Dissertation Title: Development of a Simplified Methodology to Assess the Internal Redundancy of Bolted Built-Up Tie-Beams in Tied Arch Bridges

ABSTRACT

This research presents a comprehensive analytical framework for evaluating the residual strength and fatigue performance of mechanically-fastened built-up tie beams (TBs) in tied-arch bridges following localized fracture of single component. Although the AASHTO Guide Specifications for Internal Redundancy of Mechanically-Fastened Built-up Steel Members (IRM Guide Spec.) provide procedures for assessing faulted built-up members under pure axial or pure bending loads, they offer little to no guidance for components subjected to combined axial tension and bending. This limitation is critical for TBs in tied-arch bridges, which routinely experience both loading types in service. As a result, redundancy assessment and fracture evaluation for such members remain inadequately addressed.

To fill this gap, a detailed finite element (FE) study was conducted. The investigation began with the development of global bridge models incorporating both shallow and deep TBs. Simulated fractures in the bottom and side plates produced negligible changes in global forces and displacements. This outcome indicated effective internal force redistribution within the TB cross-section and justified the use of localized submodels for further evaluation.

Thirteen TB geometries identical to or similar to those used in real highway bridges were analyzed, separately for three corner connection types: horizontal tabs, vertical tabs, or angles. Each configuration was evaluated under both bottom and side plate fracture conditions. Strength was assessed through a new axial force vs moment interaction curve approach is developed in the research using nonlinear FEA. Next, a simplified approach that relies upon simple hand calculations was formulated based on fracture area percentage and geometric parameters. Fatigue analysis in the faulted state was also performed. This effort involved applying axial and bending loads separately, identifying the critical plate in each scenario, and estimating local amplified stress ranges at the critical location (holes) using FEA. Again, a simplified approach utilizing hand calculations for the fatigue evaluation in the faulted state was then developed.

To validate the proposed method, two additional TB geometries from two real in-service bridges were analyzed. These geometries were not part of the initial formulation process. The

simplified predictions showed strong agreement with detailed FEA results for both strength and fatigue, confirming the method's reliability and accuracy for these two bridges.

This work delivers a practical and efficient methodology to assess the internal redundancy and fatigue life of TBs under combined loading conditions. It addresses a key gap in current specifications and offers engineers a useful tool for inspection planning and maintenance of tied-arch bridges and will provide the needed code and commentary for consideration for inclusion in the IRM Guide Spec.