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Evaluation and Repair of Wrought Iron and Steel Structures in Indiana

Introduction

Throughout the state of Indiana, there are numerous historical bridges that have been in service since the late 19th century and need to be either rehabilitated or replaced. Since the funds needed for replacement are often unattainable by the agencies owning these bridges, and the demolition of these historically significant bridges would be detrimental to preserving the history of the state, rehabilitation of these bridges is an option worth investigating.

Among the historical bridges existing in Indiana, many are older metal bridge structures comprised either partially or completely of wrought iron that need to be repaired or rehabilitated. Due to technological advances in material production during the late 19th century, the use of wrought iron diminished, along with a common knowledge of wrought iron material properties and behavior. When rehabilitating these bridges engineers often have a difficult time determining not only if the metal is wrought iron, but also what material properties to utilize when designing repairs. This makes the repair and rehabilitation process extremely difficult.

This research study involved three primary objectives: (1) collect information related to the performance and repair of wrought iron bridge structures, (2) initiate a database of sample material properties through data collection and experimental testing, and (3) develop suggested repair techniques for joints and members typical of wrought iron bridge construction.

Upon the completion of these objectives, the historical properties of wrought iron were more fully understood and some typical repair procedures for historical wrought iron bridge members were developed. The properties of wrought iron were determined both by collecting data from previous studies and by performing experimental testing with wrought iron materials from two different wrought iron bridges in Indiana. The repair procedures were also developed from experimental testing and analysis of literary research.

The scope of the research completed in this study consisted of a literature review / synthesis study, a survey of state Departments of Transportation and County Engineers, materials testing of historical wrought iron, analysis and evaluation of existing repair procedures and the development of repair recommendations.

Findings

In the literature review completed, an in-depth search of many databases was completed along with an in-depth search of collections in the Purdue University library system, and many other library systems. In this search, articles dealing with the repair and rehabilitation of specific bridges were located along with many articles dealing with the material properties and manufacturing processes of wrought iron. Also, many historic sources containing test data on wrought iron material properties were discovered and the data were recorded.

A survey was distributed to State Departments of Transportation, State Local Technical Assistance Programs, Indiana County Engineers, and other engineering consultants to determine the number of existing historic iron bridges in service in other locations and to collect any existing wrought iron repair procedures used by other agencies. The results from this survey did not lead to any existing wrought iron bridge member repair procedures, but it did lead to a better understanding of the need for more knowledge concerning the behavior of historic wrought iron.

Material and mechanical testing was completed on wrought iron bridge members from two existing bridges in Indiana. This testing included: micrographs, chemical analysis, hardness testing, tensile coupon testing, charpy impact testing, tensile testing of eyebar end connection, and some limited fatigue testing. The micrographs that were taken helped to develop a better understanding of the microstructure of the metal. The chemical analysis completed lead to a determination of particular elements that are commonly found in historic wrought iron. Hardness testing, tensile coupon testing, charpy impact testing, and fatigue testing helped to determine many common material properties. Eyebar end connection testing lead to a better understanding of the load distribution and force transfer behavior for one particular bridge member connection.

Testing was also performed on different types of repairs that might be typically utilized in the field. These repairs included: member straightening with heat, straightening without heat, welding to join two members, and filler welding to restore section loss from corrosion. This testing, along with articles found in the literature search, helped lead to the development of some procedures and suggestions that could be used to repair historic wrought iron bridge members.

Implementation

Upon completion of this research study, recommendations were developed to aid in the inspection and rehabilitation of existing historic truss bridges consisting of wrought iron tension members.

1. When inspecting an old, existing bridge it is important to know the type of materials for the bridge members. For bridges consisting of wrought iron members, it is helpful to determine the year and manufacturer of the bridge. A visual inspection of the surface of the material after it has been thoroughly cleaned can be used to aid in determining if the material is wrought iron. Chemical and mechanical testing are also desirable, if possible, to determine specific material properties.

2. Dynamic loading and previous repairs can cause members to move and the connections to develop an unsymmetrical loading. When this occurs, forces are not equally distributed through the connection, resulting in some members with an unsafe amount of load placed on them while others become loose and slack. If it is decided to rehabilitate a bridge and the connections are unsymmetrical, it would be beneficial to move the members and add spacers to the joint to hold them in place, and thereby ensure that force is equally distributed through each member in the future.

3. When inspecting a bridge it is important to check the condition of the pins and determine their load capacity. If the pins are severely corroded, deformed, and/or control the load capacity of the bridge, it is recommended that they be replaced with a stronger material.

4. Upon inspecting an existing historic wrought iron truss bridge, it is not uncommon to find severe corrosion near the joints of the bridge. The eyebars and diagonals should be checked thoroughly for section loss from corrosion. If severe section loss has occurred the engineer should consider either replacement or repair of the member. Repair of a corroded member could involve one of two procedures. One option is to grind the corroded areas to clean metal and then use a filler weld repair procedure similar to the one developed in this research project. The second option involves removing the corroded section entirely and welding on a new steel section using a full penetration groove weld.

5. Slack or elongated members are also prevalent in existing wrought iron truss bridges. It is important to shorten these members to ensure that load is being distributed evenly to all the members in the bridge. This should be done by removing the needed amount of material from the center of a wrought iron member and then joining the pieces together using either a bolted splice plate or a full penetration groove weld. Member shortening, however, may not be needed for members, such as zero-force members, that do not actively participate in the load path of the structure.

6. Vehicle collisions often result in the deformation, and even fracture, of the members in an existing wrought iron bridge. When

repairing a bent wrought iron tension member, is it essential to utilize heat to minimize the reduction in ductility and strength of the member. The member should be heated to a "cherry red hot" color and then straightened with judicious hammering while in that color/temperature state. Fractured members should probably be replaced altogether, due to a likely loss in ductility related to the fracture of the member. Reuse of fractured members by removal of damaged regions and splicing with new members is not recommended.

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