The University of Texas at Austin

CTR Symposium

NCHRP PROJECT NO. 12-113

PROPOSED MODIFICATION TO AASHTO CROSS-FRAME ANALYSIS AND DESIGN

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National Cooperative Highway Research Program (NCHRP) Project 12-113

“Proposed Modification to AASHTO Cross-Frame Analysis and Design”
(American Association of State Highway and Transportation Officials)

Primary Objective

Improve the design and analysis of cross-frame systems in steel I-girder bridges

Presentation Outline

Research Motivation & Objectives

Research Methods

Overview of Approved AASHTO Ballots

Current State of Cross-frame Design

- Since the 1994 Specifications, cross-frame spacing and layout is based on a “rational” analysis
- In the 25+ years since, significant research has been conducted to improve our understanding of cross-frame behavior
- Despite those recent advancements, there are still gaps in knowledge related to cross-frame design:

1. **Fatigue loading criteria**
2. **Analysis techniques**
3. **Stability bracing requirements**

1. Fatigue Loading

- AASHTO LRFD fatigue loading criteria was specifically calibrated for girder response, not cross-frame response
- TxDOT Project 0-6564 recognized that single-angle members are a Category E′ detail (worst performance in fatigue)

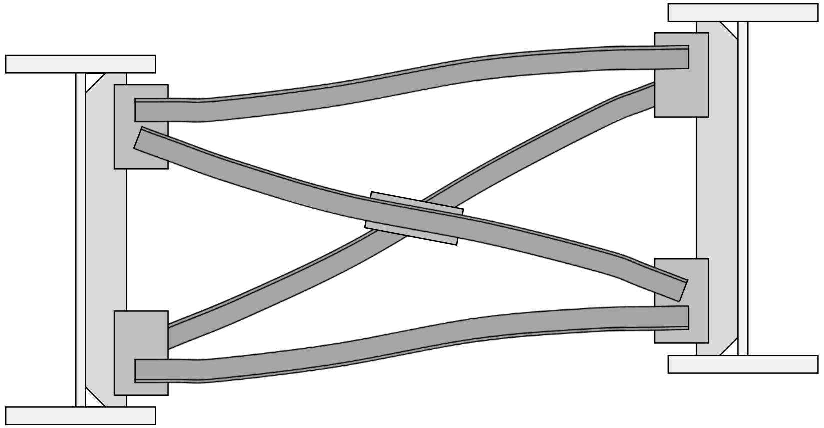
→ A lot of concerns were raised about cross-frame fatigue performance

- However, there is not widespread physical evidence of load-induced fatigue cracking in these details.

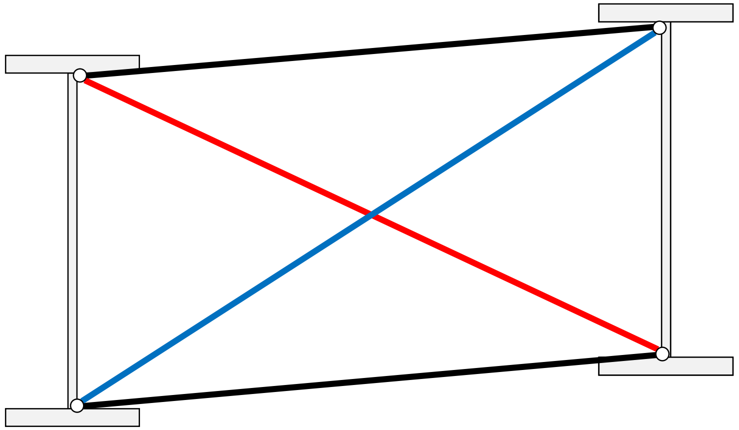
- The lack of widespread fatigue damage in cross-frames is likely due to smaller stress ranges than predicted by the existing fatigue loading criteria. → Guidance on appropriate load factors and the actual placement of the fatigue truck for cross-frame evaluation was necessary.

