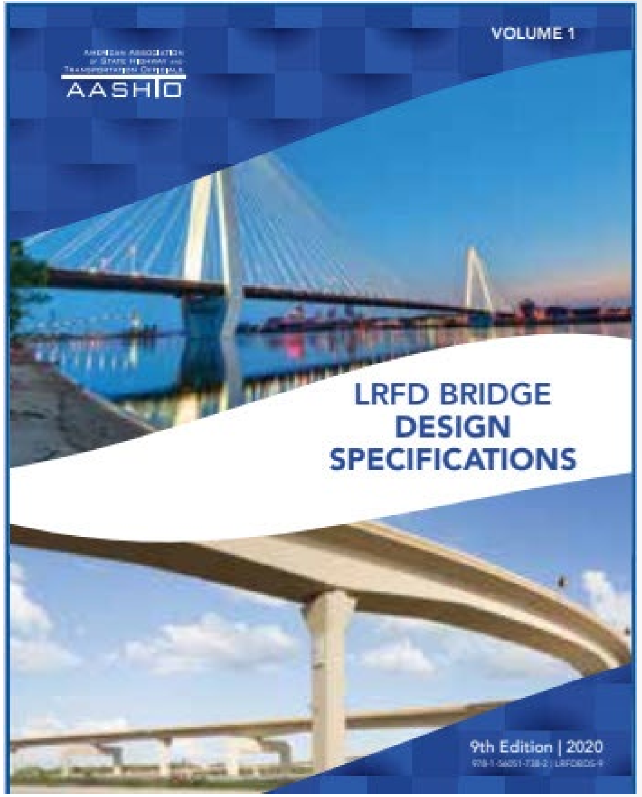
# Updates to the AASHTO LRFD Design Specifications
## (LRFD BDS Section 6 )




### Texas Steel Quality Council Meeting
### November 7, 2023

Credits

*Clear, thorough slides and erudite commentary:*

*Michael A. Grubb, P.E.*

*M.A. Grubb & Associates, LLC*

*Wexford, PA*

*Any botched or confusing presentation of said slides and commentary:*

*Domenic Coletti, PE*

*HDR*

*Raleigh, NC*

M.A. Grubb & Associates, LLC

HDR

# Significant Updates Appearing in the 9th Edition LRFD BDS (2020)

- *Improvements to the Web Load-shedding Factor, $R_b$, for Longitudinally Stiffened Girders* (2017) – to recognize the beneficial influence of the longitudinal stiffener

- *Revisions to the Fatigue Detail Table 6.6.1.2.3-1* (2018) – added a new Condition 1.6 to check fatigue of the base metal at larger manholes and hand holes

- *Revisions to the Design Provisions for Variable Web Depth Members* (2019) – to require full- or partial-depth stiffening of the web in certain cases at points where the inclined flange becomes horizontal

- *Revisions to the Flexural Design Provisions for Tees & Double Angles* (2019) - to bring the provisions up-to-date with the latest AISC Specification provisions

- *Clarification of the L/85 Guideline* (2017) – clarifications to the implementation in the design of this Commentary guideline intended to ensure that individual unspliced girder field sections are more stable and easier to handle during lifting, erection, and shipping.

- *New Design Provisions for Noncomposite Box-Section Members* (2019) – implementation of a complete new set of LRFD Specification provisions for the design of unstiffened and longitudinally stiffened noncomposite box sections, which are typically used in trusses, arches, rigid frames and bent caps.

# Look-Ahead to the AASHTO LRFD 10th Edition BDS (2024)



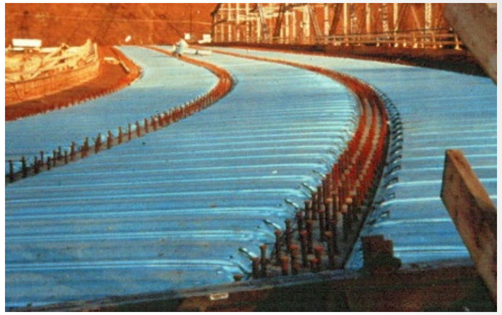

# T-14 Ballot Items Rolled Over from the 2020 to the 2021 COBS Meeting

- Revisions to the provisions for determining the flexural resistance of I- or H-shaped members and channels *subject to flexure about their weak axis* in order to bring the provisions up-to-date with the latest provisions given in the AISC Specification.

