Timber Abutment Piling and Back Wall Rehabilitation and Repair

tech transfer summary

With such a large number of bridges requiring attention and available funds decreasing while maintenance costs are increasing, it becomes important to improve or identify the best currently-used maintenance methods for timber substructures.

Background

Based on previous National Bridge Inventory data, Iowa has nearly 20,000 bridges on low-volume roads (LVRs). Thus, these bridges are the responsibility of the Iowa county engineers. Of the bridges on Iowa county roads, 24 percent are structurally deficient and 5 percent are functionally obsolete.

A large number of the older bridges on the LVRs are built on timber piling with timber back walls. In many cases, as timber abutments and piers age, the piling and back wall planks deteriorate at a rate faster than the bridge superstructure. As a result, a large percentage of the structurally-deficient bridges on LVRs are classified as such because of the condition of the timber substructure elements.

Problem Statement

As funds for replacing bridges decline and construction costs increase, effective rehabilitation and strengthening techniques for extending the life of the timber substructures in bridges with structurally-sound superstructures has become even more important.

Several counties have implemented various techniques to strengthen/repair damaged piling; however, there is minimal data documenting the effectiveness of these techniques. There are numerous instances where cracked and failed pilings have been repaired. However, there are no experimental data on the effectiveness of the repairs or on the percentage of load transferred from the superstructure to the sound pile below.

One of the LVR bridge test sites for this project

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RESEARCH PROJECT TITLE
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The Bridge Engineering Center (BEC) is part of the Institute for Transportation (InTrans) at Iowa State University. The mission of the BEC is to conduct research on bridge technologies to help bridge designers/owners design, build, and maintain long-lasting bridges.

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Objectives

The objectives of this research were to complete the following:

- Review existing products for timber preservation and repair and to document their effectiveness in extending the service life of various bridge components
- Determine techniques used by county and other engineers to repair and restore the load-carrying capacity of piling damaged by deterioration and cracking
- Review methods used to repair failed piling
- Determine/develop effective methods for transferring bridge loads through the failed portion of the pile
- Determine that safe load capacity is restored by the repair methods (existing or new) determined to be structurally efficient

Methodology

To address the research needs, a review and evaluation of current maintenance and rehabilitation methods was completed. In addition, a nationwide survey about timber abutment repairs and rehabilitation was sent to federal, state, and local bridge owners across the nation to learn the methods used beyond Iowa.

Sample damage and decay at demonstration project

Field investigation and live-load testing of four bridges with certain Iowa methods was also completed. Following the field testing, details of new strengthening systems were developed with the purpose of creating or improving constructible and economical solutions to timber pile strengthening needs.

Finally, laboratory testing was completed for two of the solutions.

The first solution that was laboratory tested involved modifying the existing method of posting with a steel H-pile or the like allowing for vertical adjustment at the connection between the existing timber pile and new steel post; the connection detail proved to be a promising solution.

The second strengthening system entailed adding steel "sisters" to a decayed or damaged pile. Each sister was bolted to the pile opposite of each other and extended beyond the simulated section loss.

One variation of casts created from corrugated metal pipe (CMP) and concrete infill

One variation of new concrete sills and pile caps

In the end, the "sisters" only aided in the strengthening when failure in the remaining portion of the pile was imminent, although it is assumed that modification to the connection details would engage the sisters earlier in the loading process.

Key Findings

Timber utilization has and continues to warrant the pursuit of maintenance methodologies, given all Iowa-county survey respondents currently use either timber, formerly-used timber, or both. Likewise, nearly all non-Iowa county survey respondents and 75 percent of state/federal level respondents indicated that timber is or has been used in substructure elements.

Where timber piling is not used currently for new structures, the reasons given were the assumed longevity of other materials versus that of timber, durability concerns, lack of reliability, uneconomical, design practices exclude timber from use, and environmental concerns with preservative treatments.

