CENTER FOR TRANSPORTATION RESEARCH

PROJECT SUMMARY

Texas Department of Transportation

0-6564: Improved Cross Frame Details

Background

To provide an effective brace, a cross frame must have adequate strength and stiffness. For use in the design of steel bridges, the individual cross frame members must also provide a minimum fatigue performance, governed by design codes. Currently, the Texas Department of Transportation (TxDOT) relies upon the use of standard details for cross frames in steel I-girder bridges—most frequently, the X-type and K-type cross frames. Both details utilize single angle members eccentrically connected to the cross frame gusset plates, potentially leading to significant bending at the connection and, subsequently, a reduced fatigue life.

Details can be improved by reducing or eliminating the eccentricity. By using concentric members, such as HSS tubes or double angles, the performance of the brace can be improved. Moreover, these concentric members can provide significant compression capacity, meaning that cross frame layouts with a singular diagonal can provide an effective brace (Z-type).

In this project, the researchers sought to characterize the current performance of the standard cross frame details in strength, stiffness, and fatigue and to offer improvements for better behavior, both relative to the currently used details as well as the proposed concentric details.

What the Researchers Did

The research included laboratory testing and finite element modeling. The laboratory tests consisted of small scale connection tests (fatigue, strength, and stiffness) as well as full scale tests on various cross frames systems. The full scale tests included stiffness tests and fatigue testing of the cross frame systems. Several different cross frames were tested to measure the stiffness and strength of the cross frames. In addition, 25 cross frames were tested to evaluate the fatigue performance.

The researchers also used computational three-dimensional finite element software to examine a recently designed Texas steel bridge, comparing the cross frame forces calculated by a three-dimensional finite element model to those determined by the commercial grillage-based software TxDOT currently uses.

What They Found

The stiffness tests revealed that the truss model frequently used in both hand calculations and commercial computer programs often grossly overestimates the stiffness of cross frames with single angle members. Laboratory tests and parametric finite element models were used to develop a correction for the stiffness calculations.

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The cross frame fatigue tests on the currently used X-type and K-type cross frames revealed the performance of single angle detail to be more similar to a Category E´ detail in the AASHTO LRFD Bridge Design Specification rather than the currently accepted Category E detail.

The X-type detail used by TxDOT could result in overlap fillet welds. The overlap, or close proximity of welds, leads to a large stress concentration that can substantially reduce fatigue life.

The K-type cross frame provides similar fatigue performance as the X-type detail. If the K-type brace can provide adequate stiffness, fabricators would prefer this detail as it does not require a flip during fabrication, yielding a time and cost savings.

The Z-type cross frame diagonal experiences substantial bending due to differential deflection of the girders. Using double angles or large square HSS members resulted in the same or slightly lower performance than the X- or K-type details, thereby not justifying the increased cost. However, rectangular HSS tubes, with the slotted connection in the long side of the cross section, can substantially increase fatigue life, being close to Category E behavior.

In terms of computational modeling, the force attracted by the cross frame members is related to the stiffness of the members. Properly modeling the brace stiffness is important when predicting cross frame forces.

What This Means

These research results provide a means to obtain a much more accurate measure of the stiffness of the cross frames in steel bridge systems. The stiffness is important for addressing the stability of the girder system and obtaining an estimate of the cross frame's fatigue performance.

From a fatigue perspective, the fatigue life of single angle details may be over-predicted by the governing codes and specifications. Classifying the single angle detail as Category E´ in the AASHTO Specification may be more prudent.

The TxDOT X-type cross frame detail should be updated to provide wider gusset plates. This measure allows for more space between the end welds of the angles and the field welds of the cross frame gusset plates to connection plates. The TxDOT K-type cross frame is preferred by fabricators to streamline production (saving time and money), provided the brace stiffness and strength is adequate for design.

The proposed Z-type cross frame with rectangular HSS tubes may offer increased fatigue performance relative to the X- and K-type cross frames for required design applications.

Finally, when using grillage software, it is important the beam elements used to model the braces have the appropriate stiffness to account for the stiffness reduction experienced by cross frames with single angles. Reducing the stiffness will decrease fatigue-induced forces, potentially preventing expensive design modifications, such as using larger braces or including additional girder lines.

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