2. Analysis Techniques

- Commercial software programs typically make use of simplified analysis methods to model bridge structures, especially cross-frames



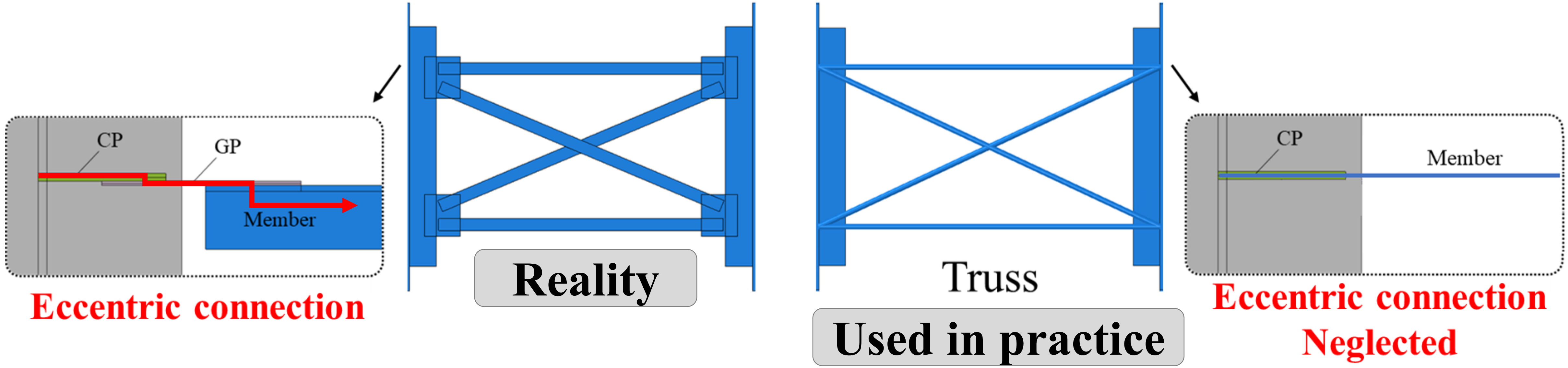
Reality



Used in practice

2. Analysis Techniques

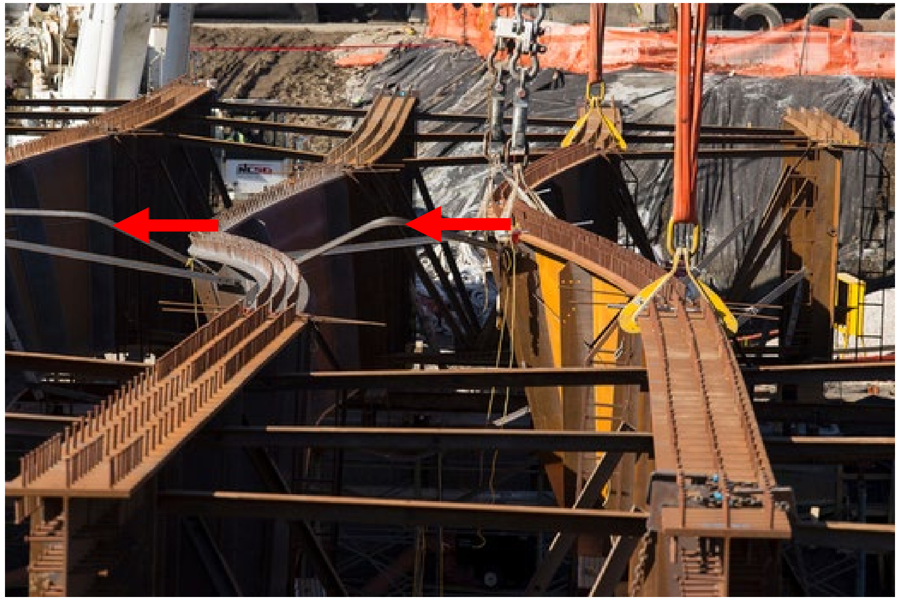
- Previous University of Texas research (TxDOT Study 0-6564) showed that truss-element models **overestimate** cross-frame stiffness compared to the actual behavior from experiments ➡ Reduction Factor (R-factor)
- The **stiffness reduction** (R-factor) in single-angle cross-frames is due to the **bending** caused by the **eccentric connection**

