from RoCap Test x bolt diameter in inches / 12). If bolt issues are discovered, more bolts may need to be checked.

712.1.5.4.5.4 Combined Method (TNA Fixed Spline Bolts), Sec 712.7.8

The fourth option listed in the specification book is the Combined Method. This method uses the fact that the nuts must be turned, after initial bolt tensioning (snug), to the rotation specified in ASTM F3148 Table X2.2, Angle Tightening Rotation, to induce at least the required minimum final bolt tension, as shown in Sec 712.7.3. This pre-verification testing shall be performed as mentioned in Sec 712.7.8 (ASTM F3148 Appendix X2).

Example

On a project you are installing 7/8” diameter bolts that are 4” long. The pre-installation verification test was performed on the bolt assemblies. When the bolts were tensioned during initial bolt tensioning (snug), the torque used by the installation tool resulted in a tension of 33,000 lbs, greater than the required minimum tension of 22,000 lbs in the minimum initial bolt tension column in the Table in Sec 712.7.3. After the subsequent application of the 120 degrees (1/3 of a turn or 2 flats) rotation required in ASTM F3148 Table X2.2, the final tension result is 64,000 lbs, greater than the minimum final bolt tension of 49,000 in the Table in Sec 712.7.3.

Day-to-Day Verification

For the day-to-day verifications, MoDOT inspectors will visually verify that the Combined Method is completed correctly. They will review marks made by the contractor and make sure that there is a general comfort level with how the contractor is doing the work. In addition to this, MoDOT inspectors will pick 10% of the bolts to also check bolt torque. The torque value MoDOT inspector will use is the highest torque value record on the RoCap Test samples shown on the Manufacturer/Supplier Test Report for the TNA Fixed Spline Structural Bolting Assembly.

The photograph to the right shows what the markings will look like when the Combined Method is used. In order to perform the test, three marks are made: one on the nut, one on the bolt, and one on the steel plate underneath after initial tensioning. Bolts may require initial tensioning (snug tightening) more than once as plies are pulled together. To begin with, mark the nut at a corner, and follow that line all the way through to the steel. Notice the left side bolts are all starting in the same position. The right-side bolts have been rotated 120°, 1/3 of a turn, or two flats of the hex head. Notice how the bolt and the steel still line up, and only the nut has moved. Marking the bolt and steel ensures that the bolt does not move during tightening. The nut will show how much it has moved. Marking the hex head accordingly is a semi-permanent record that the test was run. This also provides the inspector with the necessary information to quickly verify tightness, but a random check of 10% of bolts with a torque wrench by the QA inspector shall still occur. The inspector will not have to tighten the bolts themselves but can witness the ironworker who is tightening some of the bolts to ensure they are following the proper procedure of the Combined Method.

712.1.6 High Strength Anchor Bolts

When high strength anchor bolts are specified, ASTM F1554 Grade 55 anchor bolts shall be used unless higher grade anchor bolts are required by design. Grade 105 bolts shall not be used in applications where welding is required. Grade 36 anchor bolts are commonly referred to as “low-carbon” and may be used if specified on the plans. Grade 55 anchor bolts may be substituted for applications where Grade 36 is specified. To facilitate easy identification of anchor bolt, the following figure shows some of the typical bolt markings required by the ASTM specification. The end of the anchor bolt intended to project from the concrete shall be steel die stamped with the grade identification and color coded as follows.

Grade	Color Code	Identification
36		AB36 XYZ
55		AB55 XYZ
105		AB105 XYZ

Note: XYZ represents the manufacturer's identification mark.

712.1.7 Non-destructive Testing

In certain instances, non-destructive testing (NDT) may be required to be conducted on steel components of a bridge. The contractor will be responsible for providing and certified NDT technician to conduct the testing. This technician will usually be an employee of a third party inspection agency. Certification for NDT technicians will be in accordance with the requirements of The American Society for Nondestructive Testing (ASNT) Recommended Practice SNT-TC-1A. MoDOT does not maintain an approved list of NDT technicians. The Bridge Division does review certifications for testing agencies and keep a list of personnel of these agencies with their respective certifications.

For projects that require NDT in the field, the inspector will collect the information from the contractor as to who will be providing the NDT services. The contractor shall submit the certifications to the Resident Engineer to be forwarded to the Bridge Division at Fabrication@modot.mo.gov. These certifications shall include the following documentation for each individual performing NDT: their certifications, current eye exam, and the NDT company written practice, including the Level III individual certification used for the written practice.

At the Resident Engineer's option, they may choose to keep a list of personnel who have performed NDT work for a quick reference for future projects. However, the Resident Engineer and the inspector will always request to see the current eye exam results prior the technician providing the NDT on these future projects.

712.2 Materials Inspection for Sec 712

712.2.1 Scope

This guidance establishes procedures for inspecting and reporting those items specified in Sec 712 that are not always inspected by Bridge Division personnel or are not specifically covered in the Materials details of the Specifications.

712.2.2 Procedure

Normally all materials in Sec 712 will be inspected by Bridge Division personnel. Bolts, nuts and washers accepted by PAL may be delivered directly from the manufacturer to the project without prior inspection. When requested by the Bridge Division or construction office, the Construction and Materials Division will inspect fencing and other miscellaneous items. The Bridge Division is responsible for the inspection of shop coating of structural steel at fabricating plants.

712.2.2.1 Project Inspection and Sampling for PAL

Inspecting of PAL material will be as stated in this section and Pre-Acceptance Lists (PAL).

712.2.3 Miscellaneous Materials

712.2.3.1 High Strength Bolts

All bolts, nuts, and washers should be from a PAL supplier in accordance with Pre-Acceptance Lists (PAL). If a supplier proposes to furnish structural steel connectors and is not on PAL, a request is to be made to the Construction and Material Division for acceptance into the PAL program. Once satisfactory submittals have been received, the supplier will be placed on the PAL. Bolts, nuts, and washers, for use other than bridge construction and in quantities less than 50, may be accepted from a PAL supplier without a PAL identification number.

712.2.3.1.1 Manufacturer's Certification. Bolts and nuts specified to meet the requirements of ASTM A307 shall be accompanied by a manufacturer's certification statement that the bolts and nuts were manufactured to comply with requirements of ASTM A307 and, if required, galvanized to comply with requirements of AASHTO M232 (ASTM A153), Class C or were mechanically galvanized and meet the coating thickness, adherence, and quality requirements of ASTM B695, Class 55. Certification shall be retained by the shipper. A copy should be obtained when sampling at the shipper and submitted with the samples to the lab.

All bolts, nuts and washers are to be identifiable as to type and manufacturer. Bolts, nuts, and washers manufactured to meet ASTM A307 will normally be identified on the packaging since no special markings are required on the item. Dimensions are to be as shown on the plans or as specified.

Weight (mass) of zinc coating, when specified, is to be determined by magnetic gauge in the same manner as described for bolts and nuts in EPG 1040 Guardrail, End Terminals, One-Strand Access Restraint Cable and Three-Strand Guard Cable Material.

Samples for Laboratory testing are only required when requested by the State Construction and Materials Engineer, or when field inspection indicates questionable compliance. Samples shall be taken according to EPG 712.2.3.2.1.1 ASTM A307 Bolts.

712.2.3.1.2 High strength bolts, nuts, and washers specified shall meet the requirements of ASTM F3125 Grade A325. Bridge plans may also specify ASTM F3125 Grade 144 or A490 or ASTM F3148 Grade 144 high strength bolts. Field inspection shall include examination of the certifications or mill test reports; checking identification markings; and testing for dimensions. The certifications or mill test reports, conforming to EPG 712.2.3.1.1 Manufacturer's Certification, shall be retained in the district office. Samples for Laboratory testing shall be taken and submitted in accordance with EPG 712.2.3.2.1.2 ASTM F3125 Grade A325, 144 or A490 Bolts and ASTM F3148 Grade 144 Bolts.

712.2.3.2 PAL Manufacturer Facilities Sampling

Prior to visiting a PAL supplier or manufacturer facility, the Cognos report “PAL Shipments Within Date Range” should be run for the facility to determine what material has been given MoDOT PAL numbers. For each PAL material, the sample shall consist of six pieces rather than determined from lot quantities as given in the following sections. An individual sample shall consist of bolts, nuts, or washers as these are treated as different materials in the PAL system.

712.2.3.2.1 Sample sizes

712.2.3.2.1.1 ASTM A307 Bolts

Samples for Laboratory testing are only required when requested by the State Construction and Materials Engineer, or when field inspection indicates questionable compliance. When samples are taken, they are to be taken as shown in the following table. When galvanized bolts, nuts and washers are submitted to the Laboratory, a minimum of 3 samples of each are required for Laboratory testing.

3 for lots of 0 to 800 pcs.	

6 for lots of 801 to 8,000 pcs.	Each sample is to consist of one bolt, nut and washer. Submit for dimensions, weight (mass) of coating, mechanical properties.
9 for lots of 8,001 to 22,000 pcs.	
15 for lots of 22,001+ pcs.	

712.2.3.2.1.2 ASTM F3125 Grade A325, 144 or A490 Bolts and ASTM F3148 Grade 144 Bolts

Samples for Laboratory testing shall be taken and submitted as follows: All lots containing 501 or more, high strength bolts shall be sampled and submitted to the Laboratory for testing. If no lot offered contains 501 or more bolts, sample 10 percent of the lots offered, or one lot, whichever is greater. A lot is defined as all bolts of the same size and length, with the same manufacturer's lot identification, offered for inspection at one time. Samples shall be taken as follows:

Number of Bolts in the Lot	Number of Bolts Taken for a Sample*
~~150 and less~~	~~3~~
~~151~~ 0 through 800	3
801 through 8,000	6
8,001 through 22,000	9
22,001 plus	15
* A minimum of 3 samples will be required for galvanized materials.	

All lots containing 501 or more, high strength nuts shall be sampled and submitted to the Laboratory for testing. If no lot offered contains 501 or more nuts, sample 10 percent of the lots offered or one lot, whichever is greater. A lot is defined as all nuts of the same grade, size, style, thread series and class, and surface finish, with the same manufacturer's lot identification, offered for inspection at one time. Samples shall be taken as follows:

Number of Nuts in the Lot	Number of Nuts Taken for a Sample*
0 through 800 ~~and under~~	1

801 through 8,000	2
8,001 through 22,000	3
22,000 and over	5
* A minimum of 3 samples will be required for galvanized materials.	

All lots containing 501 or more, high strength washers shall be sampled and submitted to the Laboratory for testing. If no lot offered contains 501 or more washers, sample 10 percent of the lots offered, or one lot, whichever is greater. A lot is defined as all washers of the same type, grade, size and surface finish, with the same manufacturer's lot identification, offered for inspection at one time. Samples shall be taken as follows:

Number of Washers in the Lot	Number of Washers Taken for a Sample*
0 through 800 ~~and under~~	1
801 through 8,000	2
8,001 through 22,000	3
22,000 and over	5
* A minimum of 3 samples will be required for galvanized materials.	

712.2.3.2.2 Bolts for Highway Lighting, Traffic Signals or Highway Signing

Bolts, nuts, and washers for highway lighting, traffic signals, or highway signing shall meet the requirements given in EPG 712.2.3.1.2 High Strength Bolts. Samples for Central Laboratory testing are only required when requested by the State Construction and Materials Engineer or when field inspection indicates questionable compliance.

712.2.3.3 Slab Drains

Slab drains are to be accepted on the basis of field inspection of dimensions, weight (mass) of zinc coating, and a satisfactory fabricators certification. The dimensions, weight (mass) of zinc coating, and material specification requirements are shown on the bridge plans.

Field determination of weight (mass) of coating is to be made on each lot of material furnished. The magnetic gauge is to be operated and calibrated in accordance with ASTM E376. At least three members of each size and type offered for inspection are to be selected for testing. A single-spot test is to be comprised of at least five readings of the magnetic gauge taken in a small area and those five readings averaged to obtain a single-spot

test result. Three such areas should be tested on each of the members being tested. Test each member in the same manner. Average all single-spot test results from all members to obtain an average coating weight (mass) to be reported. The minimum single-spot test result would be the minimum average obtained on any one member. Material may be accepted or rejected for galvanized coating on the basis of magnetic gauge. If a test result fails to comply with the specifications, that lot should be resampled at double the original sampling rate. If any of the resampled members fail to comply with the specification, that lot is to be rejected. The contractor or supplier is to be given the option of sampling for Laboratory testing, if the magnetic gauge test results are within minus 15 percent of the specified coating weight (mass).

A fabricators certification shall be submitted to the engineer in triplicate stating that "The steel used in the fabrication of the slab drains was manufactured to conform to ASTM A709" or "A500, A501" as the case may be.

712.2.3.4 Miscellaneous Structural Steel

Other structural steel items not requiring shop drawings also require inspection. Inspection includes a fabricator's certification identifying the source and grade of steel, as well as verification of dimensions and inspection of any coating applied. The report is to include the grade of steel, coating applied, and results of inspection.

712.3 Lab Testing

712.3.1 Scope

This establishes procedures for Laboratory testing and reporting samples of structural steel, bolts, nuts, and washers and for welding qualifications.

712.3.2 Procedure

712.3.2.1 Chemical Tests - Bolts, Nuts, and Washers

Weight (mass) of coating shall be determined in accordance with AASHTO M232. Chemical analysis of the base metal shall be determined, when requested, according to Laboratory Testing Guidelines for Sec 1020. Original test data and calculations shall be recorded in Laboratory workbooks.

712.3.2.2 Physical Tests - Bolts and Nuts

Original test results and calculations shall be reported through AASHTOWare Project.

Low carbon steel bolts and nuts shall be tested according to ASTM A307. Tests are to be as follows:

(a) Bolts shall be tested for dimensions, hardness, and tensile strength.
(b) Nuts shall be tested for dimensions, hardness, and proof load.

Due to the shape and length of some bolts and the shape of some nuts, it may not be possible or required to determine the tensile strength of the bolts or the proof load of the nuts.

High strength bolts, nuts, and washers shall be tested according to ASTM F3125 Grade A325, 144 or A490 or ASTM F3148 Grade 144. Tests are to be as follows:

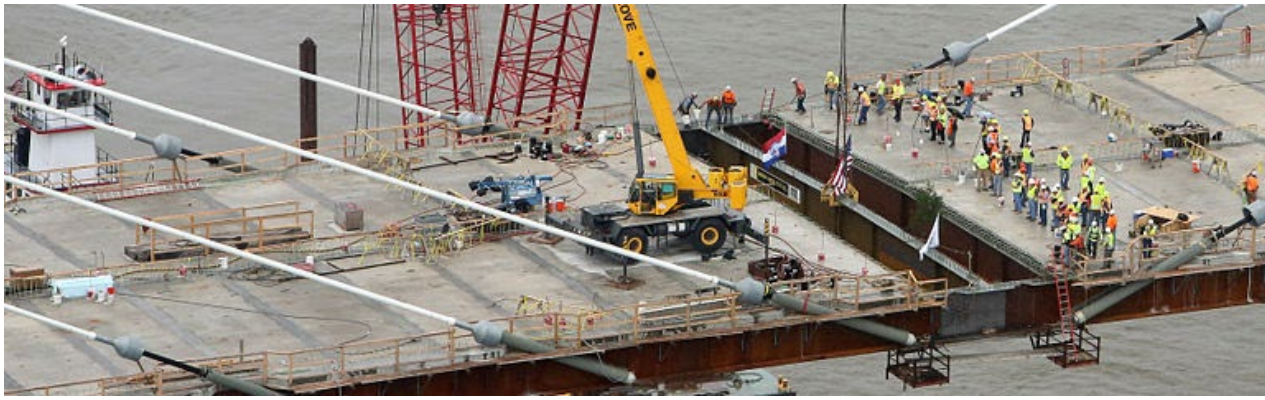
(a) Bolts shall be tested for dimensions, markings, hardness, proof load, and tensile strength.
(b) Nuts shall be tested for dimensions, markings, hardness, and proof load.
(c) Washers shall be tested for hardness.