- Introduction of a creep reduction factor, $K_c$, of 0.80 in the determination of the nominal slip resistance of a galvanized faying surface (Class C) or a duplex coated faying surface utilizing a coating producing a higher slip coefficient over a galvanized subsurface.

- Revisions to the AASHTO IRM Guide Specification to incorporate angle-only and two-channel axially loaded tension members, along with some necessary revisions & updates to the design examples.

# Revisions to Shear Stud Design Provisions (2021)



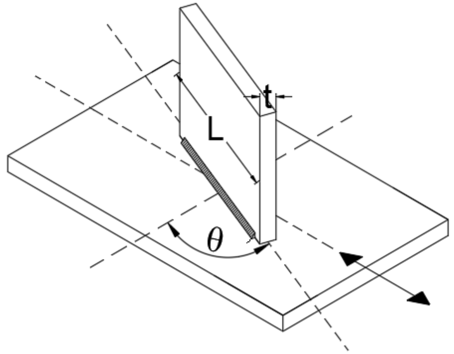
- Deleted all reference to channel shear connectors.
- Reduced the minimum center-to-center pitch of studs from 6*d* to 4*d.*
- Added a pitch correction to account for shear lag across clustered studs.
- Revised the equation for the nominal shear resistance, $Q_n$, of a stud shear connector at the strength limit state (somewhat more conservative).
- Changed the slope of the fatigue resistance curve for studs in the finite-life region from -3.00 to -5.00. Maintained the constant amplitude threshold, $(\Delta F)_{TH}$, at 7.0 ksi.
- Revised the fatigue detail Table 6.6.1.2.3-1 as follows:
  - Changed the exponent in the general equation for the finite-life fatigue resistance from 1/3 to 1/*m*, and added the "growth constant", *m*, to Table 6.6.1.2.3-1 for all fatigue details.
  - Added the fatigue resistance data for studs and high-strength bolts to Table 6.6.1.2.3-1. Streamlined Article 6.10.10.2.
  - Added the values of the 75-year $(ADTT)_{SL}$ equivalent to infinite life for each detail to Table 6.6.1.2.3-1, and eliminated Tables 6.6.1.2.3-2, 6.6.1.2.5-1, and 6.6.1.2.5-3.
  - Changed Table 6.6.1.2.3-1 from portrait to landscape format.

# Revisions from NCHRP Project 12-113 (2021)
## "Proposed Modifications to AASHTO Cross-Frame Analysis and Design"

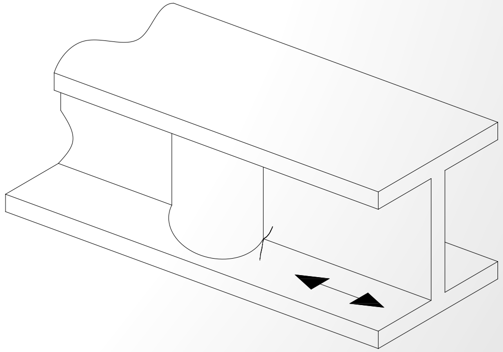
- Revisions to improve the prediction of fatigue force ranges in cross-frame members:
  - Specific fatigue truck loading requirements for refined analyses to better predict the fatigue force ranges in cross-frame members.
  - Multiply Fatigue I and Fatigue II load factors by 0.65 for cross-frames.
- Revisions to the *R* factor in Section 4 to better reflect the flexibility of cross-frame member end connections in composite bridge systems *in the analysis*.
- Addition of minimum stability bracing strength and stiffness requirements for cross-frame and diaphragm members in I-girder bridges during the deck placement (similar to the requirements in AISC Appendix Article 6.3.2).
- Recommendations to improve the prediction of cross-frame forces in 2D grid models, and the prediction in general of cross-frame forces in heavily skewed and/or curved bridges.