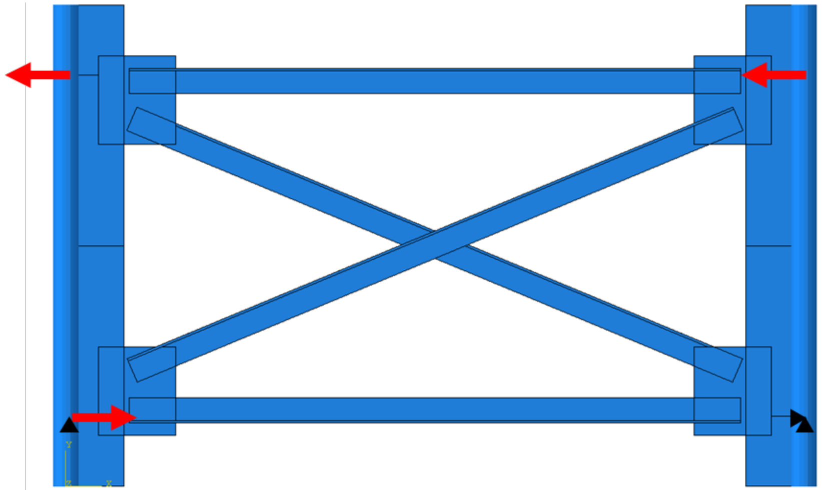


2. Analysis Techniques

AASHTO LRFD bridge design specification,

R = 0.65 based on the cross-frame behavior under **Construction Loading**





Cross-frames of in-service bridges, the behavior should be different

Battistini, A., Wang, W., Helwig, T., Engelhardt, M., and Frank, K.; "Stiffness Behavior of Cross Frames in Steel Bridge Systems," *ASCE Journal of Bridge Engineering*, Vol. 21, No. 6, pp. 04016024-1-11, June 2016.

3. Stability Bracing

- AASHTO LRFD (2020) has no formal guidance on bracing strength and stiffness requirements

Research Objectives

1. Fatigue Loading Model

- Determine the appropriate loading criteria (i.e., truck position, load factors) to represent live load effects on cross-frame stresses

2. Analysis Techniques

- Investigate the appropriate R-factor for cross-frames of in-service bridges

3. Stability Bracing

- Review and adapt the stability bracing provisions in the AISC Specifications for implementation into AASHTO LRFD

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Research Methods

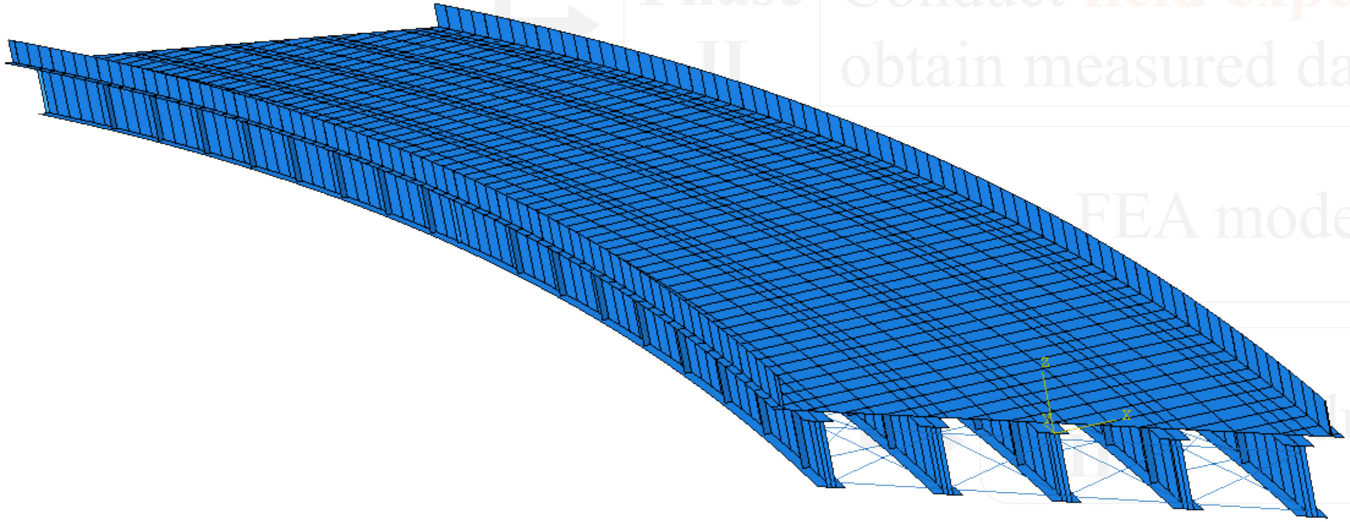
Phase I	Perform background and literature review