Due to the shape and length of some bolts and the size of some nuts, it may not be possible or required to determine the proof load and tensile strength of the bolts or the proof load of the nuts.

712.3.3 Sample Record

The sample record shall be completed in AASHTOWARE Project (AWP), as described in AWP MA Sample Record, General, and shall indicate acceptance, qualified acceptance, or rejection. Appropriate remarks, as described in EPG 106.20 Reporting, are to be included in the report to clarify conditions of acceptance or rejection.

Test results for bolts, nuts and washers shall be reported through AWP.



751.50 Standard Detailing Notes

Only showing notes affected in EPG 751.50 Standard Detailing Notes

(H1.8.1) ASTM F3148 Grade 144 bolts may be specified by design or directly substituted for a design with A325 bolts. Consult SPM or SLE before using F3148 bolts.

Bolts shall be 7/8-inch diameter ASTM F3125 Grade A325 F3148 Grade 144 Type 1 Type 3 in 15/16-inch diameter holes.

Category:1080 Structural Steel Fabrication

Refer to Sec 1080 for MoDOT's specifications.

MGS Information

Current General Services Specifications (MGS) By Subject

Contents

1080.1 High Strength Bolts

Videos Showing Strain Testing to Determine Yield Strength

Truss Chord Member for bridge in Knox Co. PT Bar for Mississippi River bridge in City of St. Louis

All bolts, nuts, and washers should be from a PAL supplier in accordance with Pre-Acceptance Lists (PAL). If a supplier proposes to furnish structural steel connectors and is not on PAL, a request is to be made to the Construction and Material Division for acceptance into the PAL program. Once satisfactory submittals have been received, the supplier will be placed on the PAL. Bolts, nuts, and washers, for use other than bridge construction and in quantities less than 50, may be accepted from a PAL supplier without a PAL identification number.

Construction inspection requirements for bolts, nuts and washers are given in EPG 712.1.5 High Strength Bolts And Washers. Materials inspection requirements are given in EPG 712.2.4.1 High Strength Bolts and Lab testing requirements in EPG 712.3.2 Procedure.

1080.1.1 Samples Taken at PAL Manufacturer Facilities

Prior to visiting a PAL supplier or manufacturer facility, the Cognos report "PAL Shipments Within Date Range" should be run for the facility to determine what material has been given MoDOT PAL numbers. For each PAL material, the sample shall consist of six pieces rather than determined from lot quantities as given in EPG 1080.1.2 Sample Sizes. An individual sample shall consist of bolts, nuts, or washers as these are treated as different materials in the PAL system.

1080.1.2 Sample sizes

1080.1.2.1 ASTM A307 Bolts

Samples for Laboratory testing are only required when requested by the State Construction and Materials Engineer, or when field inspection indicates questionable compliance. When samples are taken, they are to be taken as shown in the following table. When galvanized bolts, nuts and washers are submitted to the Laboratory, a minimum of 3 samples of each are required for Laboratory testing.

3 for lots of 0 to 800 pcs.	

6 for lots of 801 to 8,000 pcs.	Each sample is to consist of one bolt, nut and washer. Submit for dimensions, weight (mass) of coating, mechanical properties.
9 for lots of 8,001 to 22,000 pcs.	
15 for lots of 22,001 plus~~+~~ pcs.	

1080.1.2.2 ASTM F3125 Grade A325, 144 and A490 Bolts and ASTM F3148 Grade 144

Samples for Laboratory testing shall be taken and submitted as follows: All lots containing 501 or more high strength bolts shall be sampled and submitted to the Laboratory for testing. If no lot offered contains 501 or more bolts, sample 10 percent of the lots offered, or one lot, whichever is greater. A lot is defined as all bolts of the same size and length, with the same manufacturer's lot identification, offered for inspection at one time. Samples shall be taken as follows:

Number of Bolts in the Lot	Number of Bolts Taken for a Sample*
~~150 and less~~	~~3~~
~~151~~0 through 800	3
801 through 8,000	6
8,001 through 22,000	9
22,001 plus	15
* A minimum of 3 samples will be required for galvanized materials.	

All lots containing 501 or more high strength nuts shall be sampled and submitted to the Laboratory for testing. If no lot offered contains 501 or more nuts, sample 10 percent of the lots offered or one lot, whichever is greater. A lot is defined as all nuts of the same grade, size, style, thread series and class, and surface finish, with the same manufacturer's lot identification, offered for inspection at one time. Samples shall be taken as follows:

Number of Nuts in the Lot	Number of Nuts Taken for a Sample*
0 through 800~~ and under~~	1

801 through 8,000	2
8,001 through 22,000	3
22,000 and over	5
* A minimum of 3 samples will be required for galvanized materials.	

All lots containing 501 or more high strength washers shall be sampled and submitted to the Laboratory for testing. If no lot offered contains 501 or more washers, sample 10 percent of the lots offered, or one lot, whichever is greater. A lot is defined as all washers of the same type, grade, size and surface finish, with the same manufacturer's lot identification, offered for inspection at one time. Samples shall be taken as follows:

Number of Washers in the Lot	Number of Washers Taken for a Sample*
0 through 800 ~~and under~~	1
801 through 8,000	2
8,001 through 22,000	3
22,000 and over	5
* A minimum of 3 samples will be required for galvanized materials.	

1080.1.3 Bolts for Highway Lighting, Traffic Signals or Highway Signing

Bolts, nuts, and washers for highway lighting, traffic signals, or highway signing shall meet the requirements given in EPG 712.1.5 High Strength Bolts, except that mechanical galvanization of bolts, nuts and washers for highway lighting or traffic signals shall meet requirements of ASTM B695, Class 55. Field determination of weight (mass) of zinc coating, when specified, is to be determined by magnetic gauge in the same manner as described EPG 901.17 Material Inspection for Sec 901 except that a smaller number of single-spot tests will be sufficient. Samples for Central Laboratory testing are only required when requested by the State Construction and Materials Engineer or when field inspection indicates questionable compliance. When samples are taken, they are to be taken at the frequency and of the size shown in Table 1040.2.1.2 Sampling Requirements.

Bolts, nuts, and washers for traffic signals shall also be inspected for conformance with Section 902.4. Additionally, for traffic signals, anchor bolts and nuts or high strength bolts and nuts, except those meeting requirements of ASTM F3125 Grade A325, shall be accompanied by a test report certified to be representative of the mechanical tests for each size in each shipment.

SECTION 702

LOAD-BEARING PILES

702.1 Description. This work shall consist of furnishing and driving concrete and steel load-bearing piles to the minimum nominal axial compressive resistance and penetration required, at the location shown on the plans.

702.2 Material. All material shall be in accordance with Division 1000, Material Details, and specifically as follows:

Item	Section/Specification
Reinforcing Steel for Concrete	1036
Cast-In-Place Pile Shells (Thick Shell Type) Welded or Seamless Steel Pipe	ASTM A 252, Modified Grade 3*
Closure Plates	AASHTO M 270, Grade 50 (ASTM A 709 Grade 50)
Structural Steel (HP) Pile	AASHTO M 270, Grade 50 (ASTM A 709 Grade 50)
Fluted Pipe	SAE-1010 or SAE-1015
Forged Steel Tips or Noses	SAE-1020
Pile Point Reinforcement	~~ASTM A 27, Grade 65-35 or~~ ASTM A 148, Grade 90-60
Galvanizing	1081, ASTM A 123
Field Galvanizing and Galvanizing Repair	ASTM A 780**

*Physical and chemical requirements shall meet ASTM A 572 Grade 50.
**Zinc rich paints will not be allowed.

UNCHANGED SPECS – INTENTIONALLY NOT SHOWN

702.4.5 Pile Point Reinforcement. Each point shall be manufactured in one piece of cast steel. Pile points furnished for cast-in-place concrete piles shall be attached to the pile as shown on the plans. Pile points for structural steel piles shall be furnished with the minimum point web and flange thickness at the location of attachment to the pile equal to the thickness of that portion of the pile being attached thereto multiplied by the factor (t) shown below with additional requirements as described herein.

Material	(t)
~~ASTM A 27 Grade 65-35~~	~~2.0~~
ASTM A 148 Grade 90-60	1.6

UNCHANGED SPECS – INTENTIONALLY NOT SHOWN

751.50 Standard Detailing Notes

Only showing notes affected in EPG 751.50 Standard Detailing Notes

~~**(B3.5) Use for CIP pile in all bridges except for continuous concrete slab bridges.**~~

~~**All reinforcement in cast-in-place pile at non-integral end bents and intermediate bents is included in the substructure quantities.**~~

~~**(B3.6) Use for CIP pile in continuous concrete slab bridges.**~~

~~**All reinforcement in cast-in-place pile at end bents and pile cap intermediate bents is included in the superstructure quantities and all reinforcement in cast-in-place pile at open concrete intermediates bents is included in the substructure quantities.**~~

(G5a13) Use for CIP pile oin all bridges except for continuous concrete slab bridges. Remove underlined portion for non-integral end bents.

All reinforcement for cast-in-place pile at end bents is included in the Estimated Quantities for Slab on ____. Reinforcement for cast-in-place pile at intermediate bents is included in the ~~estimated quantities for bents~~substructure quantity tables.

(G5a14) Use for CIP pile oin continuous concrete slab bridges. The first underlined portion is included for pile cap intermediate bents. The second underlined portion is included for intermediate bents with pile footings.

All reinforcement in cast-in-place pile at end bents and intermediate bents is included in the superstructure quantities and all reinforcement in cast-in-place pile at intermediates bents is included in the substructure quantity tables.

(~~G5a14~~G5a15)

The contractor shall determine the pile wall thickness required to avoid damage from all driving activities, but wall thickness shall not be less than the minimum specified. No additional payment will be made for furnishing a thicker pile wall than specified on the plans.

(G5b4)

Steel casting for open ended cutting shoe pile point reinforcement shall be ~~ASTM A27 Grade 65-35~~ ASTM A148 Grade 90-60.

(G5b10) Use for CIP pile oin all bridges except for continuous concrete slab bridges. Remove underlined portion for non-integral end bentsabutments.

All reinforcement for cast-in-place pile at end bents is included in the Estimated Quantities for Slab on ____. Reinforcement for cast-in-place pile at intermediate bents is included in the substructure quantity tables estimated quantities for bents.

(G5b11) Use for CIP pile oin continuous concrete slab bridges. The first underlined portion is included for pile cap intermediate bents. The second underlined portion is included for intermediate bents with pile cap footings.

All reinforcement in cast-in-place pile at end bents and intermediate bents is included in the superstructure quantities and all reinforcement in cast-in-place pile at intermediates bents is included in the substructure quantity tables.

(G5b1211)

The contractor shall determine the pile wall thickness required to avoid damage from all driving activities, but wall thickness shall not be less than the minimum specified. No additional payment will be made for furnishing a thicker pile wall than specified on the plans.

SECTION 1045

PAINT FOR STRUCTURAL STEEL

UNCHANGED SPECS – INTENTIONALLY NOT SHOWN

1045.10 Organic Zinc-Rich Primer.

1045.10.1 Description. This specification covers an organic zinc-rich primer system designed for adhesion to field-blasted steel and suitable for use under an epoxy System G intermediate coating, waterborne acrylic System H intermediate coating or polysiloxane System I finish coating. This specification also covers organic zinc for repair of existing galvanized steel, touch-up of inorganic-zinc coated steel and other uses. The organic zinc-rich primer shall be a multiple-component material which, when mixed and applied in accordance with Sec 1081, cures without the use of a separate curing solution. The organic zinc-rich coating shall be in accordance with the latest edition of the RCSC *Specification for Structural Joints Using High-Strength Bolts* ~~ASTM A325~~ Class B requirements for slip coefficient and creep resistance on faying surfaces and other requirements specified herein. The VOC content shall not exceed 3.50 pounds per gallon. If thinning is necessary for application, the maximum VOC content after thinning shall not exceed 3.50 pounds per gallon.

1045.10.2 Manufacturer and Brand Name Approval. Prior to approval and use of organic zinc-rich primer, the manufacturer shall submit to Construction and Materials a certified test report from AASHTO Product Evaluation and Audit Solutions program showing specific test results conforming to all quantitative and resistance test requirements of these specifications. The certified test report shall also contain the exact ratio, by weight, of each component of the coating used for the tests, the lot tested, the manufacturer's name, brand name of coating and date of manufacture. Upon approval from the engineer of this certified test report, further resistance tests will not be required, except as hereinafter noted, of that manufacturer for that brand name of coating. New certified test results shall be submitted any time the manufacturing process or the coating formulation is changed and may be required by the engineer when sampling and testing of material offered for use indicates nonconformance to any of the requirements herein specified. All resistance testing shall be performed on duplicate sets of test panels, and upon completion of the prescribed exposure testing, the manufacturer shall submit one set of the exposed panels to Construction and Materials.

1045.11 High Solids Inorganic Ethyl Silicate Coating

1045.11.1 Description. The coating shall be a mono-component, high solids inorganic ethyl silicate coating compatible as a topcoat over high solids inorganic zinc primer. The inorganic ethyl silicate coating shall be in accordance with the latest edition of the RCSC *Specification for Structural Joints Using High-Strength Bolts* Class B requirements for slip coefficient and creep resistance on faying surfaces and other requirements specified herein. The VOC content shall not exceed 3.50 pounds per gallon. If thinning is necessary for application, the maximum VOC content after thinning shall not exceed 3.50 pounds per gallon.

1045.11.2 Manufacturer and Brand Name Approval. Prior to approval and use of high solids inorganic ethyl silicate, the manufacturer shall submit to Construction and Materials a certified test report from AASHTO Product Evaluation and Audit Solutions program showing specific test results conforming to all quantitative and resistance test requirements of these

specifications. An additional certified test report from an independent test lab must show that the inorganic ethyl silicate when used as a topcoat over a compatible high solids inorganic zinc primer has less than 1mm scribe corrosion when tested in accordance with two consecutive cycles of ISO 12944-9 CX, equivalent to 8400 hours cyclic aging. The certified test report shall also contain the exact ratio, by weight, of each component of the coating used for the tests, the lot tested, the manufacturer's name, brand name of coating and date of manufacture. Upon approval from the engineer of this certified test report, further resistance tests will not be required, except as hereinafter noted, of that manufacturer for that brand name of coating. New certified test results shall be submitted any time the manufacturing process or the coating formulation is changed and may be required by the engineer when sampling and testing of material offered for use indicates nonconformance to any of the requirements herein specified. All resistance testing shall be performed on duplicate sets of test panels, and upon completion of the prescribed exposure testing, the manufacturer shall submit one set of the exposed panels to Construction and Materials.

SECTION 1081

COATING OF STRUCTURAL STEEL

1081.10 PROTECTIVE PAINT SYSTEMS.

1081.10.1 Scope. This specification covers coating new and existing bridges and structures made of structural steel and miscellaneous metal with protective paint systems.

