



I-43 Leo Frigo Memorial Bridge Investigation Report

EXECUTIVE SUMMARY

Background: This report presents the findings from the investigation, under State of Emergency Executive Order #14, to repair the I-43 Leo Frigo Memorial Bridge (Structure B-5-158), as well as to mitigate potential damage caused by a sag in the bridge deck in and about Pier 22. The sag was the result of approximately 2 feet of vertical displacement at Pier 22 that is believed to have occurred between approximately 3:00 and 3:45 AM on Wednesday, September 25, 2013, after which the bridge was closed to traffic.

2013 Investigation – Entire Bridge: A site reconnaissance was performed by the Wisconsin Department of Transportation (WisDOT) on Thursday, September 26, 2013 and then by WisDOT, Federal Highway Administration (FHWA), Michael Baker Jr., Inc. (Michael Baker), and Wiss, Janney, Elstner Associates, Inc. (WJE) on Friday, September 27. A bridge inspection of the underside of the superstructure between Piers 18 and 25 was performed and no visible damage was detected on the superstructure members. A subsurface exploration then commenced on Saturday, September 28, 2013 wherein representative sections of steel piles that support the piers were exposed and test borings were drilled. Test pits were excavated at 20 out of the 51 piers. Laboratory tests were then performed on soil and water samples to determine foundation conditions, and robotic survey instruments were installed to monitor for any additional pier displacement. These investigations determined that severe corrosion of the steel piles in the foundation that support Pier 22 was the reason for the vertical displacement. Recommendations were then developed to return the bridge to service by installing temporary shoring towers and new, supplemental permanent foundation elements.

Analysis: Based on the results of the investigation, the bridge piers were grouped into three different tiers. Tier 1 piers are locations where immediate repairs were necessary in order to return the bridge to service. These locations are characterized by severe pile corrosion that significantly reduced the structural capacity of the bridge foundation. The soils around Tier 1 piers contain a highly corrosive combination of industrial porous fly ash, high concentrations of chlorides, high sulfate concentrations, low soil resistivity, and microbial activity. The water table was typically below the bottom of the Tier 1 pier footings.

Tier 2 piers are locations where much lower levels of pile corrosion damage were observed and the soils exhibit characteristics that are potentially corrosive, but much less severe than Tier 1 locations. Tier 2 locations do not include large amounts of industrial fly ash, but do have some combination of organic material, high levels of chlorides, sulfates, or microbes; or low soil resistivity values. None of the Tier 2 locations represent an immediate safety concern. However, the locations do warrant further monitoring to determine if there is potential for long-term corrosion.



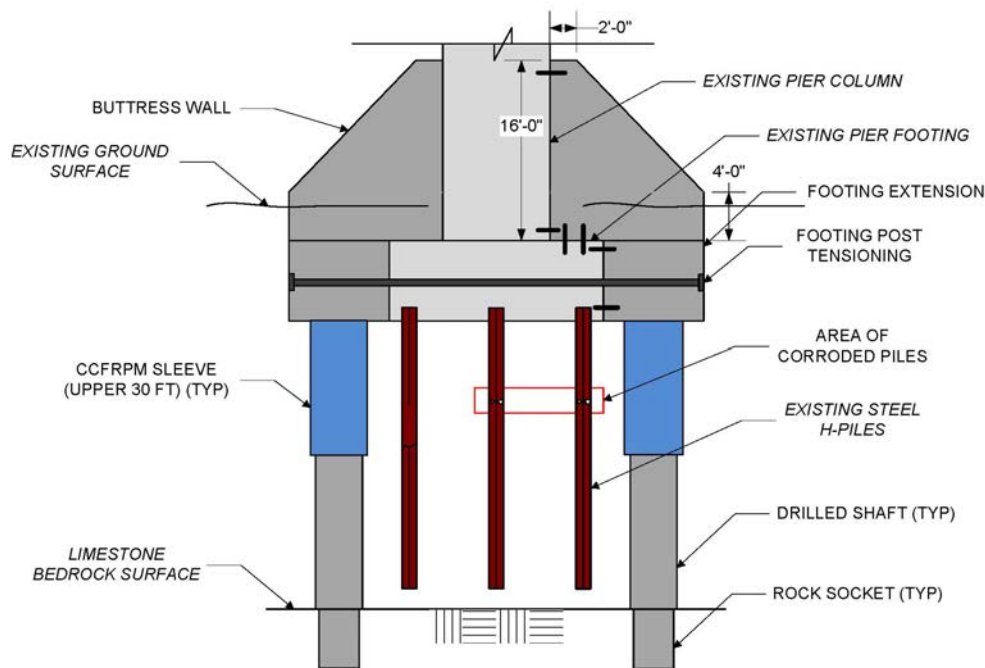
Tier 3 piers are locations where the potential for severe pile corrosion is very low. Visual inspection of exposed piles at Tier 3 locations indicated pile conditions typical for a 32+ year old bridge in normal soils. Consequently, no further investigation is warranted.