Phase I | Perform background and literature review

Phase II | Conduct field exper obtain measured dat

FEA model

Phase III | Develo comm



Parametric studies:

- **4,104** unique bridges analyzed
- > **70,000** cross-frames evaluated
- **18** weigh-in-motion sites
- ~ **46 million** truck records studied

Research Methods

Phase I	Perform background and literature review
Phase II	Conduct **field experiments** and obtain measured data
Phase II	Validate FEA models
Phase III	Conduct **parametric FEA studies**
Phase III	Develop specification and commentary language
Phase IV	Develop AASHTO ballots

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(Based on the results from the project)

Article 3.4.5 (New) & C6.6.1.2.2

3.4.5—Load Factors for Cross-Frames and Diaphragms at the Fatigue Limit State

The Fatigue I and II live load factors (γ_{LL}) shall be multiplied by an additional factor of 0.65 when evaluating load-induced fatigue in cross-frames and diaphragms.

[C6.6.1.2.2]…it is recommended that the fatigue truck be positioned to determine the maximum range of stress or force, as applicable, in these members as specified in Article 3.6.1.4.3a, with the truck confined to one critical transverse position per each longitudinal position throughout the length of the bridge in the analysis…

Cross-frame-specific load factors:

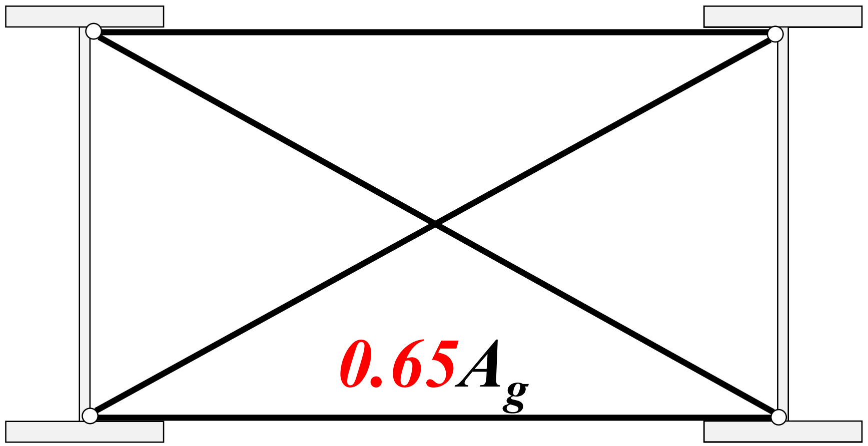
Fatigue I → 1.75 × **0.65** = **1.14**

Fatigue II → 0.80 × **0.65** = **0.52**

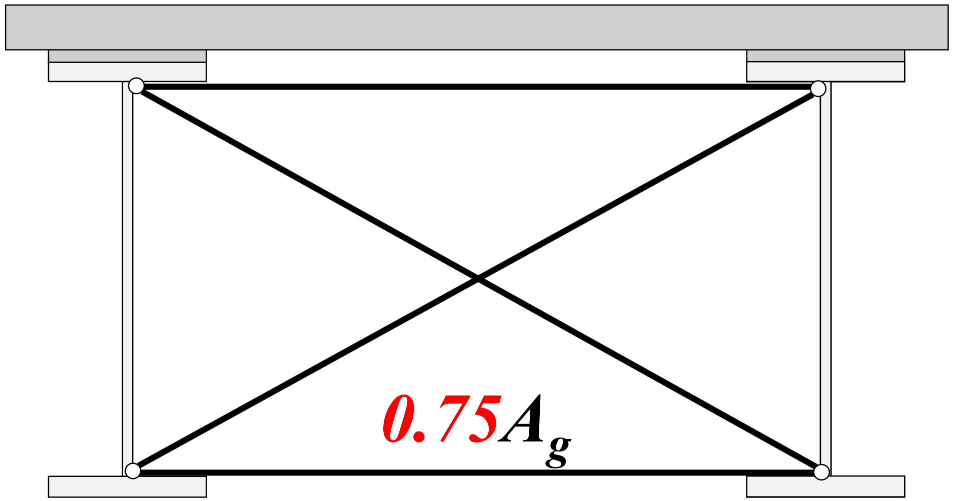
Article 4.6.3.3.4c (New)

