Evaluation of Galvanized and Painted Galvanized Steel Piling

tech transfer summary

September 2022

RESEARCH PROJECT TITLE
Evaluation of Galvanized and Painted Galvanized Steel Piling

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Iowa Highway Research Board
(IHRB Project TR-766)
Iowa Department of Transportation
(InTrans Project 18-678)

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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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The results of this research to date showed that a 100-yr pile service life can be achieved by galvanizing or galvanizing and painting steel H-piles. However, with consideration to initial pile cost, a more economical solution may be to increase the section size of the piles to allow for incremental section loss over time without compromising the required pile capacity.

Project Goal and Objectives

The primary objective of this research was to evaluate the effectiveness of galvanized and painted galvanized piles in extending bridge service life in a cost-effective manner. An economic evaluation was included to compare the use of a larger H-pile section, a galvanized coating, and a painted galvanized coating to protect the piles against corrosion.

Problem Statement

The rate at which steel corrodes is dependent on whether it is exposed to the atmosphere, soil, and/or water. While the corrosion rate of steel is predictable for atmospheric exposures, it is highly variable and difficult to predict for steel buried underground because of the high variability of soils.

Of main interest are galvanized piles and painted galvanized piles, which provide added protection. However, the information available to support the use of these coatings is limited. Thus, additional research was warranted.

Buchanan County Buffalo Creek Bridge with water levels low and high

Background

Corrosion is important to consider in the design, maintenance, and preservation of steel pile foundation systems. An inevitable phenomenon takes place when steel is exposed to the environment, as metals tend to return to their lower energy state.

Corrosion may result in a reduction of the pile cross-sectional area, leading to a loss of structural capacity and, in the worst case, possible failure.

Zinc and other coatings protect steel piles from corrosion by isolating the steel from its surrounding environment and by cathodic protection. The performance of zinc coatings is dependent on the thickness of the coating and factors influencing the environment to which the piles are exposed. For example, when considering atmospheric exposure, the zinc coating corrodes faster in industrial environments compared to rural and urban environments.

Concrete-encased steel piles are common for Iowa Department of Transportation (DOT) and Iowa county structures and have historically achieved acceptable performance. However, cases of early deterioration and pile corrosion have occurred.

As such, interest in using coatings to protect piles from atmospheric deterioration has grown. Of main interest are galvanized piles and painted galvanized piles, which provide added protection. However, the cost effectiveness and corrosion resistance performance of these coatings is basically unknown.

Research Description

A unique opportunity emerged with the Buffalo Creek Bridge in Buchanan County to monitor the performance of a galvanized pile system on a local bridge structure in Iowa.

The Buffalo Creek Bridge is a 200 ft by 40 ft three-span bridge that was under construction at the initiation of this project and available for in-service data acquisition. The performance of the galvanized piles could be evaluated based on the thickness change of the coatings.

This project began with a comprehensive literature search, which supplemented the knowledge and experience of the research team in working with substructure components.

The investigation was completed through observation of the painted galvanized piles installed in the field at the newly constructed bridge. Further investigation of the long-term protection of steel piles with galvanized and painted galvanized coatings was completed using a corrosion chamber to accelerate corrosion effects in the laboratory.

Pile specimens and coupon samples inside the cyclic corrosion chamber

Buffalo Creek Bridge galvanized and painted piles

In the laboratory, five variations of coupon samples—bare steel, galvanized, painted galvanized, painted galvanized with simulated paint layer damage, and galvanized with the galvanizing layer damaged—and four variations of one-foot pile specimens—bare steel, galvanized, painted galvanized, and painted galvanized with simulated paint layer damage—were tested using an accelerated corrosion testing protocol. This testing provided side-by-side performance data as well as valuable inputs for a life-cycle cost analysis.

The in-place performance of the bridge constructed using painted galvanized steel components was evaluated for its long-term corrosion resistance performance. The service life analysis was then performed to understand the costs and benefits associated with using substructure coatings, which is an important step in making the decision to implement the investigated coatings on a broader scale.

Key Findings

- Without protection, bare steel sees the most significant change in surface condition through the formation of iron-oxide. The thickness loss on each surface of the bare steel is about 0.00026 in/yr.
- Both galvanized and galvanized and painted coating methods perform well in protecting bare steel and in preventing corrosion. Both methods have the potential to protect piles from corrosion for more than 100 years, which is the U.S. highway bridge design life.
- Paint coatings initially offer additional protection, but eventual degradation of paint leaves the galvanized layer to provide the protection alone.
- The paint layer delayed the oxidation of the galvanized layer for at least a simulated 10-yr period. The painted galvanized coupons showed no appreciable change on the surface condition except for where the paint had been penetrated.
- Damaged galvanized layers offer better protection to smaller scratches (self-healing).
- The initial three-year period of service life of the Buffalo Creek Bridge in Buchanan County showed the paint and galvanized coating of the piles to perform well with no damage or corrosion observed.
- With respect to the Buffalo Creek Bridge, the most economical solution to maintain the required design capacity of the steel bridge piles for the expected 100-yr service life was to increase the section size of the piles to allow for section loss without compromising the required pile capacity.

Implementation Readiness and Benefits

One solution to achieve a 100-yr design life is to increase the section size of the pile to allow for section loss without compromising the required pile capacity While the cost to increase the pile size was determined to be less than the premium for galvanizing or galvanizing and painting the piles for the bridge in this study, a cost-benefit evaluation for each protection measure is suggested knowing that costs can vary widely depending on specific project requirements, location, market prices, etc.

When an HP 10×57 pile was required for the design capacity in this study, an HP 12×74 could be used with an extra cost of about 30%. However, in the same situation, if the galvanizing method or painting (and galvanizing) methods were used, these methods would induce a cost increment of 82% to 136%.

It should be noted that this example was conducted using an HP 10×57 with an HP 12×74 as an alternative, and the costs were based on the market prices of steel at the time of bridge construction. The result may change when a larger pile section is required for the design capacity.

Furthermore, the price of the galvanized and paint coatings used in this example reflect the prices for one project using uncommon methods. It is possible that increased use of duplex methods on H-piles could reduce the overall costs borne by other projects due to the economy of scale. Hence, it is recommended that a cost-benefit calculation be performed prior to the selection of pile protection measures.

This was an interim report, and the research team plans to continue to collect additional annual data from the Buffalo Creek Bridge in Buchanan County for future analysis.