# Fatigue of Obliquely Oriented Welded Attachments & Introduction of Half-Round Bearing Stiffeners (2021)

- Fatigue characterization of obliquely oriented welded attachments
  - New Condition 7.3: fatigue categories transitioning between C' and E are proposed as a function of the skew angle, θ (for attachments longer than 4 inches and less than 1-inch thick attached by groove or fillet welds)



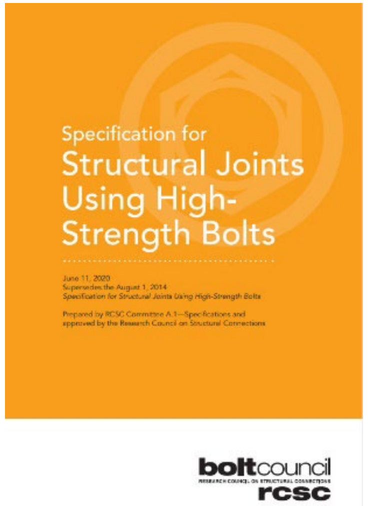

- Introduction & fatigue characterization of half-round bearing stiffeners (New Condition 4.2: Category C’)



# Revisions to Tub-Girder Specifications– Article 6.11 (2022)

- Implement advancements from the FHWA noncomposite box section research, and NCHRP 20-07 Task 415 research on bottom flange proportioning limits, into the design provisions for composite box sections in flexure, as applicable.
- Benefits:
  - Greater consistency between the design of composite bridge box girders and the other types of bridge members and components by the AASHTO LRFD provisions.
  - New bottom flange b/t limits that will place practical bounds on the use of bottom flanges with extremely large slenderness (particularly in tension) that can result in difficulties during fabrication, construction, and service.
  - Revised bottom-flange compressive resistance equations (that account for post-buckling resistance) that will allow for use of thinner unstiffened flanges where the previous conservative elastic buckling resistances required larger thicknesses or longitudinal stiffening for design.
  - A new constructibility and service plate-buckling requirement that will place additional restrictions on the use of thinner bottom flanges to avoid potential difficulties during construction or in service.
  - New provisions for longitudinally stiffened bottom flanges in Appendix E6 that will lead to additional economies and eliminate the dramatic increase in the longitudinal stiffener moment of inertia required in the current provisions when the number of stiffeners exceeds one and transverse stiffening is not provided.
  - New primary and secondary member designations for tub-girder bracing members in Table 6.6.2.1-1.

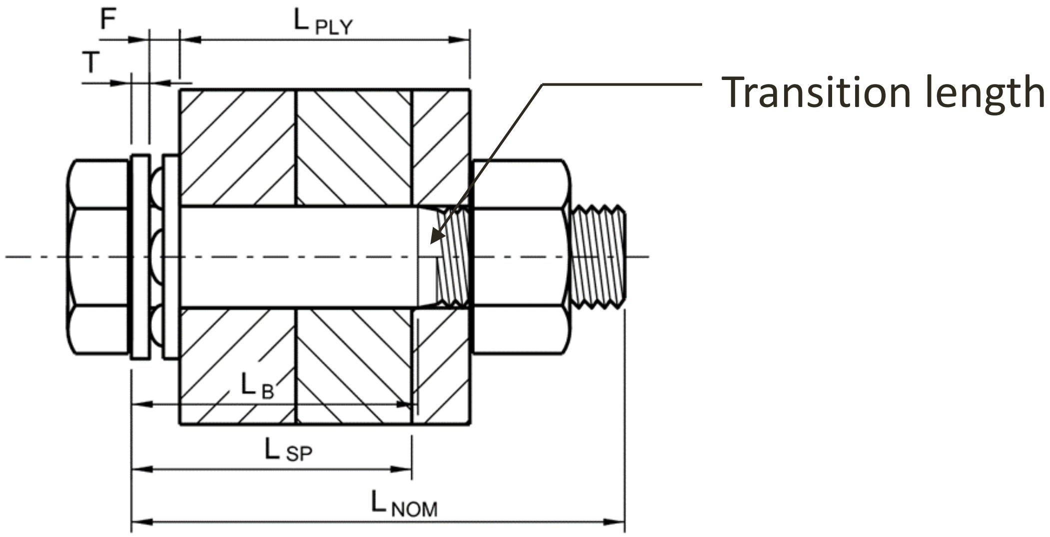
# Inclusion of ASTM F3148 High-Strength Torque-and-Angle Bolts (2022)


- ASTM F3148 high-strength torque-and-angle bolts first became an ASTM Standard in 2015, were included in the 2020 RCSC Specification, and will also now be included in the 10th Edition *AASHTO LRFD* BDS.
- ASTM F3148 bolts look like twist-off bolts, however, the splined end is not intended to shear off.
- The splined end is for torque reaction to permit one-side tensioning; installed by a torque-and-angle method, or the so-called “combined method” of installation.
- The specified minimum tensile strength of the bolts is 144 ksi.