In lieu of a more refined analysis, the equivalent axial rigidity of single-angle and flange-connected tee-section cross-frame members shall be taken as 0.65*AE* in the analysis model for the noncomposite condition during construction. In lieu of a more refined analysis, the equivalent axial rigidity of single-angle and flange-connected tee-section cross-frame members shall be taken as 0.75*AE* in the analysis model for the composite condition.

Noncomposite (construction)



Composite (in-service)



Article 6.7.4.2.2 (New)

…diaphragms or cross-frames in straight rolled-beam or plate-girder bridges with or without skew, and in horizontally curved …bridges satisfying all the conditions … for neglecting the effects of curvature, shall also satisfy the following stability bracing **strength** requirement for the applicable noncomposite *DC* loads and any construction loads…

$$M_{br} = \left(\frac{0.036L}{nC_b L_b}\right) M_r$$

In addition to the minimum design requirements specified in Article 6.7.4.1, diaphragms or cross-frames for all … bridges shall satisfy the following stability bracing **stiffness** requirement for the applicable noncomposite DC loads and any construction loads…

$$\beta_{T,br} = \frac{3.6LM_r{}^2}{\phi nEI_{yeff}C_b{}^2}$$

(Higher than current equation in AISC)

(Approved for the next version of AISC)

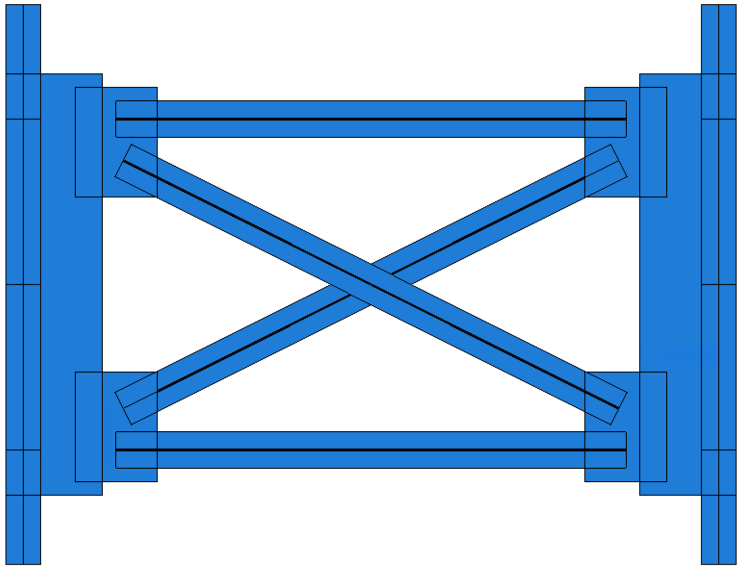
NCHRP 12-113:

Exclusively focused on single-angle sections as cross-frame members

However, WT sections are also commonly used sections in the US

Current Study:

Investigate *Analysis techniques* for cross-frames comprised of WT sections



Thank you!

Questions?