Structural Engineering Guidance No. 20-02

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Distribution: All Engineering Resources

SUBJECT: GALVANIZED BOLTED CONNECTION DESIGN REQUIREMENTS

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EPG Status: Not Included

Std. Drawing Status: NA

Effective Date: Immediately for Jobs in Design Phase

Expiration/Duration: Active until Incorporated into EPG and AASHTO LRFD 9th Ed. Interims

1. Background and Purpose:

The Engineering Policy Guidelines for Steel Superstructures, 751.14, is written for painted and weathering steel structures. The only guidance regarding the use of galvanized steel is presented in section 751.14.5.8 and reads as follows:

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).

No mention is made of the design implications for bolted connections. All slip-critical connections will see a reduced capacity and require special designs when galvanization is specified. All bridge connections in primary members including girder splices, end diaphragms and intermediate diaphragms in curved structures shall be designed as slip-critical connections. This guidance is to alert designers to the necessary design changes required for bolted connection design.

1. LRFD Design of Slip-Critical Connections

For typical painted and weathering steel bridges the surfaces are typically blast-cleaned to SSPC-SP 6 or better resulting in a Class B Surface with a slip coefficient equal to 0.5. Galvanized surfaces are considered Class C with a slip coefficient of 0.3. See AASHTO LRFD 6.13.2.8 and sec 1080.4.3 for reference. The nominal slip resistance is currently determined by the following equation.

*Rn = KhKsNsPt* LRFDeq. 6.13.2.8-1

where:

*Ns* = number of slip planes per bolt

*Pt* = minimum required bolt tension specified in LRFD Table 6.13.2.8-1 (kip)

Kh = hole size factor specified in LRFD Table 6.13.2.8-2

Ks = surface condition factor specified in LRFD Table 6.13.2.8-3 (Class B = 0.5, Class C = 0.3)

In future interims of the 9th edition of the AASHTO bridge code a factor, Kc, is being added to the above equation resulting in a further reduced slip resistance for galvanized connections. **This factor shall be included with LRFD Eq. 6.13.2.8-1. Use the following modified equation:**

***Rn = KhKsKcNsPt* Modified LRFDeq. 6.13.2.8-1**

where:

***Kc*** = creep factor taken equal to **0.80** for Class C galvanized faying surfaces or for duplex coated faying surfaces utilizing a coating over a galvanized subsurface, and taken equal to 1.0 for all other surface conditions

The creep factor accounts for relaxation of the bolts due to creep in the galvanized surface. Even if the galvanized surface is treated to increase the slip coefficient, Ks, the creep in the galvanized subsurface still occurs. This guidance makes no recommendations toward the use of duplex coatings.

1. Anticipated Effect on Splices

Following is an example to give an idea of the impact of using galvanized surfaces in a flange splice connection.

**Given:** Strength-I Force, Pu =637.5 k

 Service-II Force, Ps = 450.0 k

 A325 - 7/8” diameter Bolts with Ab = 0.60 in2, Fub =120 ksi, Pt = 39 k

 Number of Slip/Shear Planes, Ns = 2

 Kh = 1.0

 Bolt threads included in shear plane

 Joint length between exterior bolts on one side of splice < 38”

 Reduction factor for filler plates, R = 0.83

 s = 0.80

**Solution 1:** Painted or weathering steel surfaces

Shear Resistance, Rr = s0.45AbFubNsR = 0.8\*0.45\*0.60\*120\*2\*0.83 = 43.0 k… LRFD 9th Ed., 2020

 No. bolts Rqd. (1) = 637.5 K / 43.0 k = 14.8 🡸 **Controls**

Slip Resistance, Rn = KhKsKcNsPt = 1.0\*0.5\*1.0\*2\*39 k = 39 k… Future Interims

 No. Bolts Rqd. (2) = 450.0 k / 39 k = 11.5

**Solution 2:** Galvanized steel surfaces

Shear Resistance, Rr = s0.45AbFubNsR = 0.8\*0.45\*0.60\*120\*2\*0.83 = 43.0 k… LRFD 9th Ed., 2020

 No. bolts Rqd. (1) = 637.5 K / 43.0 k = 14.8

~~Slip Resistance, R~~~~n~~ ~~= K~~~~h~~~~K~~~~s~~~~N~~~~s~~~~P~~~~t~~ ~~= 1.0\*0.3\*2\*39 k = 23.4 k…LRFD 9~~~~th~~ ~~Ed., 2020~~

 ~~No. Bolts Rqd. (2) = 450.0 k / 23.4 k = 19.2 🡸~~ **~~Controls~~**

Slip Resistance, Rn = KhKsKcNsPt = 1.0\*0.3\*0.8\*2\*39 k = 18.7 k… Future Interims

 No. Bolts Rqd. (3) = 450.0 k / 18.7 k = 24.0 🡸 **Controls**

Note: The splice tables in EPG 751.14.3 were designed in 2004 using more conservative shear resistance values. The values used a 0.38 factor and 0.48 factor for threads included and excluded respectively. Using the 2004 equations, the factored shear resistance for the above example is 36.6 k and requires 17.4 bolts for shear resistance.

1. What about rehabs?

The AASHTO Standard Specifications for Highway Bridges, 17th ed., addresses galvanized connections in Table 10.32.3C. The values in this table do not include the latest research findings. Since MoDOT does not have a gage on the performance of structures with galvanized connections due to lack of experience the following is recommended:

1. Use ASD loads as outlined in the applicable AASHTO Standard Specifications for Highway Bridges.
2. Multiply the nominal slip resistance per unit of bolt area from AASHTO Table 10.32.3C, Fs, by the creep factor described in section 2. Fs = 0.8 x (15 ksi for ASTM A325, 19 ksi for ASTM A490). This will control over the shear resistance listed in Table 10.32.3B (19 ksi for ASTM A325, 24 ksi for ASTM A490) which are commonly used values for ASD design of painted or weathering steel structures.

Alternately, the connection can be designed for LRFD HL-93 loads and the provisions shown in section 2.