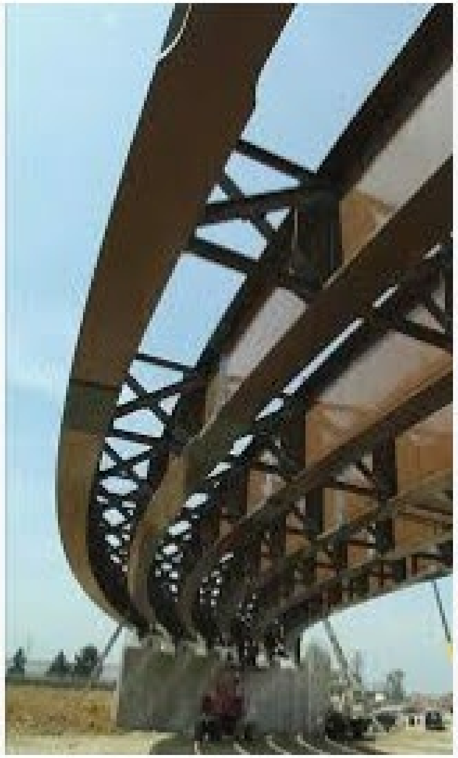
# Shear Resistance of High-Strength Bolts – Threads Included or Excluded (2022)

- Shear planes located in the transition length of high-strength bolts should be considered shear planes with the threads included (*AASHTO LRFD* Article 6.13.2.7 - 10th Edition).




- Guidance will be provided for determining whether threads are excluded from or included in the shear plane considering the bolt transition length (*AASHTO LRFD* Article C6.13.2.7 – 10th Edition).

# Slip-Critical vs. Bearing-Type Connections Bracing Members (2022)



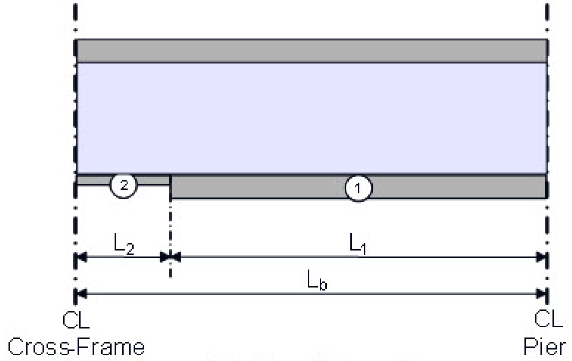
- Joints of diaphragm, cross-frame, and lateral bracing members in beam or girder bridges with pretensioned high-strength bolts installed in standard holes should be designed only as bearing-type connections (*AASHTO LRFD* Article 6.13.2.1.1 - 10th Edition).

- Field experience has indicated that slip in these connections is not likely and that any slip that may occur in these connections is not anticipated to be detrimental to the geometry or serviceability of the structure.

# Lateral Torsional Buckling of Nonprismatic Unbraced Lengths (2022)

- Agreement AS 20-0026 between AASHTO and Modjeski and Masters, Inc.: *Flexural Capacity of Steel I-Girders over Interior Piers*

<u>Georgia Tech:</u> Don White, Ryan Slein, Ryan Sherman, others…
<u>University of Texas at Austin:</u> Todd Helwig, Matt Reichenbach, Mike Engelhardt, others…
<u>Lehigh University:</u> Richard Sause, Ian Hodgson



<u>Girder Elevation</u>

<u>*Goals:*</u>

- Replace the approximate approach with more accurate and robust alternatives for determining the structural capacity of steel I-girders in negative moment regions over interior piers with nonprismatic unbraced lengths, including variable web-depth members.
- Allow for a more accurate computation of the elastic lateral-torsional buckling resistance of longer nonprismatic unbraced lengths of noncomposite I-section members during temporary construction conditions.

# Lateral Torsional Buckling of Nonprismatic Unbraced Lengths (2022) - cont

**Article D6.6** (Appendix D6 - 10th Edition) – Elastic Lateral-Torsional Buckling Load Ratio, $\gamma_e$, for Nonprismatic Unbraced Lengths of I-Section Members

**METHOD A** (Article D6.6.2)

Based generally on procedures in AISC Design Guide 25 (2nd Edition) with some modifications. Can also be used as an alternative for investigating reverse-curvature bending in a more refined manner in certain cases. Can be used for constant and variable web depths.

