Evaluation of the Stress Distributions on Gusset Plate Connections in Historic Steel Truss Bridges

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Summary

A new evaluation procedure for the gusset plate connection in steel truss bridges is presented in this paper. First, a finite element (FE) model of gusset plate connection subassemblage is built to accurately represent stress distributions on gusset plates. Then, approximate stress distribution models at the critical sections of a gusset plate are developed by observation and compare with the FE results as well as the methods used in current practice. These approximate stress distribution models show good agreement with the FE results on gusset plates. The maximum Von Mises stress on gusset plates can be quickly calculated by using these approximated stress distribution models. The procedure developed in this paper provides bridge engineers a more accurate method to evaluate the remaining strength of gusset plate connections in historic and aged steel truss bridge.

Keywords: gusset plate connection; gusset plate; steel truss bridge; elastic stress distributions, critical sections; Whitmore's method.

1. Introduction

The collapse of the Minnesota I-35W Bridge has been, in part, attributed to the overstressed and then buckled gusset plates. This catastrophic event caused concerns of the potential for a similar overstressed state in gusset plates. In this paper, a Finite Element (FE) modeling methodology was developed to quickly simulate sub-assemblage of gusset plate connections and study stress distributions at the critical sections on gusset plates. The approximated stress distribution models for stress components at critical sections on the gusset plate connection were developed. The calculated stress distributions using these approximate stress distribution models are plotted to compare with the stress distributions of the FE results. The maximum stress in the gusset plate is then found by examining several potential high stress points at these critical sections.

2. The X-direction Normal Stress Distribution at the Chord Splice

The chord load is observed to fully contribute to the X-direction normal stress at chord splices wherever the splice is located while the diagonal load affects the X-direction normal stress proportional to the splice location. An approximate stress distribution model is developed using the net force at the chord splice and a smaller dispersion angle from the first rivet row of the chord member to develop an effective section. This approximate stress distribution model also employs the bending stress to account for the geometric asymmetry.

3. The XY Shear Stress Distribution at the Horizontal and Vertical Critical Sections

The XY shear stress distributions along the horizontal and vertical critical section were found to be approximated by a uniformly distributed stress within an effective shear length. The effective shear length on one-side of the gusset plate is the horizontal critical section bound by a line with a 30^o dispersion angle and a vertical line passing through the work point. Similarly, the XY shear stress at the vertical critical section is also calculated by the effective shear length, which is bound by a line of 30^o dispersion angle from the diagonal and a horizontal line passing through the work point

4. The Y-direction Normal Stress Distribution at the Horizontal Critical Section

The vertical components of diagonal loads generate triangular Y-direction normal stress distributions on the horizontal critical section where the vertex is aligned with the diagonal corner. The hanger load generates a trapezoidal stress distribution on the horizontal section symmetric to the centreline of the hanger. The effective length of the horizontal critical section is bound by lines with a 30^o dispersion angle from the first outer fastener of the each side diagonal, similar to the Whitmore's method.

5. Procedure to Combine Stresses

Once the normal and shear stresses on the critical sections are known, the equivalent stresses at points on these sections can be calculated. There are eight points with potential high stresses in a Warren type gusset plate connection and five such points for a Pratt-type connection. The maximum equivalent Von Mises stress then can be found by examining these potential high stress locations.

6. Calculations of the Maximum Von Mises Stress and Location

An example of calculating the equivalent Von Mises stress for high potential points is provided. The magnitude and the location of the maximum stress predicted by this method agree well with the FE results.

7. Conclusion

In this paper, a method to estimate the maximum elastic Von Mises stress by looking at potential high stress points in the gusset plate connection for steel truss bridges is presented, which is suitable for any type of gusset plate connection. This method is based on approximate stress distribution models at the critical sections in the connection. These approximate stress distribution models were verified reasonably estimating the stress distributions at critical sections.

Important findings of stress distributions include: 1) X-direction normal stress distribution at the chord splice is the net force between the chord and the linearly interpolated horizontal component of the diagonal loads. The approximate stress distribution model considers the eccentricity of the gusset plate geometry, 2) XY shear stress distribution can be estimated by using the effective shear length along the horizontal and vertical sections. The diagonal loads are found to generate the horizontal XY shear stresses independently at each horizontal section, and 3) the Y-direction normal stress distribution at the horizontal section can be estimated by the sum of Y-normal stress from each diagonals and hanger load at the horizontal section.

Example of Joint U10 gusset plate connections demonstrates the accuracy of the proposed method. The FE results were used to compare with the estimated results. The proposed method is not only able to accurately predict the maximum stress and location, but also has good agreement with individual stress distributions.