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Great Lakes Accelerated Freshwater Harbor Corrosion

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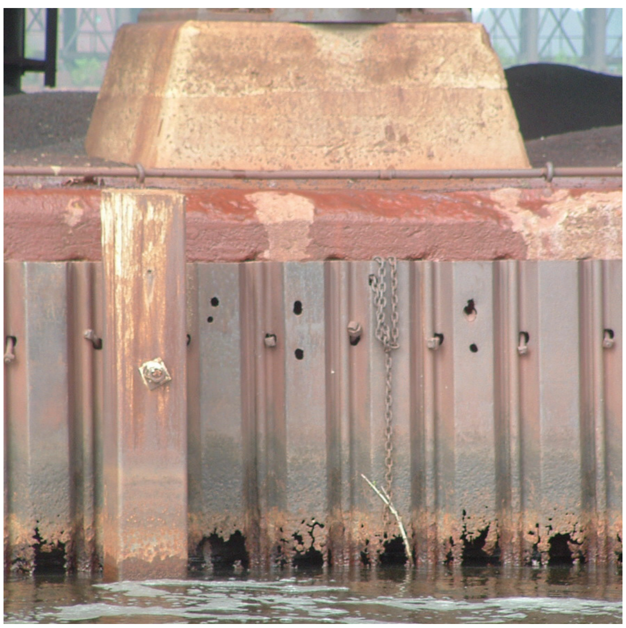
The Problem

Steel sheet piling corrosion issues have been observed at several Great Lakes harbors and marinas, the Duluth-Superior Harbor and other locations in Lake Superior, including Two Harbors, Minn.; Ontonagon and Houghton, Mich.; Ashland and Bayfield, Wis.; and Thunder Bay, Ontario. The most severe corrosion in the Great Lakes tends to be observed in Lake Superior facilities, but only the Duluth-Superior Harbor has been studied by researchers and inspected by divers. Photos of some of these locations have been posted to the project website at go.wisc.edu/9mzpy0.

The sheet piling is corroding at a highly accelerated rate. This rate of corrosion is similar to that commonly observed in saltwater ports but not seen in freshwater environments. Based on observations of both older and new sheet pile installations, the increased rate of corrosion in the Duluth-Superior Harbor appears to have begun in the late 1970s.

Quick Read

- Steel is corroding at an accelerated rate in the Duluth-Superior Harbor and elsewhere in Lake Superior.
- Experts and researchers have been investigating the issue since 2004.
- Microbes that oxidize iron have been found as one of the causes. They create conditions where copper deposits on the metal and corrodes after ice scours the pilings each winter.
- Several protective coatings for steel have been tested in the Duluth-Superior Harbor and found effective.



Widespread corrosion at Hancock, Michigan, (above) and Canadian National docks, Duluth, Minnesota (below)

More than 14 miles of steel sheet piling and structures are corroding around the Duluth-Superior Harbor, and if the problem isn't addressed, the structural integrity of docks and loading facilities could be compromised and the failing steel would have to eventually be replaced at a cost of $1,500 or more per lineal foot. The Duluth Seaway Port Authority estimates there could be $120 million of repairs needed in the harbor.

Underwater inspections have revealed the corrosion is widespread throughout the Duluth-Superior Harbor on all types of steel piling. Most of the steel is covered with small pits, scooped out in diameters of ¼ to 1 inch, primarily in the first 3 to 6 feet below the waterline and tapering off around 10 feet. For most structures there is only minor or insignificant corrosion loss deeper than 10 feet, all the way down to the mud line. Some of the steel dock structures have holes as large as 6 to 12 inches or more, and several of these structures have already been or are in the process of being repaired or replaced.

There is light marine growth evident within the pits with zebra mussels tending to cover the steel below 10 feet. However, the maturity of the corrosion indicates that its initiation predates the zebra mussel infestation, which began in 1998.

Experts Investigate

To provide a systematic focus for research and mitigation, a steering committee was formed by the Wisconsin and Minnesota Sea Grant programs, the Duluth Seaway Port Authority, the U.S. Army Corps of Engineers, and the University of Minnesota Duluth and its Natural Resources Research Institute. The committee recommended the corrosion problem be reviewed by an independent expert group. In September 2004, a panel of five experts in corrosion, microbiology and chemistry visited the harbor to examine the corrosion. The panel noted that definitive conclusions about the causes and appropriate actions to mitigate the corrosion would require data gathered through formal measurement, testing and engineering analysis. The experts listed the most likely causes of the corrosion and made study recommendations. Possible causes included water chemistry changes, microorganisms, stray electrical current from a high-voltage power line and changes in harbor use.