1081.10.2 Systems of Coatings. The required system and color or choice of systems and color will be specified on the plans. Each coat of the specified system shall be applied to all structural steel, unless the contract specifically delineates otherwise. The system and color of coating to be shop-applied shall be shown on the shop drawings. All coatings shall comply with local VOC (Volatile Organic Compound) regulations where the paint is applied. The system and color shall not vary for any portion of the entire structure, including material for field repairs and shall be compatible products of a single manufacturer. The contractor shall coordinate the various items of work to ensure compliance with the requirements of this section. Approved material specifications and dry film thickness for the coating systems shall be as indicated in the following table:

Paint Systems for Structural Steel		
System G (High Solids, Zinc-Epoxy-Polyurethane)		
Coating	**Section**	**Dry Film Thickness, mils**
Inorganic Zinc Prime Coat or Organic Zinc Prime Coat	1045.3 or 1045.10	3.0 min. to 6.0 max. or 3.0 min to 6.0 max.
Epoxy Intermediate Coat	1045.4	3.0 min. to 5.0 max.
Polyurethane Finish Coat, Gray or Brown	1045.5	2.0 min. to 4.0 max.
System H (High Solids, Zinc-Waterborne Acrylic Intermediate-Waterborne Acrylic Finish)		
Coating	**Section**	**Dry Film Thickness, mils**
Inorganic Zinc Prime Coat or Organic Zinc Prime Coat	1045.3 or 1045.10	3.0 min. to 6.0 max. or 3.0 min. to 6.0 max.
Waterborne Acrylic, Intermediate Coat	1045.6	2.0 min. to 4.0 max.
Waterborne Acrylic, Finish Coat, Gray or Brown	1045.6	2.0 min. to 4.0 max.
System I (High Solids, Zinc-Polysiloxane)		
Coating	**Section**	**Dry Film Thickness, mils**
Inorganic Zinc Prime Coat or Organic Zinc Prime Coat	1045.3 or 1045.10	3.0 min. to 6.0 max. or 3.0 min to 6.0 max.
Polysiloxane Finish Coat	1045.7	3.0 min. to 6.0 max.
System L (High Solids, Zinc-Inorganic Ethyl Silicate)		
Coating	**Section**	**Dry Film Thickness, mils**
Inorganic Zinc Prime Coat	1045.3	3.0 min. to 6.0 max.
Inorganic Ethyl Silicate	1045.11	3.0 min. to 6.0 max.
Aluminum & Gray Epoxy-Mastic Primer		
Coating	**Section**	**Dry Film Thickness mils**
Aluminum Epoxy-Mastic Primer	1045.8	5.0 min.
Gray Epoxy-Mastic Primer	1045.9	5.0 min

UNCHANGED SPECS – INTENTIONALLY NOT SHOWN

1081.10.3.4 Limits of Coating Application. Unless otherwise indicated on the plans, the application of the intermediate and finish coats for Systems G and H, and the application of the finish coat for System I and L, hereinafter referred to as field coats, shall be applied to the structure within the following limits.

1081.10.3.4.1 Bridges over Roadways. This section will not apply to bridges over railroads.

UNCHANGED SPECS – INTENTIONALLY NOT SHOWN

1081.10.3.4.1.6 When System L is specified on the plans for beam and girder spans, an intermediate coat shall not be applied to the beams and girders. The System L finish coat shall be applied to the surfaces of all structural steel, except that areas of steel to be in contact with concrete shall not receive the finish coat. The finish coat shall also be applied to the bearings, except where bearings will be encased in concrete.

1081.10.3.4.2 Bridges Over Streams or Railroads.

UNCHANGED SPECS – INTENTIONALLY NOT SHOWN

1081.10.3.4.2.5 When System L is specified on the plans for beam and girder spans, an intermediate coat shall not be applied to the beams and girders. The System L finish coat shall be applied to the surfaces of all structural steel, except that areas of steel to be in contact with concrete shall not receive the finish coat. The finish coat shall also be applied to the bearings, except where bearings will be encased in concrete.

UNCHANGED SPECS – INTENTIONALLY NOT SHOWN

1081.10.3.10.1 Contact Surfaces. Contact surfaces of high strength bolted field splice and diaphragm connections shall be prime coated to produce a dry film thickness no less than 1.5 mils or more than 2.5 mils. The limits of the coating thickness for these surfaces shall be shown on the shop drawings. The maximum limit of 2.5 mils may be increased provided acceptable test results in accordance with the Testing Method to Determine the Slip Coefficient for Coatings Used in Bolted Joints (~~AISC~~RCSC *Specification for Structural Joints Using ~~ASTM A 325 or A 490~~ High Strength Bolts*, Appendix A) are submitted and approved by the engineer. Revised shop drawings will not be required upon acceptance of the test results. The tests shall meet the requirements for the slip coefficient and creep resistance for Class B coatings and shall be performed by a nationally recognized independent testing laboratory. Any change in the formulation of the coating will require retesting, except when thinned within the limits of manufacturer's recommendations. At the contractor's option, the contact surfaces of connections for all non-slab bearing diaphragms on non-curved girders may be prime coated with a dry film thickness of no less than 3.0 mils or more than 6.0 mils, unless noted otherwise on the plans.

UNCHANGED SPECS – INTENTIONALLY NOT SHOWN

1081.10.4 Recoating of Structural Steel (System G~~,~~ H~~, or~~ I or L).

1081.10.4.1 Scope. This specification covers the field preparation of structural steel surfaces to be recoated, furnishing and applying specified coatings, protection and drying of coatings, furnishing protection from coating spatter and disfigurement, and final cleanup.

UNCHANGED SPECS – INTENTIONALLY NOT SHOWN

751.1.2.9.2 Steel Girder Options

When considering steel structures, the preliminary designer must decide if the girders should be painted or fabricated from weathering steel. If site-specific conditions allow, the use of unpainted weathering steel (ASTM A709 Grades 50W and HPS70W) should be considered and is MoDOT's preferred system for routine steel I-girder type bridges due to its performance, economic and environmental benefits. Cost savings are realized because of the elimination of the initial paint system as well as the need for periodic renewal of the paint system over the life of the structure.

Weathering steels provide significant environmental and worker safety benefits as well. Since they do not require initial and periodic repainting of the whole bridge, emissions of volatile organic compounds (VOC) are reduced. Also, they generally do not require coating removal or disposal of contaminated blast debris over the service life of the structure. By eliminating the need for periodic repainting, the closing of traffic lanes can be prevented as well as the associated hazards to painters, maintenance workers, and the travelling public.

Partial coating of weathering steel is required near expansion joints. See EPG 751.14.5.8. Periodic recoating or overcoating will be required, however, on a much smaller scale than the whole bridge with the effect that lane closures and associated hazards are greatly reduced compared to painted steel.

Although weathering steel is MoDOT's preferred system for routine I-girder bridges with proper detailing, it should not be used for box girders, trusses or other structure types where details may tend to trap moisture or debris. There are also some situations where the use of weathering steel may not be advisable due to unique environmental circumstances of the site. Generally, these types of structures would receive high deposits of salt along with humidity, or long-term wet conditions and individually each circumstance could be considered critical.

The FHWA Technical Advisory T5140.22 October 1989 should be used as guidance when determining the acceptability of weathering steel. Due to the large amounts of deicing salts used on our highways which ultimately causes salt spray on bridge girders, the flowchart below should be used as guidance for grade separations. The flowchart, Fig. 751.1.2.9, below, is general guidance but is not all inclusive. There may be cases based on the circumstances of the bridge site where the use of weathering steel is acceptable even though the flowchart may indicate otherwise. In these cases, follow MoDOT's design exception process.

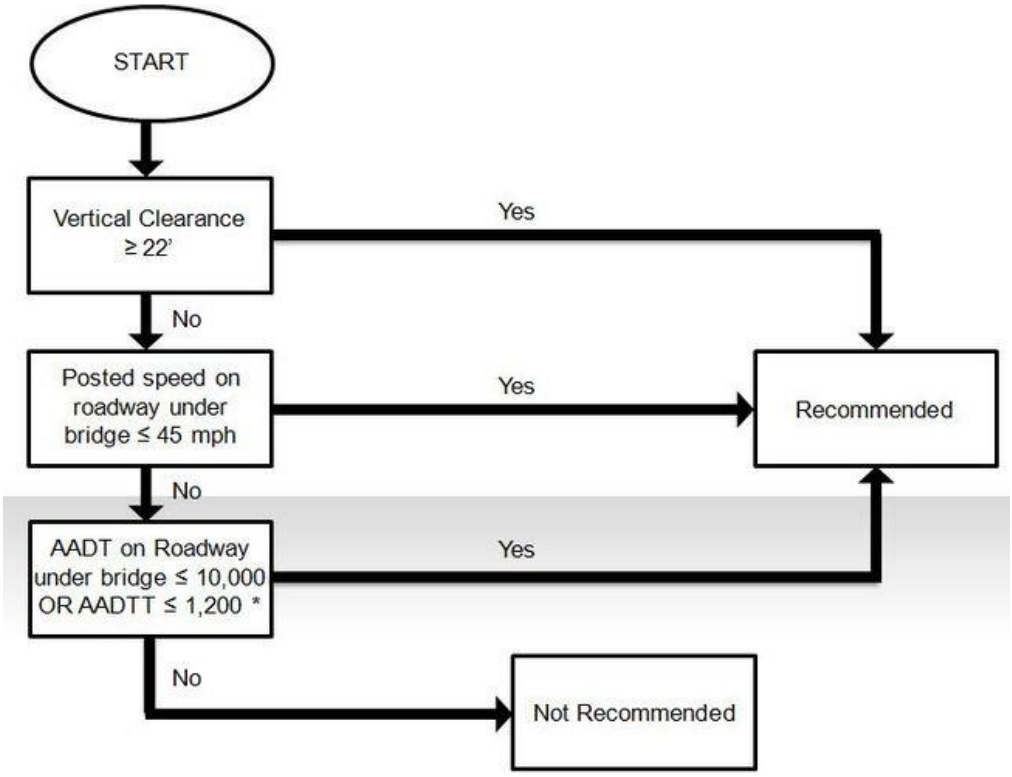


Fig. 751.1.2.9 Guidance on the Use of Weathering Steel for Grade Separations

***** For multi-lane divided or undivided highways, consider the AADT and AADTT in one direction only.

Weathering steel may be used for stream crossings where 1) the base flood elevation is lower than the bottom of girder elevation and 2) the difference between the ordinary high water and bottom of girder elevations is greater than 10 ft. for stagnant and 8 ft. for moving bodies of water. Where the difference in elevations is less than noted, weathering steel may be used upon approval of the Assistant State Bridge Engineer.

Additional documents that can be referenced to aid in identifying the site-specific locations and details that should be avoided when the use of weathering steel is being considered include:

1. Transportation Research Board. (1989). *Guidelines for the use of Weathering Steel in Bridges*, (NCHRP Report 314). Washington, DC: Albrecht, et al.
2. American Iron and Steel Institute. (1995). *Performance of Weathering Steel in Highway Bridges, Third Phase Report*. Nickerson, R.L.
3. American Institute of Steel Construction. (2022). Uncoated Weathering Steel Reference Guide. NSBA
4. MoDOT. (1996). *Missouri Highway and Transportation Department Task Force Report on Weathering Steel for Bridges*. Jefferson City, MO: Porter, P., et al.

The final brown rust appearance could be an aesthetic concern. When determining the use of weathering steel, aesthetics and other concerns should be discussed by the Core Team members, with input from Bridge Division and Maintenance Division.

If weathering steel cannot be used, the girders should be painted gray (Federal Standard #26373). If the district doesn't want gray, they can choose brown (Federal Standard #30045). If the district or the local municipality wants a color other than gray or brown, they must meet the requirements of EPG 1045.5 Policy on Color of Structural Steel Paint. ~~System G paint is the preferred system on all steel plate girders.~~ See EPG 751.6.2.11, EPG 751.6.2.12 and EPG 751.14.5.8 for further guidance on paint systems.

751.6.1 Index of Quantities

Only showing Index of Quantities

712-51.00 thru 712-99.11

712-51.00	1	lump sum	Surface Preparation for Recoating Structural Steel
712-51.01	1	lump sum	Surface Preparation for Overcoating Structural Steel (System G)
712-51.02	1	lump sum	Surface Preparation for Applying Epoxy-Mastic Primer
712-51.09	1	lump sum	Field Application of Organic Zinc Primer
712-51.10	1	lump sum	Field Application of Inorganic Zinc Primer
712-51.11	1	lump sum	Intermediate Field Coat (System G)
712-51.12	1	lump sum	Finish Field Coat (System G)
712-51.13	1	lump sum	Intermediate Field Coat (System H)
712-51.14	1	lump sum	Finish Field Coat (System H)
712-51.15	1	lump sum	Finish Field Coat (System I)
712-51.16	1	lump sum	Finish Field Coat (System L)
712-52.00	100	sq. foot	Surface Preparation for Recoating Structural Steel
712-52.01	100	sq. foot	Surface Preparation for Overcoating Structural Steel (System G)
~~712-52.02~~	~~100~~	~~sq. foot~~	~~Chloride Remediation Surface Preparation~~

712-52.09	100	sq. foot	Field Application of Organic Zinc Primer
712-52.10	100	sq. foot	Field Application of Inorganic Zinc Primer
712-53.15A	0.1	ton	Intermediate Field Coat (System G)
712-53.20A	0.1	ton	Finish Field Coat (System G)
712-53.35A	0.1	ton	Intermediate Field Coat (System H)
712-53.40A	0.1	ton	Finish Field Coat (System H)
712-53.46	0.1	ton	Finish Field Coat (System I)
712-53.47	0.1	ton	Finish Field Coat (System L)
712-53.65A	100	sq. foot	Intermediate Field Coat (System G)
712-53.70A	100	sq. foot	Finish Field Coat (System G)
712-53.85A	100	sq. foot	Intermediate Field Coat (System H)
712-53.90A	100	sq. foot	Finish Field Coat (System H)
712-53.96	100	sq. foot	Finish Field Coat (System I)
712-53.97	100	sq. foot	Finish Field Coat (System L)
712-59.60	1	lump sum	Aluminum Epoxy-Mastic Primer
712-59.61	1	lump sum	Gray Epoxy-Mastic Primer

712-60.00	1	linear foot	Non-Destructive Testing
712-99.01	1	lump sum	Galvanizing Structural Steel

751.6.2.11 Structural Steel Protective Coatings (Non-weathering Steel)

The protective coating, as specified on the Design Layout, shall be System G, H ~~or,~~ I or L with the color being gray or brown. The coating color shall be specified on the Design Layout. The following gives pay item guidelines for most bridges.

Note: The figures in this section are provided to aid in interpretation of the specifications and do not intend to represent a preference for any particular system.

Coating New Multi-Girder/Beam Bridges

Intermediate Field Coat and Finish Field Coat (System G, H ~~or,~~ I or L) (Gray or Brown) - The quantity shall be computed to the nearest one hundred square foot of structural steel to be field coated. The area computations do not include bearings, diaphragms, stiffeners and all other miscellaneous steel within the limits of the field coatings.

