Joint Transportation Research Program

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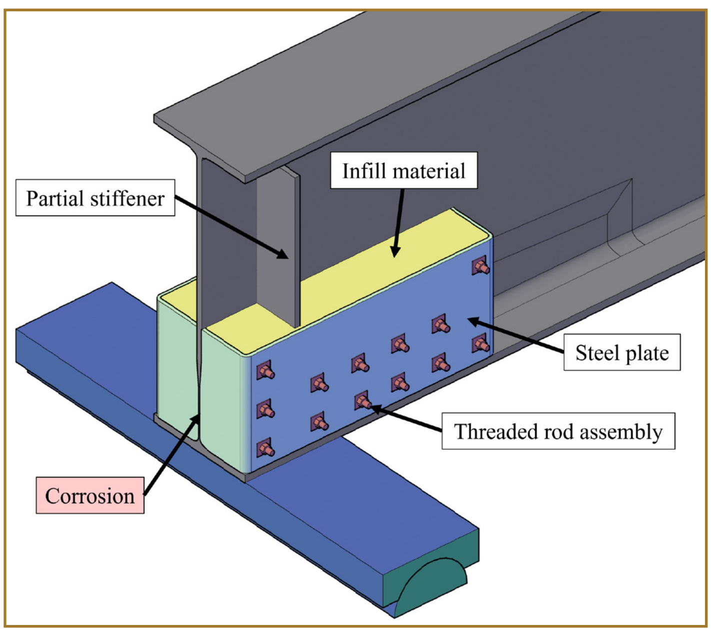
New Repair Strategies for Life-Cycle Extension of Corroded Steel Girder Bridges

Introduction

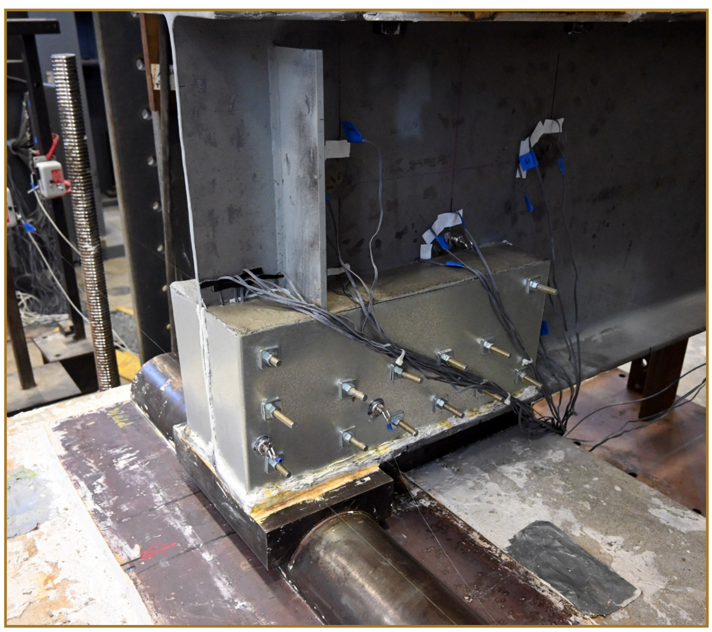
Steel girder ends are susceptible to corrosion damage due to deicing salts, water, and other contaminants that leak from failed expansion joints. When corrosion becomes significant, it leads to a reduction in the sectional properties of steel girders; thus, reducing bearing and shear resistance. Conventional repair methods, although effective, require substantial time and resources to complete, causing public inconvenience due to necessary traffic closures. Therefore, there is a need for practical, rapid, and robust repair methods suitable for implementation by local Department of Transportation (DOT) maintenance personnel.

In this study, five innovative repair methods were systematically evaluated through a selection process called the House of Quality Matrix. After the comprehensive evaluation and additional numerical simulations, the sandwich panel repair method was selected for further investigation. The core concept of the proposed sandwich panel repair method involves the encasement of the corroded region with a filler material reinforced by threaded rods. Two thin steel plates installed on both girder sides serve as stay-in-wplace formwork, expediting the installation process and eliminating the labor-intensive steps of jacking, welding, and formwork disassembly, making it more cost-effective and less time-consuming.

The structural performance of the repair method was evaluated experimentally by conducting seven



Concept of “Sandwich Panel” repair method.



Repaired specimen using “Sandwich Panel” repair method.

large-scale tests. Various test parameters were considered in the tests, including (1) threaded rod layout, (2) filler material, and (3) support condition. The test specimens were obtained from the corrosion-damaged steel girders of the North-Split Reconstruction Project in Indiana. The experimental results indicated that the method was effective in restoring the original design strength. A parametric study complemented the experimental evaluation by using the finite element models benchmarked with experimental results. Design guidelines and recommendations were developed based on the experimental and numerical results.

This study focused on achieving the following three objectives.

1. Developing innovative method(s) to repair corrosion-damaged steel girder bridges.
2. Verifying the structural robustness of the developed innovative repair method(s) through experimental testing and numerical simulations.
3. Preparing design guidelines and recommendations for the Indiana Department of Transportation (INDOT).

Findings

Seven large-scale experiments revealed complete recovery of the design bearing capacity and retained at least 85% of the design shear capacity in all repaired specimens, except for Specimen 3. Specimen 3 exhibited improved capacity and performance compared to the non-repaired girder, but it did not reach the design bearing capacity. This confirmed the effectiveness of the sandwich panel method for rehabilitating corroded steel bridge girders. Experimental data was utilized to validate the results of finite element simulations. Finite element models reasonably predicted the behavior of specimens, deviating from the experimental data by no more than 10% in terms of the maximum applied load. Additionally, the developed finite element models accurately captured the failure modes of web local crippling and threaded rod rupturing; therefore, they were used to conduct further parametric study.

A numerical parametric study comprised of three cases with over 30 finite element models was performed. The parametric study clarified the effects of three parameters: (1) the number of threaded rods used in repair, (2) their layout, and (3) material properties on the post-repair strength of the girder. Recommendations on the optimal threaded rod layout, location, and filler material selection were provided, acknowledging their impact on failure modes, load-carrying capacity, and cracking patterns. In addition, an equation to estimate the minimum required number of threaded rods was formulated and verified based on numerical and experimental studies that considered post-repair capacity, residual capacity of the corroded girder, and sectional and material properties of the threaded rod.

Implementation

The proposed novel repair method, known as the sandwich panel, demonstrated effectiveness for the rehabilitation of corroded steel girder bridges. The developed equations and recommendations offer comprehensive guidance for successful implementation in the field. Additionally, by incorporating this repair method, traffic closure can be either significantly reduced or eliminated. The sandwich panel repair method, by excluding labor-intensive steps of jacking, welding, and formwork disassembly, could be more cost-effective, competitive, and less time-consuming compared to traditional repair methods.

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