**METHOD B** (Article D6.6.3)

Based on the use of a weighted-average section approach; i.e., using a prismatic unbraced length with effective section properties to "replace" the nonprismatic unbraced length. Can be used for constant and variable web depths.

**METHOD C** (Article D6.6.4)

Refined analysis – estimate $\gamma_e$ as the eigenvalue from an elastic buckling analysis using a thin-walled open-section member model or an elastic three-dimensional shell-element model that captures the significant effects of the nonprismatic geometry (e.g., SABRE2 or ABAQUS). Use where Method A or B are not applicable or to get a more refined (and likely less conservative) estimate of the member resistance.

# Lateral Torsional Buckling of Nonprismatic Unbraced Lengths (2022) - cont

- *Other significant revisions*:

  - Replacement of the current equation for the moment-gradient modifier, $C_b$, with the quarter-point equation given in the AISC Specification:

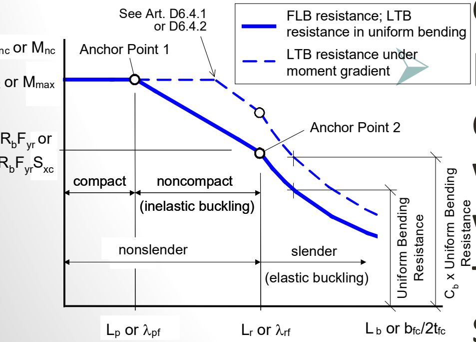
$$C_b = \frac{12.5M_{max}}{2.5M_{max} + 3M_A + 4M_B + 3M_C}$$

Methods to handle reverse curvature are discussed in the Commentary.

  - Replacement of the current equation for the compact unbraced length limit, $L_p$, with the equation given in the AISC Specification for general I-section members (in both Articles 6.10.8.2.3 and A6.3.3):

$$L_p = 1.1 r_t \sqrt{\frac{E}{F_{yc}}}$$

  - Removes error in Appendix A6 related to the current approximate approach for estimating the LTB resistance of nonprismatic unbraced lengths.
  - For welded sections, revision of the definition of $F_{yr}$ for LTB from a variable value, often equal to $0.7F_{yc}$ in previous Specifications, to $0.5F_{yc}$ for longitudinally unstiffened webs, and to the minimum of $0.5F_{yc}$ and $F_{crw}$ for I-girders with longitudinally stiffened webs, to provide a more uniform level of reliability consistent with the target levels in the AISC and AASHTO LRFD Specifications. The value $0.7F_{yc}$ is retained for rolled sections.



# Revise ‘FCM’ to ‘NSTM (2023)

- Revise ‘Fracture-Critical Member (FCM)’ to ‘Nonredundant Steel Tension Member (NSTM)’ in the AASHTO LRFD BDS.

- The National Bridge Inspection Standards (NBIS) were revised in May 2022 and eliminated the term Fracture-Critical Member (FCM) in favor of the term Nonredundant Steel Tension Member (NSTM) because of its implicitly negative connotation and because it was frequently misunderstood by those that did not work regularly with the NBIS. Until such time as other specifications are revised, for consistency, the terms FCM and NSTM are to be considered synonymous. Also, the term Load Path Redundant Member (LPRM) is to be considered synonymous with the term nonfracture-critical member.

~~*Fracture-Critical Member (FCM)* — A steel member in tension, or with a tension element, whose failure would probably cause a portion of or the entire bridge to collapse, as per the NBIS (23 CFR 650.305).~~

*Nonredundant Steel Tension Member (NSTM)* — A primary steel member fully or partially in tension, and without load path redundancy, system redundancy or internal redundancy, whose failure may cause a portion of or the entire bridge to collapse.

*Load Path Redundant Member (LPRM)*—A primary steel member fully or partially in tension, that has load path redundancy.