1. Bridges over Roadways (does not include over Railroads)

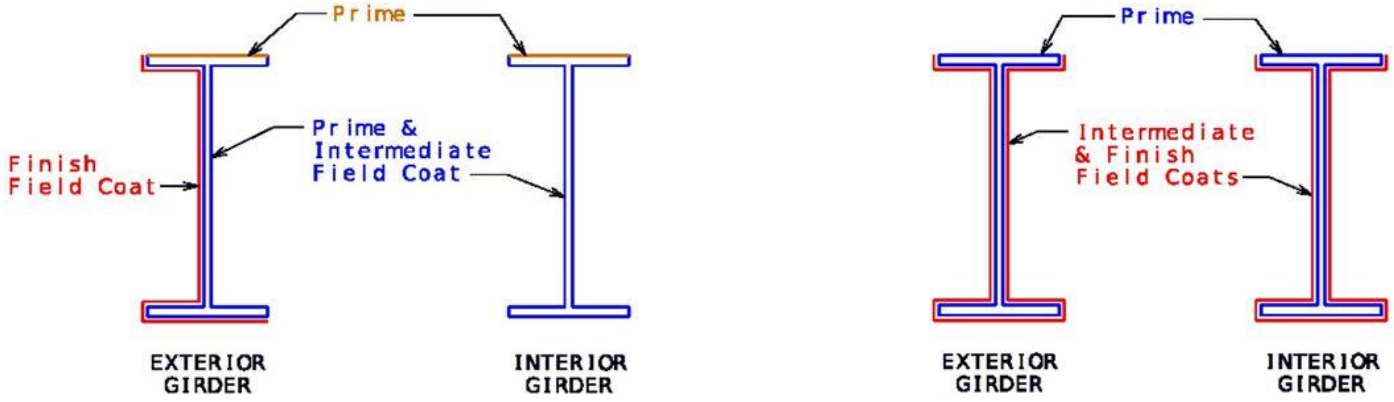
The intermediate field coat for System G and H and the finish field coat for System L for beam and girder spans shall be applied to the surfaces of all structural steel except those surfaces to be in contact with concrete ~~shall not receive the intermediate coat~~. The ~~intermediate~~ field coat shall also be applied to the bearings, except where bearings will be encased in concrete.

The finish field coat for System G or H for beam and girder spans shall include the facia girders or beams. The limits of the facia girders or beams shall include the bottom of the top exterior flanges, the top of the bottom exterior flanges, the exterior web area, the exterior face of the top and bottom flanges, and the bottom of the bottom flange. Areas of steel to be in contact with concrete shall not receive the finish coat. The finish coat shall also be applied to the exterior bearings, except where bearings will be encased in concrete.

The surfaces of all structural steel located under expansion joints of beam and girder spans shall be field coated with intermediate and finish coats for a distance of one and a half times the girder depth, but not less than 10 feet from the center line of the joint. Within this limit, the items to be field coated shall include all surfaces of beams, girders, bearings, diaphragms, stiffeners and miscellaneous structural steel items. Areas of steel to be in contact with concrete shall not receive the field coats. ~~The limits of the field coatings shall be masked to provide crisp, straight lines and to prevent overspray on adjacent areas.~~

When System I finish field coat is specified on the plans with System G intermediate coat, System I finish field coat quantity will be figured the same as above for the finish field coat for System G or H. System G intermediate coat with System I finish field coat will be as above for the intermediate field coat except that the area of the System I finish field coat will not be included in the System G intermediate field coat area. When the plans state System I finish field coat shall be substituted for System G intermediate coat, System I finish field coat quantity will be figured for all girder surfaces as discussed above for ~~intermediate~~ finish field coat area for System L.

New Non-Weathering Bridge Over Roadway



Typical Coating ~~(~~ for System G~~)~~

Coating Near Deck Joints ~~-~~(System G)

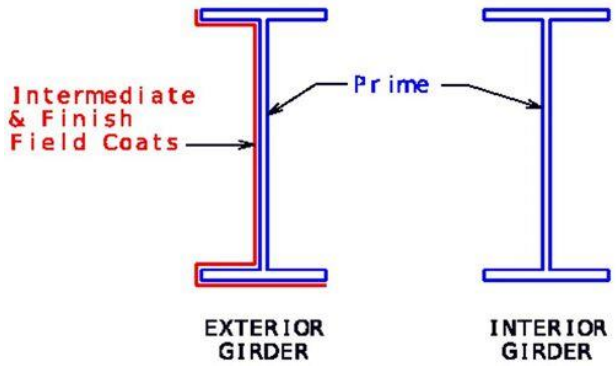
2. Bridges over Streams and Bridges over Railroads

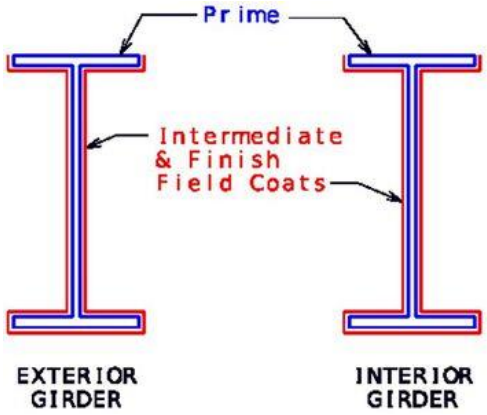
The field coatings (including intermediate and finish coats) for beam and girder spans shall include the facia girders or beams. The limits of the facia girders or beams shall include the bottom of the top exterior flanges, the top of the bottom exterior flanges, the exterior web area, the exterior face of the top and bottom flanges, and the bottom of the bottom flange. Areas of steel to be in contact with concrete shall not receive the field coats. The field coatings shall also be applied to the exterior bearings, except where bearings will be encased in concrete. The interior beams or girders shall only have the prime coat applied with no other field coatings required.

The surfaces of all structural steel located under expansion joints of beam and girder spans shall be field coated with intermediate and finish coats for a distance of one and a half times the girder depth, but not less than 10 feet from the center line of the joint. Within the limit, the items to be field coated shall include all surfaces of beams, girders, bearings, diaphragms, stiffeners and miscellaneous structural steel items. Areas of steel to be in contact with concrete shall not receive the field coats. ~~The limits of the field coatings shall be masked to provide crisp, straight lines and to prevent overspray on adjacent areas.~~

When System I or L is specified, the intermediate field coat will not be required.

New Non-Weathering Bridge Over Stream or Railroad





Typical Coating ~~(~~for System G~~)~~

Coating Near Deck Joints (System G)

Coating New Truss Bridges or Other Unusual Structures

Intermediate Field Coat and Finish Field Coat (System G, H, I or ~~l~~L) (Gray or ~~b~~Brown) - The quantity shall be computed as a lump sum quantity.

All structural steel for truss or steel box girder spans shall be field coated with intermediate and finish coats, except the area of steel to be in contact with concrete. ~~and il~~ntermediate field coat is not required when System I or L is specified.

Recoating Existing Multi-Girder/Beam Bridges

Quantities shall be computed to the nearest one hundred square feet of structural steel to be prepared or coated. The area computations do not include bearings, diaphragms, stiffeners and all other misc. steel within the limits of surface preparation or field coatings.

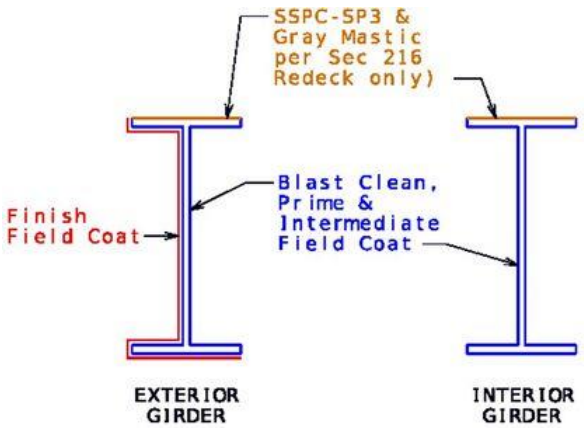
1. Surface Preparation for Recoating Structural Steel - Preparation shall include the surfaces of all structural steel except areas to be in contact with concrete.

2. Field Application of Inorganic or Organic Zinc Primer - Coverage shall meet the same requirements of Surface Preparation for Recoating Structural Steel.

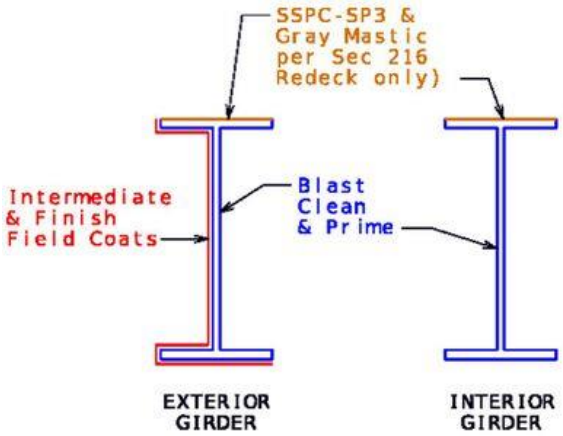
3. Intermediate Field Coat (System G or H) (Gray or Brown) - Coverage shall meet the same requirements as new multi-girder/beam bridges.

4. Finish Field Coat (System G, H ~~or,~~ I or L) (Gray or Brown) - Coverage shall meet the same requirements as new multi-girder/beam bridges.

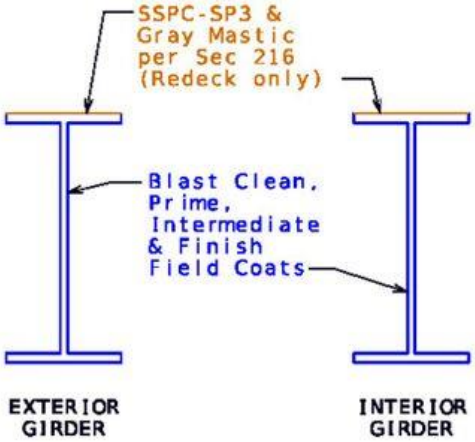
Existing Non-Weathering Bridge



Typical Recoating Over Roadway ~~(~~for System G~~)~~ or H



Typical Recoating Over Stream or Railroad ~~(~~for System G~~)~~ or H



Recoating Near Deck Joints (System G or H)

Recoating Existing Truss Bridges or other Unusual Structures

Quantities shall be computed as lump sum quantities. The approximate weight of steel shall be shown to the nearest ton in the contract documents.

1. Surface Preparation for Recoating Structural Steel - Preparation shall include the surfaces of all structural steel except areas to be in contact with concrete.

2. Field Application of Inorganic or Organic Zinc Primer – Coverage shall meet the same requirements of Surface Preparation for Recoating Structural Steel.

3. Intermediate Field Coat (System G or H) (Gray or Brown) – Coverage shall meet the same requirements as new truss bridges.

4. Finish Field Coat (System G, H, I or ~~I~~L) (Gray or Brown) – Coverage shall meet the same requirements as new truss bridges.

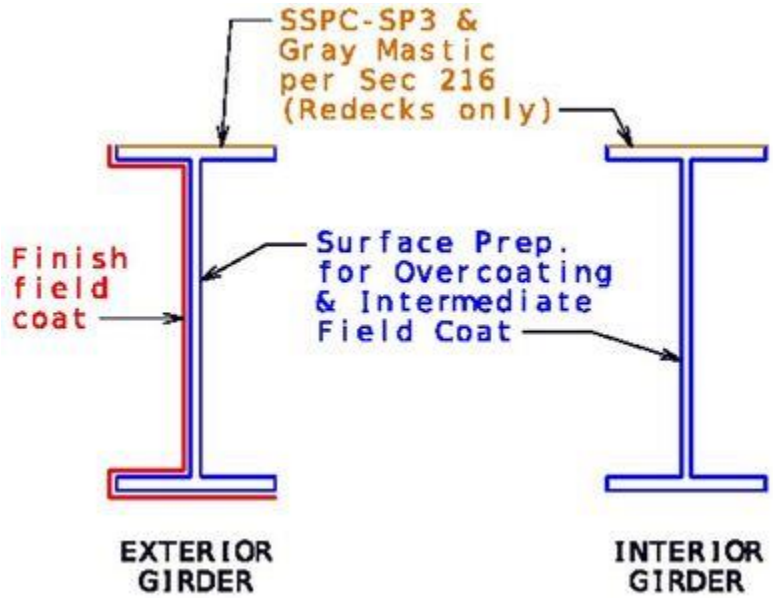
Overcoating Existing Multi-Girder/Beam Bridges

Quantities shall be computed to the nearest one hundred square feet of structural steel to be prepared or overcoated except as noted below. The area computations do not include bearings, diaphragms, stiffeners and all other misc. steel within the limits of surface preparation or field coatings. Partial overcoating of steel structures is allowed and the areas of partial overcoating should be clearly indicated ~~shown~~ on the plans.

1. Surface Preparation for Overcoating Structural Steel (System G) - Preparation shall include the surfaces of all structural steel except areas to be in contact with concrete.

2. Intermediate Field Coat (System G) - Coverage shall meet the same requirements as Surface Preparation for Overcoating Structural Steel (System G).

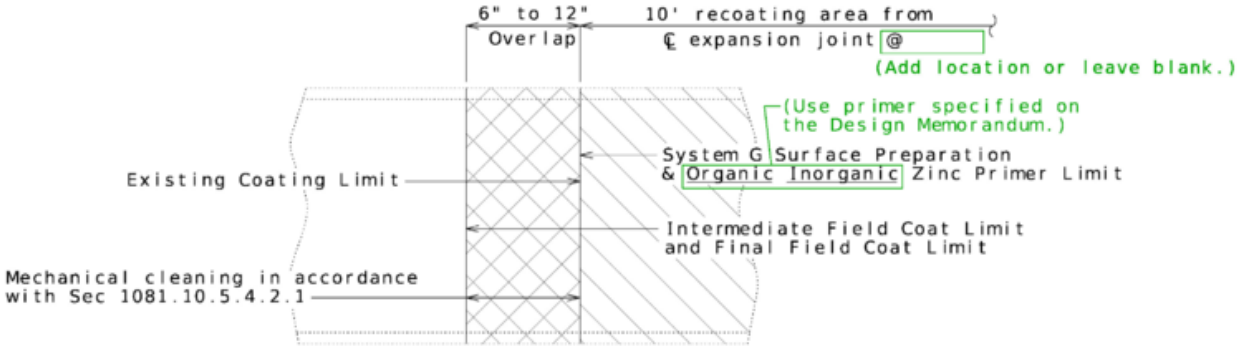
3. Finish Field Coat (System G) - Coverage shall meet the same requirements as new bridges.



Overcoating Existing Non-Weathering Bridge (System G)

Limits of Paint Overlap

Refer to EPG 751.50 Note A4a1.24. The figure below with note is available in a CADD cell. Detail should be modified as necessary for paint systems other than System G.



PART ELEVATION SHOWING LIMITS OF PAINT OVERLAP

(Vertical or horizontal paint limit. Horizontal limit shown)

Limits of Paint Overlap: System G shall overlap the existing coating between 6 inches and 12 inches in order to achieve maximum coverage at the paint limit of each complete system near the expansion and contraction areas. The final field coating shall be masked to provide crisp, straight lines and to prevent overspray beyond the overlap required.

751.6.2.12 Structural Steel Protective Coatings (Weathering Steel)

Coating New Multi-Girder/Beam Bridges, Truss Bridges or other Unusual Structures

There will not be a quantity item for coating weathering steel. The cost of coating weathering steel structures will be considered completely covered by the contract unit price for the Fabricated Structural Steel.

