JOINT TRANSPORTATION RESEARCH PROGRAM

Principal Investigator: Mark D. Bowman, Purdue University, bowmanmd@purdue.edu, 765.494.2220

Program Office: jtrp@purdue.edu, 765.494.6508, www.purdue.edu/jtrp

Sponsor: Indiana Department of Transportation, 765.463.1521

SPR-4121 2018

Pack Rust Identification and Mitigation Strategies for Steel Bridges

Introduction

Corrosion is a major problem in the infrastructure industry, costing millions of dollars every year for maintenance, repair, or replacement. By improving the coating systems and frequency of application, surface corrosion can be effectively controlled. However, very few studies have been conducted to study the influence of pack rust (crevice corrosion) on steel bridges.

When steel elements of a member are unprotected and in contact with another metal, or even non-metal, the steel usually begins to corrode, and rust (iron oxide) starts to develop, or pack in, between the surfaces. Pack rust is not visible until rust product starts deforming the adjoining members and elements. It can cause overstressing of bolts and rivets, and unchecked rust growth may result in bolt and rivet failure. This will reduce the effective capacity of the connection, or might even cause its failure. The Mianus River bridge collapse is an example of the failure of a connection due in part to pack rust formation.

The average age of the existing steel bridges in Indiana is currently about 50 years, and with the continued aging of the bridge infrastructure, the problem of pack rust is most likely going to increase without proactive intervention. In 2012 INDOT included stripe coating in its painting specifications to mitigate pack rust in new structures. But because this adoption is relatively recent, stripe coating for pack rust mitigation is still in question. This study collected quantitative data on the occurrence of pack rust on steel bridges in the state of Indiana and reviewed mitigation strategies used by other DOTs.

Findings

- Pack rust was found to occur frequently in Indiana. About one-third of the state-owned steel bridges exhibit some form of pack rust. The member element most commonly affected (in terms of numbers) is rocker bearings: 318 of 982 bridges showed evidence of pack rust in the rocker bearings. The second member element to frequently exhibit pack rust is a bolted or riveted splice connection: 214 of 1611 bridges were observed to have developed pack rust in a beam or girder splice connection. The members with the highest percentage of pack rust occurrence are gusset plates and hinge-pin connections: pack rust occurred in both of these components in more than 90% of the bridges with such details. End diaphragms, cross bracings, and beam cover plates were also found to be susceptible; however, the frequency of pack rust occurrence in these members is less than 10%.
- The percentage of observed pack rust occurrence for each district was tabulated. Occurrence in the Greenfield and LaPorte Districts is the least among the six districts in Indiana. The LaPorte District, which experiences the highest amount of annual snowfall and also has the highest salt and brine usage in the state, has a pack rust occurrence of 24%, which is less than half of that observed in the Fort Wayne District. There are multiple possible reasons for this observation. One factor that may play a large role is that the LaPorte maintenance crews annually wash the decks and bearings of every bridge using water jets to remove dirt, debris, and salts.
- The occurrence of pack rust in girder and beam splices of bridges that intersect a water body is higher than that of bridges that intersect roads and railroads. The percentage of bridges with pack rust in the splice of exterior beams is higher than that of bridges with pack rust in the splices of interior beams. The study found that it takes 12 years on average after painting a bridge (i.e., re-coating) for crevice corrosion to start in the gap between the members and the splice plates to exhibit visible rust bleeding from the splices. The use of spot painting or recoating at a frequency of less than 12 years may help to minimize pack rust formation. From

the point of initiation, it would then take an additional 20 years to reach a very severe pack rust condition.

- With the help of images present in inspection reports, it was observed that the edge distance and the initial pretension in the bolts play a major role in preventing pack rust in splice connections and other connections.
- Stripe coating as a pack rust mitigating strategy is the most popular technique utilized, with 24 state DOTs recommending it in their painting specifications. Thirteen states recommended caulking and 8 states recommended the use of penetrating sealers. Oregon is the only state DOT that outlined a method to repair members affected by pack rust.
- Experimental studies showed that stripe coated connections with the bottom crevice un-caulked experienced the least amount of corrosion and minimum pit depth for new structures. A second series of specimens involved plates that were corroded, cleaned, assembled, and then stripe coated and caulked: caulk placed on all sides was found to produce the best results.

Implementation

- The use of small edge distances with properly tightened high-strength bolts will keep material in firm contact and minimize crevice openings. The use of bolt stagger in new splice connections should be avoided.
- Current INDOT provisions for stripe coating of new structures should be retained. Further study should be done to investigate the effectiveness of stripe coating and the need to modify the number of stripe coats utilized.
- Pack rust formation can be minimized in splice plate details where no pack rust has been detected if the connection region is cleaned and a stripe coat is applied along the crevice at a frequency of no more than 12 years. The opening between the flanges can be sealed with a suitable filler material to prevent moisture entry. If rust bleeding is observed in splice connections, use of an alkaline penetrating sealer appears to be the best option.
- If caulk is used to seal crevices, rust, debris, and salts should be removed and the surfaces cleaned before caulking the crevice. Otherwise they should not be caulked. Caulking an active crevice corrosion cell will likely accelerate the corrosion process.
- Penetrating sealers that are alkaline and have the appropriate viscosity to penetrate into crevices show promising results in mitigating pack rust. The crevice should be cleaned by mechanical tools or high-pressure water jets before applying penetrating sealers. Further study of these sealers should be considered to establish whether they should be used regularly in Indiana.
- Pressurized water jet washing appears to be an effective maintenance practice that reduces the chances of pack rust occurrence in bearings.

Recommended Citation for Report

Patel, C. H., & Bowman, M. D. (2018). Pack rust identification and mitigation strategies for steel bridges (Joint Transportation Research Program Publication No. FHWA/IN/JTRP-2018/16). West Lafayette, IN: Purdue University. https://doi.org/10.5703/1288284316788

View the full text of this technical report here: https://doi.org/10.5703/1288284316788

Published reports of the Joint Transportation Research Program are available at http://docs.lib.purdue.edu/jtrp/.