# Revise 'FCM' to 'NSTM (2023) - cont

- The 2022 NBIS also recognized System Redundant Members (SRMs) and Internally Redundant Members (IRMs) for purposes of alleviating NSTMs from in-service NSTM inspection. The NBIS defines the conditions under which NSTMs may be reclassified as SRMs or IRMs. Per a FHWA memo (FHWA Memorandum, May 9, 2022), the AASHTO *Guide Specifications for Analysis and Identification of Fracture Critical Members and System Redundant Members* and AASHTO *Guide Specifications for Internal Redundancy of Mechanically-Fastened Built-Up Steel Members*, or an alternative method satisfying either of the two criteria specified in 23 CFR 650.313(f)(1)(i)(B), are considered nationally recognized methods to determine SRMs or IRMs.

- *AASHTO LRFD Article 6.6.2.2 – Nonredundant Steel Tension Members* -> The Engineer shall classify primary steel members fully or partially in tension that are without load path redundancy, system redundancy, or internal redundancy as Nonredundant Steel Tension Members (NSTMs). For flexural members, only the portions of the member located in designated tension zones under Strength Load Combination I shall be classified as an NSTM. Such members or the portions of a flexural member located in the designated tension zones, as applicable, shall be identified on the contract plans as an NSTM. Fracture Control (FC) practice shall apply for NSTMs.

  *Fracture Control (FC) Practice*—Practice required for materials and fabrication of NSTMs, newly designed SRMs, and primary plate components in newly designed IRMs. For flexural members, FC Practice only applies in the portions of the member located in designated tension zones under Strength Load Combination I where the preceding classifications apply.

# Revise ‘FCM’ to ‘NSTM (2023) - cont

- For materials, FC Practice requirements include the more stringent Charpy V-Notch impact energy requirements designated as “F” in AASHTO M 270M/M 270 (ASTM A709/A709M. For fabrication, when welding is required, FC Practice requirements include those found in AASHTO/AWS D1.5M/D1.5 *Bridge Welding Code* Clause 8.19.8 and Clause 12, the AASHTO *LRFD Steel-Bridge Fabrication Specifications*, and any other Owner-specified requirements.

- *AASHTO LRFD Article 6.6.2.2 - Nonredundant Steel Tension Members* -> The Engineer may classify primary steel members fully or partially in tension that are without load path redundancy, but have system or internal redundancy, as System Redundant Members (SRMs) or Internally Redundant Members (IRMs) for in-service inspection per 23 CFR 650.313(f)(1)(i) with FHWA-approved procedures in conformance with a nationally recognized method. These members shall be identified on the contract plans as a SRM or an IRM, as applicable; for flexural members, only the portions of the member located in the designated tension zones should be identified as such. FC Practice shall apply for newly designed SRMs and primary plate components in newly designed IRMs, or for the portions of a flexural member located in the designated tension zones where these classifications apply.

- The Engineer need only identify NSTMs, SRMs, and IRMs on the contract plans where these classifications apply; all other primary members or portions of primary members are LPRMs by default and need not be identified as LPRMs on the contract plans. The designation “FC” and identification of the specific FC Practice requirements for these members, or portions thereof, is not necessary on the contract plans and should be avoided. Fabricators will use the term “Fracture Control Practice” or the designation “FC” on shop drawings to identify the need for the FC Practice requirements.

# Other Revisions

- Eq 6.11.2.2-3 shall only apply to built-up tub section members (2021):

$$t_f \geq 1.1 t_w$$

- Revisions to Article 6.8.2.2 and 6.13.5.2 – i.e., further "clean-up" of Table 6.8.2.2-1 containing the shear lag factor, U, for tension members – are made (2021).
- Revisions to various articles regarding the minimum thickness of steel and miscellaneous connection design issues are made (2021).
- Addition to Article C6.6.1.2.4 summarizing the conditions associated with susceptibility to constraint-induced fracture at welded details along with a brief discussion of intersecting welds (2021)
- Mixed faying surfaces utilizing an unsealed pure zinc thermal-sprayed coating mating with a hot-dip galvanized surface are classified as a Class D surface condition for slip (2022).
- References to the new AASHTO *LRFD Steel-Bridge Fabrication Specifications* are added to the *AASHTO LRFD* BDS (2022).
- Significant revisions to the cross-frame/diaphragm and lateral bracing requirements for steel tub girders based on research conducted over the last few years at the University of Texas at Austin. Also allow for offset top flanges and shallower web inclinations if desired (2023).
- Allow for optional inclusion of the longitudinal deck reinforcement in the bolted splice design if the reinforcement is also considered in the moment design of the girder section (2023).

# Questions?