Recoating Existing Multi-Girder/Beam Bridges, Truss Bridges or other Unusual Structures

Recoating weathering steel when performing joint repair/replacement may be included on the contract plans. Other areas may be recoated depending upon inspection of the condition of weathering steel and the future deterioration expectations of same by Bridge Maintenance. See Structural Project Manager or Structural Liaison Engineer.

For existing multi-girder/beam bridges, quantities shall be computed to the nearest one hundred square feet of structural steel to be prepared or recoated. The area computations do not include bearings, diaphragms, stiffeners and all other misc. steel within the limits of surface preparation or field coatings. For truss bridges or other unusual structures, quantities shall be computed as lump sum quantities.

1. Surface Preparation for Recoating Structural Steel - Preparation shall be on a case-by-case basis except areas to be in contact with concrete.

2. Field Application of Inorganic or Organic Zinc Primer - Coverage shall meet the same requirements of Surface Preparation for Recoating Structural Steel.

3. Intermediate Field Coat (System G) (Brown) - Coverage shall be on a case-by-case basis.

4. Finish Field Coat (System G ~~or,~~ I or L) (Brown) - Coverage shall be on a case-by-case basis.

751.14.5.8 Protective Coating Requirements

Coating requirements for new steel girder bridge shall be in accordance with Sec 1080 and Sec 1081. See EPG 751.1.2.9.2, EPG 751.6.2.11 and EPG 751.6.2.12 for additional guidance.

System G (three-coat system) may be used for non-weathering steel and ~~is the preferred system for both non-weathering and~~ weathering steel structures (Sec 1081). System G typically is not preferred when overlapping an existing vinyl coating but may be allowed if the existing coating is determined to be in good condition. System G uses a solvent based finish coat which may cause issues when overlapping an existing solvent-based vinyl coating system (System C) because it may re-wet the existing coating and cause delamination of the base coat. If the existing coating is in good condition as determined by paint pull-off tests the intermediate epoxy coating will provide a reliable barrier between the solvent-based coatings. Consult the structural project manager or structural liaison engineer before using System G near existing vinyl coatings.

System G has replaced calcium sulfonate as the preferred overcoating system. To ensure sufficient bond of the existing coating, adhesion pull-off tests shall be performed in accordance with ASTM D4541. If the adhesion test fails, as determined by the engineer of record, then overcoating shall not be allowed and recoating should be considered.

System H (three-coat system) is typically used when the bond for System G is considered questionable where recoating operations will take place near an existing vinyl coating system (System C). System H uses a waterborne acrylic for the intermediate and finish field coats that does not tend to interfere with the solvent-based vinyl coating.

System I (two-coat system) may be used for non-weathering and weathering steel and should be based on the following guidance:

(a) System I should be considered in areas where the aesthetics of a coating system over the long term is ~~unusually more~~ critical ~~than System G~~. While System G, L and I provide long term protection, System I has excellent gloss retention and UV resistance. System I is a context sensitive design (CSD) solution. CSD follows from project scoping and is subject to the project core team protocols.

(1) Consider for locations where the structure is more visible or the public has leisurely time for more than just a casual glance, for example structures near a ballpark or a pedestrian bridge. Using same rationale, bridges that are tall or have wide girder spacing or a low number of girders where more of the superstructure is visible could also be candidates.

(2) Consider the image consciousness of the surroundings in conjunction with rather than solely the protection of the structure which is equally provided by ~~both~~ systems G and I. Maintenance of either System G or I should be considered the same. Reduced maintenance is an expectation for System L.

(b) System I is a polysiloxane finish coat that is normally applied directly over an inorganic or organic zinc primer with no intermediate coating. Since the system is a two-coat system, it may be applied in less time which can influence critical path scheduling and impacts to the driving public. For example, it may be possible for a contractor to get in and out quicker than if they were to use a three-coat system. MoDOT coating policy as described in Standard Specification Section 1081 requires different field coating requirements based on the type of bridge crossing. For roadway grade separations, it is required that interior girders have only a single field coat in order to satisfy that all girders on a roadway grade separation bridge have at least two coatings for protection. In the case of System I, the Standard Specifications require that a System G epoxy intermediate field coat be applied to all interior girders and the interior of fascia girders and that the System I polysiloxane finish coating be applied to the exterior of the facia girders only. This is based on a system I polysiloxane coating cost being greater than a system G epoxy coating on a per-gallon cost basis. It also requires that the contractor be given the option to substitute the System I finish coat in place of a System G intermediate coat. If CSD determines that the polysiloxane should be applied to all girders, then the general notes for coatings and the quantities on the contract plans will need to reflect the revised coating requirements.

(c) System I is approved for use on state highway projects beginning February 2011. Alternate bidding is encouraged if guideline (a) is not required to be met and with approval of the Structural Project Manager or Structural Liaison Engineer and the project core team.

System L (two-coat system) may be used for non-weathering steel and weathering steel structures. System L requires an inorganic zinc primer so organic zinc shall not be substituted. Testing indicates that System L is expected to outlast System G, H or I coatings when properly applied. Since the system is a two-coat system, it may be applied in less time which can influence critical path scheduling and impacts to the driving public. Similarly, the expectation for reduced maintenance should be considered for areas where access is limited or impactful (e.g., over railroads and interstates).

~~System G, H or I typically require an inorganic or organic zinc primer per Sec 1081.~~ Inorganic zinc primer shall be used for new steel fabrication with System G, I or L coatings. For recoating operations with System G, H or I, where closure time has severe impacts on cost or safety, organic zinc primer should be considered as a direct replacement for the inorganic zinc required in the specifications. Organic zinc primers require a lower level of surface preparation (SSPC-SP6: commercial blast cleaning vs SSPC-SP10: near white blast cleaning) and are generally easier to apply in the field than inorganic zinc primers. Only organic zinc primers that can provide a Class B slip coefficient are allowed for use in recoating operations.

See EPG 751.50 A4. Protective Coatings for standard detailing notes and guidance on how they are used.

Epoxy-mastic primers may be used for overcoating lead-based coatings if the existing coating is determined to be in good condition, but this is considered a short-term solution in comparison to System G overcoating. Consult the structural project manager or structural liaison engineer before using epoxy-mastics near existing lead-based coatings.

Galvanized non-weathering structural steel beams, girders, bracing and diaphragms may be used as required or allowed by alternate, on a case-by-case basis, with approval of the Structural Project Manager or Structural Liaison Engineer and the project core team.

When galvanized structural steel is required, place note EPG 751.50 (A4a1.8.2a) on the plans. Do not use notes EPG 751.50 (A4a1.1 – A4a1.7). When galvanized structural steel is bid as an alternate, place notes EPG 751.50 (A4a1.8.1a, A4a1.8.1b, and A4a1.8.1c) on the plans under the applicable coating new steel notes EPG 751.50 (A4a1.1-A4a1.7).

751.50 Standard Detailing Notes

Only showing notes affected in EPG 751.50 Standard Detailing Notes

A4. Protective Coatings

A4a. Structural Steel Protective Coatings

In "**General Notes:**" section of plans, place the following notes under the heading "Structural Steel Protective Coatings:".

A4a1. Steel Structures- Non-weathering Steel

Coating New Steel (Notes A4a1.1 – A4a1.7)

(A4a1.1) Use the 2nd underlined option for grade separations where System I finish field coat is only required on the fascia surfaces per Sec 1081. "System I" may be used for water crossings or where note A4a1.3 is used.

Protective Coating: System G System I Prime Coat with System I Finish Field Coat and System G Intermediate Field Coat System I System L in accordance with Sec 1081.

(A4a1.4) The coating color shall be as specified on the Design Layout. When System L or note (A4a1.3) is used, omit the 2nd sentence.

Field Coat(s): The color of the field coat(s) shall be Gray (Federal Standard #26373) Brown (Federal Standard #30045) Black (Federal Standard #17038) Dark Blue (Federal Standard #25052) Bright Blue (Federal Standard #25095). The cost of the intermediate field coat will be considered completely covered by the contract lump sum unit price per sq. foot for Intermediate Field Coat (System G). The cost of the finish field coat will be considered completely covered by the contract lump sum unit price per sq. foot for Finish Field Coat (System G I L) ~~Finish Field Coat (System I)~~.

(A4a1.5) When System L is specified, System I is specified for water crossings or when note (A4a1.3) is used, omit the underlined part.

At the option of the contractor, the intermediate field coat and finish field coat may be applied in the shop. The contractor shall exercise extreme care during all phases of loading, hauling, handling, erection and pouring of the slab to minimize damage and shall be fully responsible for all repairs and cleaning of the coating systems as required by the engineer.

Recoating Existing Steel (Notes A4a1.9 - A4a1.13)

(A4a1.9) Use the 2nd underlined option for grade separations where System I finish field coat is only required on the fascia surfaces per Sec 1081. "System I" may be used for water crossings or where note A4a1.13 is used.

Protective Coating: System G System I Prime Coat with System I Finished Field Coat and System G Intermediate Field Coat System I System L in accordance with Sec 1081.

(A4a1.10) Use primer specified on the Design Memorandum. System L must be used with inorganic zinc primer only.

Surface Preparation: Surface preparation of the existing steel shall be in accordance with Sec 1081 for Recoating of Structural Steel (System G, H, I or ~~I~~L) with organic inorganic zinc primer. The cost of surface preparation will be considered completely covered by the contract lump sum unit price per sq. foot for Surface Preparation for Recoating Structural Steel.

(A4a1.12) The coating color shall be as specified on the Design Layout. When System L or note (A4a1.13) is used, omit the 2nd sentence.

Field Coat(s): The color of the field coat(s) shall be Gray (Federal Standard #26373) Brown (Federal Standard #30045) Black (Federal Standard #17038) Dark Blue (Federal Standard #25052) Bright Blue (Federal Standard #25095). The cost of the intermediate field coat will be considered completely covered by the contract lump sum unit price per sq. foot for Intermediate Field Coat (System G). The cost of the finish field coat will be considered completely covered by the contract lump sum unit price per sq. foot for Finish Field Coat (System G I L) ~~Finish Field Coat (System I)~~.

(A4a1.23) The 2nd underlined portion in the first sentence is applicable only for bridges over streams and railroads.

Field Coat(s): The color of the field overcoat shall be Gray (Federal Standard #26373) Brown (Federal Standard #30045) Black (Federal Standard #17038) Dark Blue (Federal Standard #25052) Bright Blue (Federal Standard #25095) and shall be applied in accordance with Sec 1081.10.3.4, except that all structural steel shall have the intermediate field coat applied in accordance with Sec 1081.10.3.4.1.1. The cost of the intermediate field coat will be considered completely covered by the contract lump sum unit price per sq. foot for Intermediate Field Coat (System G). The cost of the finish field coat will be considered completely covered by the contract lump sum unit price per sq. foot for Finish Field Coat (System G).

A4a2. Steel Structures- Weathering Steel

Coating New Steel (Notes A4a2.1 - A4a2.3)

(A4a2.1)

Protective Coating: System G I L in accordance with Sec 1080.

Prime Coat: The cost of the inorganic zinc prime coat will be considered completely covered by the contract unit price for the fabricated structural steel.

(A4a2.3)

At the option of the contractor, the intermediate and finish field coats may be applied in the shop. The contractor shall exercise extreme care during all phases of loading, hauling, handling, erection and pouring of the slab to minimize damage and shall be fully responsible for all repairs and cleaning of the coating systems as required by the engineer.

(A4a2.11) Use primer specified on Design Memorandum. System L must be used with inorganic zinc primer only.

Surface Preparation: Surface preparation of the existing steel shall be in accordance with Sec 1080 and Sec 1081 for Recoating of Structural Steel (System G, H or I) with inorganic organic zinc primer. The cost of surface preparation will be considered completely covered by the contract lump sum unit price per sq. foot for Surface Preparation for Recoating Structural Steel.

(A4a2.13) The coating color shall be as specified on the Design Layout. When System L or I is specified, omit the 2nd sentence.

Field Coats: The color of the field coats shall be Brown (Federal Standard #30045). The cost of the intermediate field coat will be considered completely covered by the contract lump sum unit price per sq. foot for Intermediate Field Coat (System G). The cost of the finish field coat will be considered completely covered by the contract lump sum unit price per sq. foot for Finish Field Coat (System G I).

Category:1045 Paint for Structural Steel

This article establishes procedures for inspecting, sampling and reporting paint and paint constituents. Refer to Sec 1045 for MoDOT's specifications.

Discussions on non-standard colors of structural steel paint and color of structural steel paint policies are available.

For Laboratory testing and sample reporting procedures, refer to EPG 1045.6 Laboratory Testing Guidelines for Sec 1045.

Contents

1045.1 Apparatus

All sample containers and equipment used in sampling paint and paint constituents shall be clean and free of all contaminants. The apparatus required shall consist of:

(a) Appropriate size and type of sample container as given in the following subsections for the type of paint to be sampled.

(b) Appropriate thief or sampling device to obtain a representative sample.

(c) Packaging and labeling materials as described in EPG 106.3.1.2.2 Transportation of Samples and EPG 106.3.1.3 Sampling Supplies.

Approved and Pre-Qualified List

Qualified Aluminum Epoxy Mastic Paint

Qualified High Solids Inorganic Zinc Silicate Paints

Qualified Epoxy\Polyurethane Paints

Qualified Waterborne Acrylic Paints

Qualified Gray Epoxy-Mastic Primer

Qualified Organic Zinc Paints

Qualified Polysiloxane Paints

Qualified High Solids Inorganic Ethyl Silicate Paints

MGS Information

Current General Services Specifications (MGS) By Subject

1045.2 Procedure

Samples shall be taken by, or under the direct supervision of, the inspector, using all possible caution, skill and judgment to ensure that a representative sample is obtained.

When sampling paint and paint constituents, take precautions to ensure that the samples are not contaminated or altered by any material not representative of the lot being sampled. Some paints or liquid constituents exhibit a tendency to settle or separate upon standing. Because of this, it is important to ensure that containers to be sampled, no matter the size container, is uniform prior to obtaining a sample. Mark all sample containers with the type of material, lot number, and the inspector's identification number. It is essential that samples of constituents be marked with the chemical names as called for in the given specification. Unless specifically requested, obtain only one random sample from each lot, batch, day's pack or other unit of production. In cases where several small lots are uniformly mixed in a larger mixer or tank, the mixed material shall be considered as one lot.

Whenever possible, obtain samples from original, unopened containers for all types of materials. When constituent containers have no markings distinguishing between units of production, take samples from different containers or storage units in the ratio of two samples for each 10,000 pounds (4500 kg) or portion thereof and blended in equal quantities to form a composite sample. Submit constituent samples only when requested by the Laboratory.

Packaging must comply with the applicable requirements of Sec 1045.

1045.2.1 Vehicle Constituents

When samples are requested by the Laboratory, ensure that the contents of the container or tank to be sampled has been thoroughly mixed. Fill the sample container, leaving approximately one inch (25 mm) space for expansion. Secure friction top lids with clips or other fastening devices before shipment. Observe shipping regulations when preparing samples for shipment.

1045.2.2 Pigments

When the Laboratory requests samples, open the package or storage container and take a sample at random from the contents.

1045.2.3 Mixed Paints

Sample containers are one quart (1 L), friction top cans and should be filled, leaving approximately one inch (25 mm) space for expansion. The inspector may mark and submit an original, unopened container of paint to the Laboratory in cases where the containers are small, such as quarts (L) or gallons (L). When an original container of paint cannot be sent to the Laboratory and there are no facilities for mixing or shaking the material mechanically, the inspector must ensure a representative sample by the following steps:

(a) Pour off the top liquid into a clean, suitable container having a volume equal to or larger than the one being sampled.