Cause of Vertical Displacement at Pier 22:

The investigation determined that several factors contributed to a highly unusual environment that caused the severe corrosion of the steel pile foundation supporting Pier 22. A corrosive environment was created by the presence of a moist, porous fly ash fill with high levels of chlorides and sulfides combined with a low resistivity. A dense clay layer was present below the porous fly ash, leading to differential oxygen concentration and differential chemical concentrations within the fill layers. Bacteria were found at many of the piers and it is likely that microbiologically influenced corrosion also played a role in the corrosion at Pier 22. An aggressive corrosion mechanism of differential oxygen concentration corrosion in the form of Accelerated Low Water Corrosion (ALWC) is likely responsible for the deterioration in the localized failure zone at Pier 22.

These site conditions led to rapid corrosion of sections of the steel piles. Once sufficient material and support were lost from enough piles, the remaining piling became unstable. Visual examination of selected Pier 22 piles indicated that the most common, perhaps only, mode of pile instability was crushing/buckling of the most heavily deteriorated sections of pile. Severe deterioration and crushing/buckling was observed on all piles that were exposed.

Tier 1 Pier Repairs: Visual inspection and soil borings confirmed the presence of fly ash surrounding severely corroded steel piles at Piers 21, 22, 23 and 25. While the piles observed at Pier 24 were substantially less corroded, Pier 24 was conservatively treated similar to Piers 21, 22, 23 and 25 based on its proximity to those critically corroded pier locations. Therefore, repairs were performed at Piers 21 through 25 prior to returning the bridge to service. Tier 1 repairs included installation of new concrete drilled shaft foundations, which are capable of supporting the entire pier design load. These new foundations were then connected to the existing piers and provided corrosion protection measures designed to offer 75 years of service life.



Schematic of Tier 1 Repair

Tier 2 Pier Monitoring: Numerous steel piles at pier locations outside the Tier 1 repair area contained localized areas of corrosion pitting and minor section loss. Seventeen of these piers were included in the Tier 2 category.



Typical Tier 2 Corrosion

In order to estimate the future corrosion rates to determine the remaining service life of the Tier 2 steel piles, monitoring probes and steel coupons (pile sample sections) were installed in 2014 adjacent to Piers 6, 13, 19, 32, 39, 44 and 50. Data will be collected from the probes during typical bi-annual bridge maintenance inspections performed by WisDOT. The probe data will be supplemented by section loss measurements conducted on the pile coupons. If the

measured corrosion rates from the probes turn out to be greater than the estimated

rate, the Department will have multiple treatment options available to reduce the corrosion rate and extend the service life of the bridge.

In addition to the work described above at the Tier 2 piers, monitoring probes were also installed at Pier 22. The information collected at this location can be compared with the data across the rest of the project site and provide information on what is anticipated to be the upper range of corrosion activity present at the site.

Summary: In response to the bridge sag on Wednesday, September 25, 2013, an in-depth investigation of the bridge was performed. Emergency pier repairs were completed on the bridge at five locations in January 2014. These repairs provided corrosion protection measures that will offer 75 years of service life. Future monitoring of additional Tier 2 piers at the site will continue to ensure the safety of the bridge. As a result of the investigation, repairs, and future monitoring, the public should have confidence that the bridge is safe for their continued use well into the future.



Tier 2 Overview