UNIVERSITY of HOUSTON

PROJECT SUMMARY

Texas Department of Transportation

0-6731: Repair Systems for Deteriorated Bridge Piles

Background

Thousands of bridges in Texas are supported on steel piles. Many of these bridges have been in service for 40 years or more. Prolonged exposure to water and repeated wetting and drying of these piles leads to severe corrosion that is localized in the splash zone, which is the portion of the pile that is just above and below the water surface. For piles that are founded in near small creeks or seasonal streams, this corrosion is typically localized within a few inches to a few feet above and below the ground surface. While the corrosion is localized, it can be severe, resulting in near total loss of the cross-sectional area of the structural steel member. This can severely compromise the capacity and structural integrity of the members, and the structure as a whole. Corrosion of these substructure elements can be addressed in several ways: load posting the structure, repairing the deteriorated member, or replacing the entire structure. Among these alternatives, developing an effective and economical repair system is often the most desirable solution.

The most commonly used techniques for repairing corroded steel piles underwater include building a coffer dam to dewater the area and welding steel plates to the existing pile, or casting a concrete jacket around the corroded region. Dewatering and field welding are costly and challenging operations and there are currently no rational, comprehensive design approaches for casting concrete repair jackets, although this technique is widely used. Additionally, quantifying the remaining capacity of corroded steel piles is challenging since current design specifications are not formulated for members with severe, localized section loss.

What the Researchers Did

The objectives of this research were to:

1) Quantify the remaining capacity of steel H-piles with severe but localized corrosion.

2) Identify a suitable technique to calculate the remaining capacity of a corroded steel H-pile using an approach that can be easily implemented in the design office with data that can be ready obtained from standard field inspections.

3) Evaluate the effectiveness of different repair techniques that can be implemented in the field, and without the need for dewatering.

4) Develop a rational approach to design the evaluated repair systems.

5) Conduct a life-cycle cost analysis (LCCA) of the evaluated repair systems.

The research included both experimental and numerical components. Thirteen small-scale steel piles and seven full-scale steel piles with various

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patterns of simulated corrosion were tested under axial load to quantify the effect section loss on the remaining capacity of the deteriorated members. Three different sets of design equations, the American Association of State and Highway Transportation Officials (AASHTO) design approach, the American Iron and Steel Institute (AISI) effective width method (EWM), and the AISI direct strength method (DSM), were utilized to predict the remaining capacity of the deteriorated piles. A numerical analysis framework was also developed using the commercial finite element analysis (FEA) package Abaqus to accurately predict the remaining capacity of the corroded piles.

What They Found

The results indicated that the remaining capacity of the tested piles with simulated corrosion was proportional to the remaining cross-sectional area at the most severely degraded section of the pile. The three sets of design equations that were considered accurately predicted the capacities of piles with moderate corrosion, less than 50 percent loss of cross-section. But, for more severely corroded members, the AASHTO method and the AISI DSM were overly conservative, while the AISI EWM provided the most accurate prediction of the remaining capacity while still being conservative.

Two different types of repair systems were evaluated in this study: grout-filled fiber reinforced polymer (FRP) jackets, and a friction-based clamped steel plate system. A total of 21 full-scale steel piles with different simulated corrosion patterns were repaired with the different repair systems and tested under axial compression to evaluate the effectiveness of the repairs. The test results indicated that, when properly designed, the proposed repair systems can effectively restore the capacities of the deteriorated piles to above the nominal capacity of the un-corroded piles. Simplified design approaches were developed to facilitate the design of the repair systems using hand calculations or widely available spreadsheet programs. Both types of repair systems were implemented in the field on a bridge in Texas to identify practical challenges associated with their installation.

A life-cycle cost analysis was conducted using the Federal Highway Administration's (FHWA) freely available RealCost LCCA software. Cost data were collected through a survey of regional and national repair contractors. The LCCA indicated that the grout-filled FRP jackets provided a lower life-cycle cost than a commercially available steel-based repair approach for different discount rates and expected service lives.

What This Means

This research demonstrates that both grouted FRP jackets and friction-based clamped steel plate repair systems are effective and economical systems for underwater repair of steel H-piles with severe but localized corrosion.

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