(b) Stir the settled portion of the paint with a paddle, gradually reincorporating the poured off liquid in small quantities until all has been returned.

(c) Mix the paint by pouring it back and forth between the two containers several times.

(d) Obtain a sample promptly so that settling does not occur before the sample is obtained.

NOTE: This process is referred to as “boxing” the material.

When samples are taken during the filling of containers, obtain a composite sample by combining samples taken at the beginning, middle, and near the end of the operation.

Mechanically mix paint in holding tanks or 55 gallon (208 L) drums to ensure uniformity and sample promptly after mixing.

1045.2.4 Submission of Samples

Paint and some paint constituents require special handling. See EPG 106.3.1.2.2 Transportation of Samples and EPG 106.3.1.3 Sampling Supplies for packaging, labeling and marking instructions. Enter a Basic Sample Data report into AASHTOWARE Project (AWP) (see AWP MA Sample Record, General) for each sample of material submitted to the Laboratory. Include all pertinent information necessary to the sample, such as: kind of paint or constituent, batch or lot number, project number, purchase order or "general construction" for warehouse stock, inspector, source, quantity, intended use, contractor, destination, manufacturer's name and address.

1045.2.5 High Solids Inorganic Zinc Silicate Coating

Field inspection of existing bridge coatings

Refer to the applicable requirements of Sec 1045 for requirements pertaining to prequalification. The list of paints that are qualified by manufacturer and brand name appears as Qualified High Solids Inorganic Zinc Silicate Paints. Sample each batch or lot of each component. A sample

consists of one pint (500 mL) of inorganic silicate vehicle, one pint (500 mL) of metallic zinc powder and four ounces (120 mL) of activator component. Note that the activator is not to be sampled in metal containers and will be required only when sampling 3-component, high-solids primer. Submit the samples to the Laboratory through AWP, including the brand name, the batch or lot number of each component and the net weight (mass) shown on the container of each component.

1045.2.6 Polyurethane System G Final Coating

Refer to the applicable requirements of Sec 1045 for requirements pertaining to prequalification. The list of paints that are qualified by manufacturer and brand name appears as Qualified Epoxy\Polyurethane Paints. Sample each batch or lot of each component. A sample consists of each component in the approximate volume proportions recommended by the manufacturer so that the mixed sample will consist of at least one quart (1 L). Submit the samples to the Laboratory through an AWP record, including the brand name, the batch or lot number of each component, and the net weight (mass) shown on the container of each component.

1045.2.7 High Solids Epoxy Intermediate Coat

Refer to the applicable requirements of Sec 1045 for requirements pertaining to prequalification. The list of paints that are qualified by manufacturer and brand name appears as Qualified Epoxy\Polyurethane Paints. Sample each batch or lot of each component. A sample consists of one pint (500 mL) of each component. Submit the samples to the Laboratory using an AWP record, including the brand name, batch or lot number of each component, and the net weight (mass) as shown on the container of each component.

1045.2.8 Waterborne Acrylic System H Intermediate and Finish Coating

Refer to the applicable requirements of Sec 1045 for requirements pertaining to prequalification. The list of paints that are qualified by manufacturer and brand name appears as Qualified Waterborne Acrylic Paints. Sample each batch or lot of each intermediate or finish coat. A sample consists of one quart (1 L) in a friction top can. Submit the sample to the Laboratory through an AWP record, including the brand name, the batch or lot number of each component, and the net weight (mass) shown on the container.

1045.2.9 Aluminum Epoxy Mastic Primer

Refer to Sec 1045 for requirements pertaining to prequalification. Aluminum epoxy mastic primer is not suitable for use in contact with freshly poured concrete. Brands that have been qualified are listed in Qualified Aluminum Epoxy Mastic Paint. Sample each batch or lot submitted for use. A sample consists of one pint (500 mL) of each component in friction top cans. Submit the sample to the Laboratory through an AWP record, including the brand name, batch or lot number(s) of each component, and the weight (mass) shown on each container.

1045.2.10 Gray Epoxy Mastic Primer

Refer to Sec 1045 for requirements pertaining to prequalification. Gray epoxy mastic primer may be used in lieu of aluminum epoxy mastic. The list of paints that have been qualified by manufacturer and brand name are listed in Sec 1045. Each batch or lot submitted for use shall be sampled. A sample consists of one pint (500 mL) of each component in friction top cans. Submit the sample to the Laboratory through an AWP record, including the brand name, batch or lot number(s) of each component, and the weight (mass) shown on each container.

1045.2.11 Organic Zinc-Rich Coating

Refer to the applicable requirements of Sec 1045 for requirements pertaining to prequalification. The list of paints that are qualified by manufacturer and brand name appears as Qualified Organic Zinc Paints. Sample each batch or lot of each component. A sample consists of one pint (500 mL) of organic vehicle, one pint (500 mL) of metallic zinc powder and four ounces (120 mL) of activator component. Note that the activator is not to be sampled in metal containers and will be required only when sampling 3-component, high-solids primer. Submit the samples to the Laboratory through AWP, including the brand name, the batch or lot number of each component and the net weight (mass) shown on the container of each component.

1045.2.12 High Solids Inorganic Ethyl Silicate Coating

Refer to the applicable requirements of Sec 1045 for requirements pertaining to prequalification. The list of paints that are qualified by manufacturer and brand name appears as Qualified High Solids Inorganic Ethyl Silicate Paints. Sample each batch or lot submitted for use. A sample consists of one pint (500 mL) in a friction top can. Submit the sample to the Laboratory through an AWP record, including the brand name, the batch or lot number of each component, and the net weight (mass) shown on the container of each component.

1045.3 Acceptance

Confirm that the paint is on the current approved list and that the paint is within its shelf life. Obtain a certification specific to the batch of paint, with lot or batch numbers, date of manufacture and quantity represented by the certification. Confirm that the lot or batch of paint has been sampled and approved by the Laboratory. If not, sample the paint and submit it for approval prior to use.

1045.4 Sample Record

The Laboratory will issue the reports for samples submitted to the Laboratory. Sample records indicating acceptance for project use will typically state “Prior Approval or Acceptance”, and will include the information provided in the certification, and where the certification is filed.

751.24.2.1 Design

Only showing sections affected in EPG 751.24.2.1

MSE Wall Construction: Pipe Pile Spacers Guidance

For bridges not longer than 200 feet, pipe pile spacers or pile jackets shall be used at pile locations behind mechanically stabilized earth walls at end bents. Corrugated pipe pile spacers are required when the wall is built prior to driving the piles to protect the wall reinforcement when driving pile for the bridge substructure at end bents(s). Pile spacers or pile jackets may be used when the piles are driven before the wall is built. Pipe pile spacers shall have an inside diameter greater than that of the pile and large enough to avoid damage to the pipe when driving the pile. Use EPG 751.50 Standard Detailing Note E1.2a on bridge plans.

For bridges longer than 200 feet, pipe pile spacers are required and the pile spacer shall be oversized to mitigate the effects of bridge thermal movements on the MSE wall. For HP12, HP14, CIP 14” and CIP 16” piles provide 24-inch inside diameter of pile spacer for bridge movement. Minimum pile spacing shall be 5 feet to allow room for compaction of the soil layers. Use EPG 751.50 Standard Detailing Note E1.2b on bridge plans.

The bottom of the pipe pile spacers shall be placed 5 ft. min. below the bottom of the MSE wall leveling pad. The pipe shall be filled with sand or other approved material after the pile is placed and before driving. Pipe pile spacers shall be accurately located and capped for future pile construction.

Alternatively, for bridges shorter than or equal to 200 feet, the contractor shall be given the option of driving the piles before construction of the mechanically stabilized earth wall and placing the soil reinforcement and backfill material around the piling. In lieu of pipe pile spacers contractor may place pile jackets on the portion of the piles that will be in the MSE soil reinforced zone prior to placing the select granular backfill material and soil reinforcement. The contractor shall adequately support the piling to ensure that proper pile alignment is maintained during the wall construction. The contractor’s plan for bracing the pile shall be submitted to the engineer for review.

Piling shall be designed for downdrag (DD) loads due to either method. Oversized pipe pile spacers with sand placed after driving or pile jacket may be considered to mitigate some of the effects of downdrag (DD) loads. Sizing of pipe pile spacers shall account for pile size, thermal movements of the bridge, pile placement plan, and vertical and horizontal placement tolerances.

When rock is anticipated within the 5 feet zone below the MSE wall leveling pad, prebore into rock and prebore holes shall be sufficiently wide to allow for a minimum 10 feet embedment of pile and pipe pile spacer. When top of rock is anticipated within the 5 to 10 feet zone below the MSE wall leveling pad, prebore into rock to achieve a minimum embedment (pile only) of 10 feet below the bottom of leveling pad. Otherwise, the pipe pile spacer requires a minimum 5 feet embedment below the levelling pad. Consideration shall also be given to oversizing the prebore holes in rock to allow for temperature movements at integral end bents.

For bridges not longer than 200 feet, the minimum clearance from the back face of MSE walls to the front face of the end bent beam, also referred to as setback, shall be 4 ft. 6 in. (typ.) unless larger than 18-inch pipe pile spacer required. The 4 ft. 6 in. dimension serves a dual purpose:

1) ~~is based~~the setback ensures that soil reinforcement is not skewed more than 15° for nut and bolt reinforcement connections ~~on the use of~~to clear an 18-inch inside diameter pipe pile spacers by 6 inches ~~&~~ per FHWA-NHI-10-24, Figure 5-17C, while considering ~~and thermal movements of the bridge, pile placement plan, and~~ vertical and horizontal pile placement tolerances

2) the setback helps to reduce the forces imparted on the MSE wall from bridge movements that typically are not accounted for in the wall design and cannot be completely isolated using a pipe pile spacer. ~~which will help ensure that soil reinforcement is not skewed more than 15° for nut and bolt reinforcement connections. Similarly,~~Increasing the minimum setback shall be ~~determined~~ considered when larger diameter pile spacers are required or when other types of soil reinforcement connections are anticipated.

For bridges longer than 200 feet, the minimum setback shall be 5 ft. 6 in. based on the use of 24-inch inside diameter of pipe pile spacers. ~~Other types of connections may require different methods for splaying.~~

~~In the event that the minimum setback cannot be used~~If interference with soil reinforcement is not a concern and the wall is designed for forces from bridge movement, the following guidance for pipe pile spacers clearance shall be used: pipe pile spacers shall be placed ~~18~~ 36 in. clear min. from the back face of MSE wall panels to allow for proper compaction; 12 in. minimum clearance is required between pipe pile spacers and leveling pad and 18 in. minimum clearance is required between leveling pad and pile. For isolated pile (e.g, walls skewed from the bent orientation), the pipe pile spacer~~s~~ may be placed 18 in. clear min. from the back face of MSE wall panels.

751.50 Standard Detailing Notes

Only showing notes affected in EPG 751.50 Standard Detailing Notes

(E1.2b) Use note when pipe pile spacers are shown on plan details for HP12, HP14, CIP 14" and CIP 16" piles and bridge is longer than 200 feet. For larger CIP pile size modify following note and use minimum 6" larger pipe pile spacer diameter than CIP pile.

The pipe pile spacers shall have an inside diameter equal to 24 inches.

751.9.1 Seismic Analysis and Design Specifications

Additional Information

- Bridge Seismic Design Flowchart

All new or replacement bridges on the state system shall include seismic design and/or detailing to resist an expected seismic event per the Bridge Seismic Design Flowchart. For example, for a bridge in Seismic Design Categories A, B, C or D, complete seismic analysis or seismic detailing only may be determined as per "Bridge Seismic Design Flowchart".

Missouri is divided into four Seismic Design Categories. Most of the state is SDC A which requires minimal seismic design and/or detailing in accordance with SGS (Seismic Zone 1 of LRFD) and "Bridge Seismic Design Flowchart". The other seismic design categories will require a greater amount of seismic design and/or detailing.

For seismic detailing only:

When A_S is greater than 0.75 then use A_S = 0.75 for abutment design where required per "Bridge Seismic Design Flowchart" and SEG 24-01

For complete seismic analysis:

When A_S is greater than 0.75 then use A_S = 0.75 at zero second for seismic analysis and response spectrum curve. See Example 1_SDC_Response_Spectra. The other data points on the response spectrum curve shall not be modified.

Additional Information

- Bridge Seismic Retrofit Flowchart

When existing bridges are identified as needing repairs or maintenance, a decision on whether to include seismic retrofitting in the scope of the project shall be determined per the "Bridge Seismic Retrofit Flowchart", the extent of the rehabilitation work and the expected life of the bridge after the work. For example, if the bridge needs painting or deck patching, no retrofitting is recommended. However, redecking or widening the bridge indicates that MoDOT is planning to keep the bridge in the state system with an expected life of at least 30 more years. In these instances, the project core team should consider cost effective methods of retrofitting the existing bridge. Superstructure replacement requires a good substructure and the core team shall decide whether there is sufficient seismic capacity. Follow the design procedures for new or replacement bridges in forming logical comparisons and assessing risk in a rational determination of the scope of a superstructure replacement project specific to the substructure. For example, based on SPC and route, retrofit of the substructure could include seismic detailing only or a complete seismic analysis may be required determine sufficient seismic capacity. Economic analysis should be considered as part of the decision to re-use and retrofit, or re-build. Where practical, make end bents integral and eliminate expansion joints. Seismic isolation systems shall conform to AASHTO Guide Specifications for Seismic Isolation Design 4th Ed. 2023.

Bridge seismic retrofit for widenings shall be in accordance with Bridge Seismic Retrofit Flowchart. Seismic details should only be considered for widenings where they can be practically implemented and where they can be uniformly implemented as not to create significant stress redistribution in the structure. When a complete seismic analysis is required for widenings the existing structure shall be retrofitted and the new structural elements shall be detailed to resist seismic demand.

- **Seismic Details for Widening (one side):** When widening the bridge in one direction there is not a significant benefit, and it could be detrimental, to strengthen a new wing or column while ignoring the existing structure. It may be practical to use FRP wrap to retrofit the existing columns to provide a similar level of service to a new column with seismic details, but this will likely require design

computations to verify (see below). For SDC C and D, seismic details typically require a T-joint detail in the beam cap and footing, but t-joint details shall be ignored if the existing beam cap is not retrofitted. For abutments it is not practical to dig up an existing wing solely to match the new wing design so the abutment need not be designed for mass inertial forces. SPM, SLE or owner's representative approval is required to determine the appropriate level of seismic detail implementation.