Condition assessment should be conducted using a multitude of tools. These tools include visual assessment, probing and picking, moisture measurement, sounding, stress wave devices, drill resistance devices, core boring, and preservative retention analysis. Any single method may give an incomplete or inaccurate assessment of the given substructure element.

A multitude of preservative treatments exists. Most fall under the categories of oil-borne or water-borne preservatives. The preservatives can be applied pre-construction in the manufacturing plant or post-construction while in the field. Copper naphthenate is the preservative most commonly used among the respondents of the nationwide survey.

The longevity or service life of preservative-treated wood depends on a range of factors, including type of preservative, treatment quality, construction practices, type of exposure, and climate. The American Wood Preservation Association (AWPA) has developed standards for treatment and care of timber products to be used in bridge-like applications.

Maintenance activities depend entirely on the extent of deterioration present within the substructure element. Depending if the deterioration is minor, moderate, or severe, the maintenance activities will be either preventive, remedial, or major, respectively.

For each of the four Iowa bridges utilizing different methods of repair or strengthening that were subjected to live load testing, the repairs proved to be effective in that the desired stiffness was restored.

At the first of these bridges, corrugated metal pipe was used to create a form around the decayed or damaged portions of the pile, which was filled with concrete, thereby creating a cast and providing additional stiffness.

The near-term performance of this method appears to be adequate to maintain a functioning bridge. However, given this method of repair has not been observed over the long-term, conclusions regarding its indefinite performance cannot be made.

At the second bridge, supplemental piles were placed adjacent to each existing pile. Although seemingly a more expensive option, when installed correctly, this method effectively restores the bridge substructure system to its original condition. Theoretically, the original piles would not require additional maintenance procedures and could progressively lose bearing capacity without any adverse effects on overall bridge performance.

Instrumentation at one of the four bridge test sites

Instrumentation at steel post connection to existing pile

At the third bridge, a cast system similar to that used in the first bridge was used to stiffen the pier piles; whereas, at the abutment piles, timber planking was installed across the stream-side face of the piles and the created void between the planking and existing back wall was subsequently filled with concrete.

This method, at a minimum, provides much greater protection to the piles from debris flows. Even more, the piles are reinforced in the transverse direction and, as such, may have a greater bearing capacity.

At the fourth bridge, a posting method of repair was used. One pile had been partially removed and replaced with a steel section extending from the sound portion of the existing pile near the ground surface to the pile cap.

If installed correctly, with proper bearing achieved at the pile cap and existing pile, the method is quite adequate. However, only select piles in any one pile bent should be repaired using this method, as the lateral stiffness in the piles and, therefore, the bridge would be lost at the pile/post connection.

Timber sistered with steel was one of the two solutions that was laboratory tested

Recommendations

The researchers provide the following recommendations regarding the assessment, preservation, repair, and rehabilitation of timber substructure elements:

- Utilize multiple methods to more accurately assess the condition of timber substructure elements including any or all of those previously mentioned in this summary
- Make provisions for physically protecting timber structure elements from environmental conditions (e.g., precipitation), debris, and other damage-causing objects
- Adhere to the AWPA standards for the treatment and care of timber bridge elements
- Be cognizant of applying preservative treatments to cut or fastened portions of timber substructure elements to avoid point of entry for biological decay mechanisms
- When decay or damage is present, conduct maintenance activities at the earliest possible stage to avoid increased cost associated with maintenance postponement
- The addition of mild-steel reinforcement in the form of angles, channels, W shapes, or similar has the ability to provide increased load capacity to mildly- or moderately-decayed existing pile
- Field adjustability can be achieved with few minor and relatively inexpensive parts when completing the posting method of repair
- The current method of casting a single pile with corrugated steel pipe and concrete effectively restores the desired stiffness within the casted portion of the pile and this method has been used in numerous locations around the state

Implementation Benefits and Readiness

Most of the techniques evaluated exhibited their effectiveness by restoring the desired stiffness. The additional methods of repair and strengthening evaluated in the Iowa State University Structures Laboratory showed promise of improving techniques currently used in Iowa counties.