JOINT TRANSPORTATION RESEARCH PROGRAM

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SPR-3105 2013

Effects of Realistic Heat Straightening Repair on the Properties and Serviceability of Damaged Steel Beam Bridges

Introduction

Over-height trucks occasionally collide (impact) with steel highway bridges, causing structural damage to the steel beams. This permanent deformation can be repaired by heat straightening, which is a structurally efficient and cost-effective repair process. However, in the real field implementation of heat straightening, the repair process violated the limits and guidelines presented by various state highway agencies and the FHWA. These violations included, but were not limited to (a) underheating below 1200 °F and over restraining; (b) overheating above 1200 °F; and (c) multiple heat straightening of the same beam more than two times. Currently, there is a lack of knowledge of the effects of these imperfections in the heat straightening repair process on the condition and serviceability of the damaged-repaired beams.

The objectives of this research are to (a) determine and evaluate the realistic implementation of heat straightening repair (with imperfections) in Indiana using database analysis and in situ field measurements; (b) experimentally investigate the effects of realistic heat straightening (with imperfections such as overheating, overstraining, or multiple heat straightening) on the structural properties, fracture toughness, and serviceability performance of steel beam bridges; and (c) develop research-based guidelines and recommendations for damaged steel beam bridges subjected to realistic heat straightening with imperfections.

Findings

- Overheating (1400 °F) significantly reduced the required number of heating cycles to repair the damaged specimen when compared with normal heating (1200 °F).
- Multiple damage-repair cycles increased the number of heating cycles required to fully straighten the damaged specimen.
- Compared with the undamaged specimen, the Charpy impact toughness values of all specimens were decreased by heat straightening.
- A maximum heating temperature of 1400 °F may be an acceptable imperfection. In this research, overheating specimens (heated up to 1400 °F) and normal-heating specimens (heated up to 1200 ºF) showed similar test results. However, additional studies are required to support this recommendation.
- Three damage-repair cycles might be acceptable. The test results of this research indicated that the difference between three damage-repair specimens and single damage-repair specimens was not that significant. However, additional research will also be needed to validate this recommendation.
- An excessive restraining force over 0.5 Mp should not be combined with underheating (lower than 1000 °F).
- Service load deflections increased significantly after each damage process. However, the increased deflections reduced to undamaged deflections by the heat straightening repair.
- To avoid serviceability issues, unless the bridge traffic is closed, damaged girders should be repaired immediately.

Implementation

The research objectives were achieved by conducting the following tasks.

Task I—Evaluation of Heat Straightening in Indiana
Task I was focused on evaluating the realistic implementation of heat straightening in Indiana. The Indiana heat straightening repair site was visited to observe the realistic implementation of heat straightening in the field. Field measurements were performed to determine the damage location and magnitude, the restraining forces used in the repair process, and the maximum heating temperatures

achieved using the oxy-fuel torches. Heat straightening database analysis was performed to finalize the test matrix based on the Indiana Department of Transportation's real bridge repair data.

Task II—Small Scale Experimental Investigations

In Task II, experimental investigations were conducted to evaluate the effects of realistic heat straightening with imperfections on the small scale test. Prior to the real scale test (large scale test), small pieces of steel girders were fabricated and tested to explore the effects of various damage and repair parameters on realistic heat straightening repair.

The small scale test setup focused on the damage and repair of the bottom flange of steel beam girders. In total, six built-up section specimens were prepared and tested. A hydraulic actuator placed at the midpoint applied damaging and restraining force to the test specimen. After the damage, Vee heat was applied on a plastically deformed region to repair the damage with restraining force. This damage and repair behavior was simulated by taking beam specimens with comparable flanges and subjecting them to weak axis bending.

The material properties, including the structural properties, fracture toughness, and microstructure of the damaged-repaired specimens, were determined and evaluated experimentally.

Task III—Large Scale Experimental Investigations

The large scale experimental investigations focus on evaluating the effects of heat straightening on damaged and heat straightened steel beam bridges. Similarly to the small scale test, the test variables of the large scale test were also identified using the database analysis. Prior to the experimental investigations, finite element analysis of the large scale test was conducted to estimate the bridge behavior during the damage and repair process.

The test bridge is composed of two steel rolled beams and concrete slab deck. Two main girders were placed over six abutment blocks. All four beam spans in the test setup were subjected to damage and realistic heat straightening repair simulating field activities and conditions. The specimens were damaged at each midspan. After the damage, Vee heats were applied at the bottom flange of the girders to repair the damage. After the specimens were subjected to damage and heat straightening repair, the serviceability performance of the repaired bridge was determined by subjecting static loads simulating the AASHTO (2007) live loading. The material properties, including the structural properties, fracture toughness, and microstructure of the damaged and repaired steel beam specimens, were also determined and evaluated experimentally.

Task IV—Guidelines and Recommendations for Realistic Heat Straightening

Based on the findings and experimental results from previous tasks, heat straightening guidelines and recommendations were developed for steel beam bridges in Indiana.

Recommended Citation

Varma, A. H., and Y. Sohn. *Effects of Realistic Heat Straightening Repair on the Properties and Serviceability of Damaged Steel Beam Bridges*. Publication FHWA/IN/JTRP-2013/03. Joint Transportation Research Program, Indiana Department of Transportation and Purdue University, West Lafayette, Indiana, 2013. doi: 10.5703/1288284315184.

View the full text of this technical report here:
http://dx.doi.org/10.5703/1288284315184

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