- **Seismic Details for Widening (both sides):** When widening in both directions the wings shall be designed to resist the mass inertial forces. Seismic details shall be added to the new columns in SDC B only if the existing columns can be retrofitted with FRP wrap to provide a similar level of service as discussed below. SDC C and D bridges may be detailed and retrofitted similar to SDC B since retrofitting the beam cap or footing is likely not practical.
- **Seismic Details for Widening (FRP wrap):** Carbon or glass fiber reinforced polymer (FRP) composite wrap should be considered to strengthen the factored axial resistance of existing columns. There are limitations to the existing and achievable column factored axial resistance with FRP wrap. The goal of the FRP wrap is to increase the factored axial resistance of the existing column to be not less than the factored axial resistance of the new column with seismic details. If an existing column cannot be retrofitted with FRP wrap to match the factored axial resistance of a new column with seismic details at the same bent then seismic details shall be ignored for all columns in the bridge substructure. See AASHTO Guide Spec for Design of Bonded FRP Systems for Repair and Strengthening of Concrete Bridge Elements, March 2023, 2nd Ed., Appendix A, ~~e~~Example 6 for an example for increasing column factored axial resistance with FRP wrap. Use EPG 751.50 Standard Detailing Notes I5 on plans to report factored axial resistance of existing column and new column. The flexural resistance of the column is also increased with FRP wrap, but it may not be practical to match the flexural resistance of a new column using existing longitudinal steel. For additional references, see EPG 751.40.3.2 Bent Cap Shear Strengthening using FRP Wrap.

751.40.3.2 Bent Cap Shear Strengthening using FRP Wrap

Bridge Standard Drawings
Rehabilitation, Surfacing & Widening; Fiber Reinf. Polymer (FRP) Wrap for Bent Cap Strengthening [RHB08]

Fiber Reinforced Polymer (FRP) wrap may be used for Bent Cap Shear Strengthening. FRP wrap may also be used for seismic retrofit of existing columns, but that procedure is not discussed herein (see EPG 751.9.1 Seismic Analysis and Design Specifications).

When to strengthen: When increased shear loading on an existing bent cap is required and a structural analysis shows insufficient bent cap shear resistance, bent cap shear strengthening is an option. An example of when strengthening a bent cap may be required: removing existing girder hinges and making girders continuous will draw significantly more force to the adjacent bent. An example of when strengthening a bent cap is not required: redecking a bridge where analysis shows that the existing bent cap cannot meet capacity for an HS20 truck loading, and the new deck is similar to the old deck and the existing beam is in good shape.

How to strengthen: Using FRP systems for shear strengthening follows from the guidelines set forth in *NCHRP Report 678, Design of FRP System for Strengthening Concrete Girders in Shear*. The method of strengthening, using either discrete strips or continuous sheets, is made optional for the contractor in accordance with *NCHRP Report 678*. A Bridge Standard Drawing and Bridge Special Provision have been prepared for including this work on jobs. They can be revised to specify a preferred method of strengthening if desired, strips or continuous sheet.

What condition of existing bent cap required for strengthening: If a cap is in poor shape where replacement should be considered, FRP should not be used. Otherwise, the cap beam can be repaired before applying FRP. Perform a minimum load check using (1.1DL + 0.75(LL+I))***** on the existing cap beam to prevent catastrophic failure of the beam if the FRP fails (*ACI 440.2R, Guide for the Design and Construction of Externally Bonded FRP, Sections 9.2 and 9.3.3*). If the factored shear resistance of the cap beam is insufficient for meeting the factored minimum load check, then FRP strengthening should not be used.

***** ACI 440.2R: *Guide for the Design and Construction of Externally Bonded FRP*

Design force (net shear strength loading): Strengthening a bent cap requires determining the net factored shear loading that the cap beam must carry in excess of its unstrengthened factored shear capacity, or resistance. The FRP system is then designed by the manufacturer to meet this net factored shear load, or design force. The design force for a bent cap strengthening is calculated considering AASHTO LFD where the factored load is the standard Load Factor Group I load case. To determine design force that the FRP must carry alone, the factored strength of the bent cap, which is 0.85 x nominal strength according to LFD design, is subtracted out to give the net factored shear load that the FRP must resist by itself. *NCHRP Report 678* is referenced in the special provisions as guidelines for the contractor and the manufacturer to follow. The report and its examples use AASHTO LRFD. Regardless, the load factor case is given and it is left to the manufacturer to provide for a satisfactory factor of safety based on their FRP system.

Other References:

***** ACI 201.1R: *Guide for Making a Condition Survey of Concrete in Service*
***** ACI 224.1R: *Causes, Evaluation, and Repair of Cracks in Concrete*
***** ACI 364.1R-94: *Guide for Evaluation of Concrete Structures Prior to Rehabilitation*
***** ACI 440.2R-08: *Guide for the Design and Construction of Externally Bonded FRP Systems for Strengthening Concrete Structures*
***** ACI 503R: *Use of Epoxy Compounds with Concrete*
***** ACI 546R: *Concrete Repair Guide*
***** International Concrete Repair Institute (ICI) ICI 03730: *Guide for Surface Preparation for the Repair of Deteriorated Concrete Resulting from Reinforcing Steel Corrosion*
***** International Concrete Repair Institute (ICI) ICI 03733: *Guide for Selecting and Specifying Materials for Repairs of Concrete Surfaces*
***** NCHRP Report 609: *Recommended Construction Specifications Process Control Manual for Repair and Retrofit of Concrete Structures Using Bonded FRP Composites*
* AASHTO Guide Spec for Design of Bonded FRP Systems for Repair and Strengthening of Concrete Bridge Elements, March 2023, 2nd Ed.

751.50 Standard Detailing Notes

Only showing notes affected in EPG 751.50 Standard Detailing Notes

I5. Fiber Reinforced Polymer (FRP) Wrap – Intermediate Bent Column Strengthening for Seismic Details for Widening. Report following notes on Intermediate bent plan details.

(I5.1)

Factored axial resistance of new columns = xxxxx kip and factored axial resistance of existing columns = xxxxx kip. The factored axial resistance of the existing column with FRP wrap shall not be less than the factored axial resistance of the new columns.

(I5.2)

See special provisions.

751.31.2.4 Column Analysis

Refer to this article to check slenderness effects in column and the moment magnifier method of column design. See Structural Project Manager for use of P Delta Analysis.

Transverse Reinforcement

Seismic Zone 1

Columns shall be analyzed as “Tied Columns”. Unless excessive reinforcement is required, in which case spirals shall be used.

Bi-Axial Bending

Use the resultant of longitudinal and transverse moments.

Slenderness effects in Columns

The slenderness effects shall be considered when:

$$l_u \geq \frac{22r}{K}$$

Where:

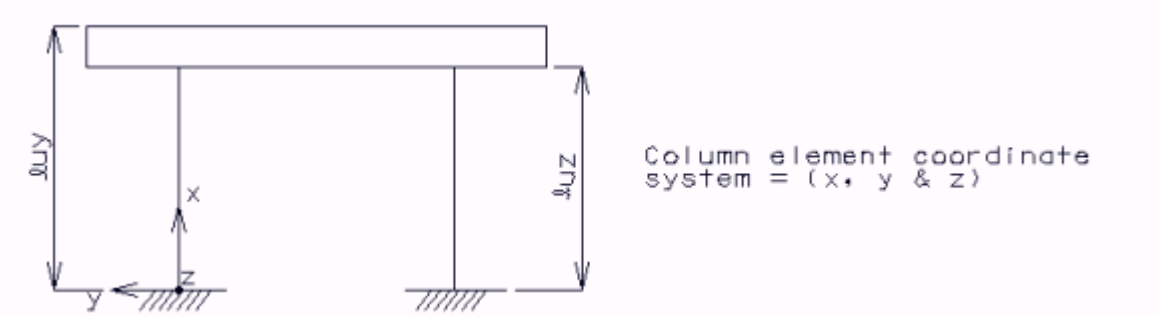
l_u = unsupported length of column

r = radius of gyration of column cross section

K = effective length factor

Effects should be investigated by using either the rigorous P-Δ analysis or the Moment Magnifier Method with consideration of bracing and non-bracing effects. Use of the moment magnifier method is limited to members with $Kl_u/r \leq 100$, or the diameter of a round column must be $\geq Kl_u/25$. A maximum value of 2.5 for moment magnifier is desirable for efficiency of design. Increase column diameter to reduce the magnifier, if necessary.

When a compression member is subjected to bending in both principal directions, the effects of slenderness should be considered in each direction independently. Instead of calculating two moment magnifiers, δ_b and δ_s, and performing two analyses for M_{2b} and M_{2s} as described in LRFD 4.5.3.2.2b, the following conservative, simplified moment magnification method in which only a moment magnifier due to sidesway, δ_s, analysis is required:



Typical Intermediate Bent

General Procedure for Bending in a Principal Direction

$M_c = \delta_s M_2$

Where:
M_c = Magnified column moment about the axis under investigation.
M_2 = value of larger column moment about the axis under investigation due to LRFD Load Combinations.
δ_s = moment magnification factor for sidesway about the axis under investigation

$$= \frac{C_m}{1 - \frac{\sum P_u}{\phi_k \sum P_e}} \geq 1.0;\ C_m = 1.0$$

Where:

ΣP_u = summation of individual column factored axial loads for a specific Load Combination (kip)

ϕ_k = stiffness reduction factor for concrete = 0.75

ΣP_e = summation of individual column Euler buckling loads

$$= \sum \frac{\pi^2\ EI}{(\ Kl_u)^2}$$

Where:

K = effective length factor = 1.2 min. (see the following figure showing boundary conditions for columns)

l_u = unsupported length of column (in.)

$$EI = \frac{E_c I_g / 2.5}{1 + \beta_d}$$

Where:

E_c = concrete modulus of elasticity as defined in EPG 751.31.1.1 (ksi)

I_g = moment of inertia of gross concrete section about the axis under investigation

β_d = ratio of maximum factored permanent load moments to maximum factored total load moment: always positive

Column Moment Parallel to Bent In-Plane Direction

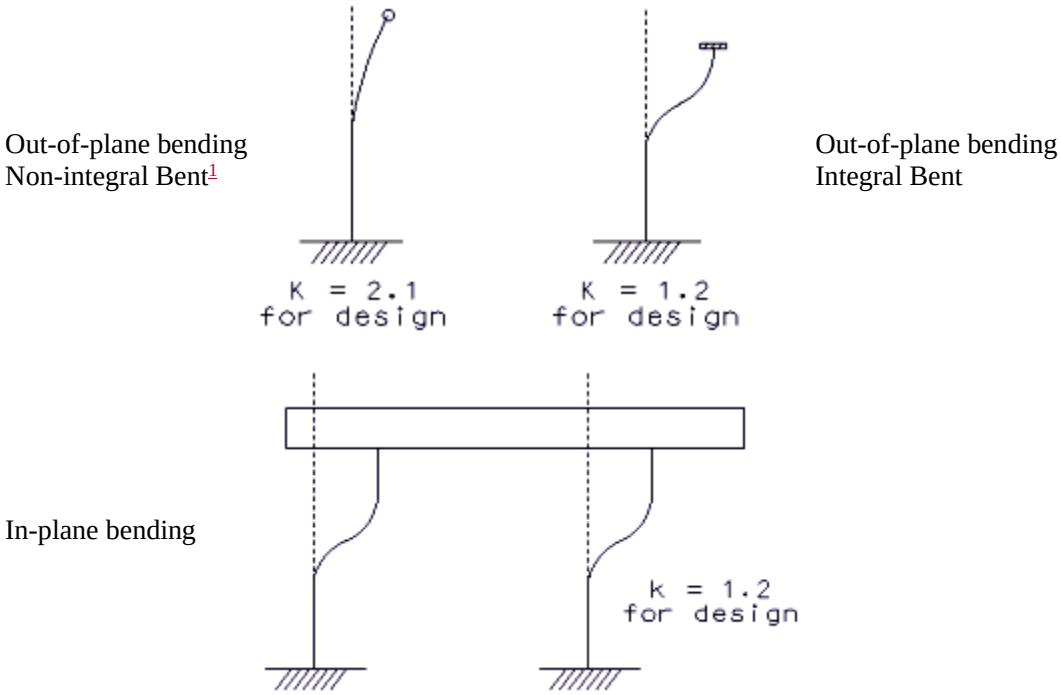
$M_{cy} = \delta_{sy} M_{2y}$

l_{uy} = top of footing to top of beam cap

Column Moment Normal to Bent In-Plane Direction

$M_{cz} = \delta_{sz} M_{2z}$

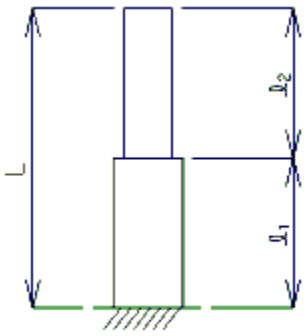
l_{uz} = top of footing to bottom of beam cap or tie beam and/or top of tie beam to bottom of beam cap



Boundary Conditions for Columns

[1]A refined procedure may be used to determine a reduced effective length factor (less than 2.1) for intermediate bents where the beam cap is doweled into a concrete superstructure diaphragm. The procedure is outlined at the end of this section.

For telescoping columns, the equivalent moment of inertia, *I*, and equivalent effective length factor, *K*, can be estimated as follows:



Telescoping Columns

$$I = \frac{\sum (l_n I_n)}{L}$$

Where:

l_n = length of column segment

I_n = moment of inertia of column segment

L = total length of telescoping column

Equivalent Effective Length Factor

$$K = \sqrt{\frac{\pi^2 EI}{P_c L^2}}$$

Where:

E = modulus of elasticity of column

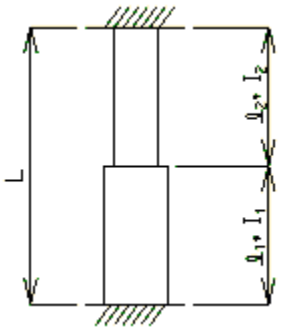
I = equivalent moment of inertia of column

L = total length of telescoping column

P_c = elastic buckling load solved from the equations given by the following boundary conditions:

Warning: The following equations were developed assuming equal column segment lengths. When the segment lengths become disproportionate other methods should be used to verify P_c.

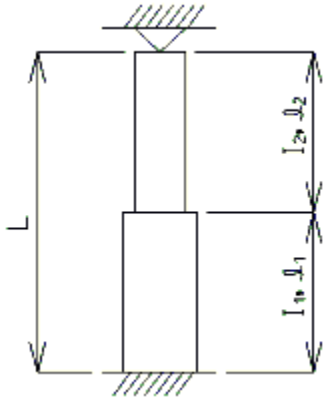
Fixed- Fixed Condition



$$(a_1 + a_2)\left[(d_1 + d_2) - P_c\left(\frac{1}{l_1} + \frac{1}{l_2}\right)\right] - (c_1 - c_2)^2 = 0$$

$$a_1 = \frac{4EI_1}{l_1} \qquad a_2 = \frac{4EI_2}{l_2}$$
$$c_1 = \frac{6EI_1}{{l_1}^2} \qquad c_2 = \frac{6EI_2}{{l_2}^2}$$
$$d_1 = \frac{12EI_1}{{l_1}^3} \qquad d_2 = \frac{12EI_2}{{l_2}^3}$$

Hinged-Fixed Condition



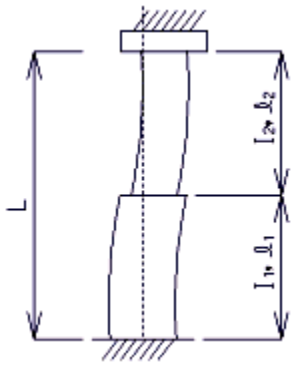
$$(a_2)(a_1 + a_2)\left[(d_1 + d_2) - P_c\left(\frac{1}{l_1} + \frac{1}{l_2}\right)\right] - (2b_2c_2)(c_2 - c_1)$$
$$-(b_2)^2\left[(d_1 + d_2) - P_c\left(\frac{1}{l_1} + \frac{1}{l_2}\right)\right] - (a_2)(c_2 - c_1)^2$$
$$-(c_2)^2(a_2 + a_1) = 0$$

Where:

$$b_1 = \frac{2EI_1}{l_1} \qquad b_2 = \frac{2EI_2}{l_2}$$

a_1, a_2, c_1, c_2, d_1, and d_2 are defined in the previous equations.