Short-Term Pre-Project Funding Studies

Prior to allocation of project funding, two short-term investigations were completed. The first was a coating test to observe a few of the commercial products available for protecting steel sheet pile structures from corrosion. The coatings had been in place for almost five years and then were removed in fall 2006. Some appeared to work, while others did not.

The second investigation involved visual inspection of the chains and harbor channel marker buoy anchors

Pile test protection methods

placed and removed by the U.S. Coast Guard each year throughout the harbor. These were visually inspected for evidence of pitting and corrosion as they were removed in early winter 2005. Observations of the anchor chains indicate a gradual lessening of corrosion as one moves upstream from the lower harbor basin. This trend is consistent with the general observations of more severe corrosion in the lower harbor structures than those that are farther upstream.

Formal Studies

Multiple sources of study funding were pursued. Initial project funding began in 2005 when the state of Minnesota appropriated $100,000 and the U.S. Army Corps of Engineers approved $300,000 for studies to determine causes of the corrosion. Additionally, the University of Minnesota Center for Urban and Regional Affairs and Minnesota Sea Grant began supporting research into specific biological influences that may be contributing to corrosion. Other cooperators and funders since then have included the Wisconsin Coastal Management Program, the Federal Water Resources Development Act, Wisconsin Sea Grant, the state of Wisconsin, the city of Superior, the Great Lakes Maritime Research Institute, AMI Consulting Engineers and the Duluth Seaway Port Authority.

A timeline of early studies and their findings are available on the project website: seagrant.wisc.edu/corrosion.

Results

Conclusions in 2013 from several studies by the University of Minnesota Duluth and the Naval Research Laboratory established microorganisms as the first culprit behind the corrosion. One or more unique microbiologically influenced corrosion processes are occurring in the harbor. Through DNA analysis, researchers have pinpointed the process by which several species of native iron-oxidizing bacteria attach to carbon steel, creating an orange "rounded projection" of biomass. Conditions beneath those projections, known as tubercles, cause copper dissolved in harbor water to precipitate and adhere to the iron. When ice chunks scrape against the pilings each winter, the tubercles break, exposing the copper-covered iron to oxygen. This causes the steel in those pitted areas to corrode at a faster rate.

Why the corrosion is happening at a faster rate now than in the past is still in question, but some researchers suspect that cleaner water conditions after the Clean Water Act was passed in the 1970s might have provided an environment for the bacteria to thrive.

Several protective coatings for new steel have been tested on steel samples placed at a number of sites throughout the harbor. Positive results to-date were found for these coatings for new steel:

ACOTEC – Humidor ML Coating

Chevron Phillips – TZ-904 Coating

Marine Coatings, LLC – Aquapure HR Coating

Wasser – Moisture Cure Urethane

Sherwin Williams – Fast Clad ER Coating

Standard Coal Tar Epoxy – Two types were tested

Vinyl System – VZ-108

The cost of the coatings ranges from $7-12 per square foot of coating area.

Steel H-pile corroded completely through (left) and Murphy oil dock (right)

Other coatings were tested on existing, corroded steel. Each coating was evaluated for ease of installation (often applied with the use of a specially made cofferdam), cost, corrosion prevention, ability to resist ice abrasion and bonding adhesion to the base metal. Positive results to-date were found for these coatings on existing steel:

ACOTEC – Humidor ML Coating
Ceilcoate – Enerzone 954 Coating
Marine Coatings, LLC – Aquapure HR Coating
Versaflex – FSS50DM
Thiokol – LPE 5100

The cost of the coatings ranges from $40-50 per square foot of coating area.

Fiberglass jackets used for corroding steel H-pilings and polyethylene or coated steel panels installed on existing steel structures have also proven effective. More information can be found on the project website.

Cathodic protection was also studied, since it is a common solution for saltwater conditions. The studies found that the amount of anodes needed for protection was much greater than the amount used in salt water, making them cost prohibitive.

Additional Information:

seagrant.wisc.edu/corrosion

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