Fixed-Fixed with Lateral Movement Condition

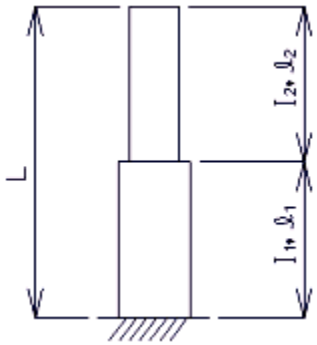


$$\left[(d_1+d_2)-\frac{(c_2-c_1)^2}{a_1+a_2}-P_c\left(\frac{1}{l_1}+\frac{1}{l_2}\right)\right]\left[d_2-\frac{{c_2}^2}{a_1+a_2}-P_c\left(\frac{1}{l_2}\right)\right]$$
$$-\left[(-d_2)+\frac{c_2(c_2-c_1)}{a_1+a_2}+P_c\left(\frac{1}{l_2}\right)\right]^2=0$$

Where:

a_1, a_2, b_1, b_2, c_1, c_2, d_1, and d_2 are defined in the previous equations.

Fixed-Free with Lateral Movement Condition



$$\left[(d_1+d_2)-P_c\left(\frac{1}{l_1}+\frac{1}{l_2}\right)-\frac{A_1}{\beta}\right]\left[d_2-\frac{P_c}{l_2}-\frac{A_3}{\beta}\right]$$
$$-\left[(-d_2)+\frac{P_c}{l_2}-\frac{A_2}{\beta}\right]^2=0$$

Where:

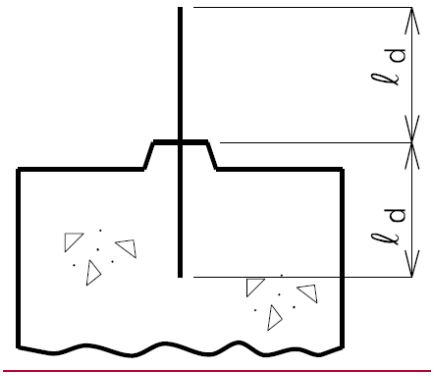
$$\beta = (a_2)(a_1 + a_2) - (b_2)^2$$
$$A_1 = (c_1 - c_2)[a_2(c_1 - c_2) + (b_2 c_2)] + (c_2)[b_2(c_1 - c_2) + (c_2)(a_1 + a_2)]$$
$$A_2 = (c_1 - c_2)[(a_2 c_2) - (b_2 c_2)] + (c_2)[(b_2 c_2) - (c_2)(a_1 + a_2)]$$
$$A_3 = (c_2)[(a_2 c_2) - (2b_2 c_2) + (c_2)(a_1 + a_2)]$$

a_1, a_2, b_1, b_2, c_1, c_2, d_1, and d_2 are defined in the previous equations.

Refined Effective Length Factor for Out-of-plane Bending

The following procedure may be used to reduce the effective length factor for column or pile bents where the beam cap is doweled into a concrete superstructure diaphragm. This procedure is applicable for out-of-plane bending only. The less stiff the substructure the larger the benefit expected from this procedure.

The equation for rotational stiffness assumes the dowel bars are fully bonded in the superstructure and beam. To utilize this procedure the dowel bars shall be developed l_d min into diaphragm and beam but shall not extend into slab and shall clear bottom of beam by 3 inches minimum. Dowel bars shall not be hooked to meet development requirements.



SECTION THRU KEY

The following procedure is developed for the most common substructure type (columns on drilled shafts). This procedure is greatly simplified for non-telescoping column bents and pile bents.

Step 1 – Determine the rotational stiffness at top of bent per ft length of diaphragm, R_{ki}

$$R_{ki} = -12500 + 300A_d + 600D_W - 150 \times \theta$$

Where:

R_{ki} = rotational stiffness at top of bent per ft length of diaphragm (k-ft/rad per ft)

A_d = total area of dowel bars (in^2)

D_W = diaphragm width between girders and normal to bent (in)

θ = skew angle of bent (deg.)

Step 2 – Determine the rotational stiffness at top of column, R_{kb}

To determine the rotational stiffness at top of column, the rotational stiffness at top of bent, R_{ki}, shall be multiplied by the beam cap length and divided by the number of columns. The beam cap length is substituted for the diaphragm length to simplify the calculations and has a marginal affect on the final result.

$$R_{kb} = \frac{R_{ki}(beam\ cap\ length)}{No.\ Columns}$$

Step 3 – Determine the buckling load assuming no rotational stiffness at top, P_{co}

For a non-telescoping column on footing or pile with in-ground point of fixity:

Note: this step is not required for a non-telescoping column or pile bent but shown here for completeness.

$$P_{co} = \frac{\pi^2 EI}{4L^2}$$ …Note: assumes K = 2.0

Where:

P_{co} = initial buckling load assuming no rotational stiffness at top of bent (k)

E = modulus of elasticity of column or pile (ksi)

I = moment of inertia of column or pile for out-of-plane bending (in^4)

L = length between point of fixity and top of beam cap (in)

For a telescoping column:

As noted above the equations provided for determining the buckling load of telescoping columns are not accurate for diverging segment lengths. The following equation is provided and may be used for the fixed-free with lateral movement condition.

$$P_{co} = \frac{\pi^2 E I_2}{4L^2} \frac{1}{\frac{l_2}{L} + \frac{l_1 I_2}{L I_1} - \frac{1}{\pi}\left(\frac{I_2}{I_1} - 1\right) sin\frac{\pi l_2}{L}}$$ …fixed-free with lateral movement

Where:

$$E = \frac{\sum(l_n E_n)}{L}$$

l_1, l_2, I_1, I_2, and L are shown in the figures above.

Step 4 – Determine the equivalent moment of inertia for a non-telescoping column using P_{co}

$$I_{eq} = \frac{P_{co} 4L^2}{E\pi^2}$$ …Note: assumes K = 2.0

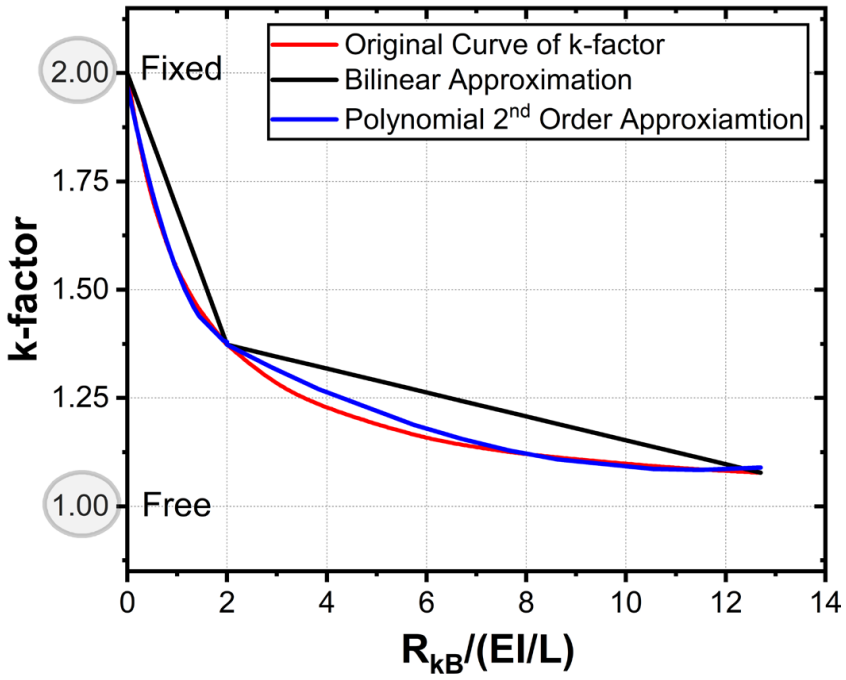
Note: This step is only required for telescoping columns.

Step 5 – Determine ideal k

A bilinear approximation is used to determine the ideal effective length factor for out-of-plane bending, k.

$$k = \begin{cases} 2.000 - 0.3135\left(\frac{R_{kb}L}{EI_{eq}}\right) for \frac{R_{kb}L}{EI_{eq}} < 2 \\ 1.428 - 0.0275\left(\frac{R_{kb}L}{EI_{eq}}\right) for \frac{R_{kb}L}{EI_{eq}} \geq 2 \end{cases}$$

Note: I_{eq} = I for non-telescoping columns or piles



Graphical Approximation of k-factor

Step 6 – Adjust k for design

The effective length factor for out-of-plane bending requires an adjustment for design conditions.

$$K = \frac{2.1k}{2.0}$$

Step 7 – Determine refined buckling load

The buckling load can be calculated using the equivalent non-telescoping column moment of inertia.

$$P_c = \frac{\pi^2 E I_{eq}}{(KL)^2}$$

751.21.2 Design

The design shall be in accordance with the appropriate design guidance found in EPG 751.22.2 Design except as specified in this article.

751.21.2.1 Distribution Factors

Deck Superstructure Type (LRFD 4.6.2.2.1)

Spread beams (including voided slab beams) are considered as precast concrete boxes supporting components with a cast-in-place concrete slab deck, typical cross-section (b).

Adjacent beams composite with a reinforced concrete slab are considered as precast solid, voided, or cellular concrete boxes with shear keys supporting components with a cast-in-place concrete overlay deck, typical cross-section (f).

Adjacent beams with an asphalt wearing surface shall be considered as precast solid, voided, or cellular concrete box with shear keys and with or without transverse post-tensioning supporting components with an integral concrete deck, typical cross-section (g).

LRFD Exception for Shallow Spread Beams

The live load distribution factor for moment in interior beams specified for spread beams greater than or equal to 18 inches may be used for the 15- and 17-inch spread beams.

751.21.2.2 Pretensioned Anchorage Zones

The bursting and spalling resistance in the ends of box beams shall be provided by vertical reinforcement (U1, S4 and S5 bars). The bursting and spalling resistance shall be based on LRFD 5.9.4.4.1 splitting resistance but modified based on strut-and-tie modeling developed by Davis, Buckner and Ozyildirimon (Dunkman et al. 2009).

The bursting and spalling resistance (Pr) at the service limit state shall meet both of the following:

Within h/3 from the end of beam:
$P_r = f_s A_s \geq 0.0375 f_{pbt}$
Within 3h/4 from the end of beam:
$P_r = f_s A_s \geq 0.06 f_{pbt}$

Where:

f_s = Stress in mild steel not exceeding 20 ksi
A_s = Total area of vertical reinforcement within specified distances; where h is overall beam height.
f_{pbt} = Prestressing force immediately prior to transfer

Confinement Reinforcement

In accordance with LRFD Article 5.9.4.4.2 confinement reinforcement is not required for box beams and voided and solid slab beams. Rather the provided top and bottom transverse reinforcement shall be anchored into the web of the beam.

751.21.2.3 Temporary Tensile Stress Reinforcement

The #5-A1 and #4-A2 bars shall resist the tensile force in a cracked section computed on the basis of an uncracked section.

Required Steel Area: A1 + A2 = T_f/f_s

Where:

f_s = 0.5fy ≤ 30 ksi, allowable tension stress of mild steel, (ksi)
T_f = Resultant of total tensile force computed on the basis of an uncracked section, (kips)

Designer shall verify the A2 bars are actually in tension before including them in the check. Additional A1 bars may be needed where there isn't enough deadload to put the top of the beam into compression.

Reinforcement shall be designed and spliced using f'ci in accordance with EPG 751.5.9.2.8 Development and Lap Splices.

751.21.2.4 Limiting Tensile Stresses

For prestressed beams made continuous and where the A1 and A2 reinforcement is proportioned as stated above:

The limiting tensile stress after losses at the top of beams near interior supports is

$0.24\sqrt{f'c}$ …(Service III)

Th~~is~~e above stress limit shall be checked even though the PS beam is designed as a reinforced concrete member at regions of negative flexure.

The limiting tensile stress after losses near the midspan of beams is

$0.19\sqrt{f'c} \leq 0.6$ ksi …(Service III)

The limiting tensile stress before losses at the top of beams is

$0.24\sqrt{f'ci}$

751.22.2.3 Flexure

Flexure capacity of girders shall be determined as the following.

Flexural resistance at strength limit state

$$M_r = \phi M_n \geq M_u$$

Where:

M_r = Flexural resistance

M_n = Nominal flexural resistance

M_u = Total factored moment from Strength I load combination

ϕ = Flexural resistance factor as calculated in LRFD 5.5.4.2

Negative moment reinforcement design

P/S I-girder shall be designed as a reinforced concrete section at regions of negative flexures (i.e., negative moments).

At least one-third of the total tensile reinforcement provided for negative moment at the support shall have an embedment length beyond the point of inflection not less than the specified development length of the bars used.

Slab longitudinal reinforcement that contributes to making the precast beam continuous over an intermediate bent shall be anchored in regions of the slab that can be shown to be crack-free at strength limit states. This reinforcement anchorage shall be staggered. Regular longitudinal slab reinforcement may be utilized as part of the total longitudinal reinforcement required.

Effective Slab Thickness

An effective slab thickness shall be used for design by deducting from the actual slab thickness a 1” integral, sacrificial wearing surface.

Design A1 reinforcement in the top flange

The A1 reinforcement shall resist the tensile force in a cracked section computed on the basis of an uncracked section.

For I girders and bulb-tee girders, A1 reinforcement shall consist of deformed bars (minimum #5 for Type 2, 3 and 4 and minimum #6 for Type 6, 7 and 8).

For NU girders, A1 reinforcement shall consist of the four 3/8-inch diameter reinforcement support strands with deformed bars added only as needed. The WWR in the top flange shall not be used for A1 reinforcement because there is insufficient clearance to splice the WWR.

Reinforcement shall be designed and spliced using f'_{ci} in accordance with EPG 751.5.9.2.8 Development and Lap Splices.

Required steel area is equal to:

$$A1 = \frac{T_t}{f_s}$$

Where:

$f_s = 0.5 f_y \leq 30KSI$, allowable tensile stress of mild steel, (ksi)

T_t = Resultant of total tensile force computed on the basis of an uncracked section, (kips)

Limits for reinforcement

The following criteria shall be considered only at composite stage.

Minimum amount of prestressed and non-prestressed tensile reinforcement shall be so that the factored flexural resistance, M_r, is at least equal to the lesser of:

1) M_{cr} LRFD Eq. 5.6.3.3-1
2) $1.33M_u$

Where:

M_{cr} = Cracking moment, (kip-in.)

M_u = Total factored moment from Strength I load combination, (kip-in.)

Limiting tensile stress

For prestressed girders made continuous and where the A1 reinforcement is proportioned as stated above:

The limiting tensile stress after losses at the top of girders near interior supports is

$0.24\sqrt{f'c}$ …(Service III)

Thise above stress limit shall be checked even though the PS girder is designed as a reinforced concrete member at regions of negative flexure.

The limiting tensile stress after losses near the midspan of girders is

$0.19\sqrt{f'c} \leq 0.6$ ksi …(Service III)

The limiting tensile stress before losses at the top of girders shall satisfyis

$0.24\sqrt{f'ci}$