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THIS MONTH: CORROSION IN MARINE ENVIRONMENTS

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Coating Performance in Duluth Superior Harbor—Part 1

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Nine coatings were evaluated for corrosion protection of carbon steel coupons and I-beams around Duluth Superior Harbor after 46 and 35 months, respectively. Coupons were intentionally scribed to metal before exposure. Part 1 of this article describes the coatings used and the locations of coupons and I-beams. Part 2, to be published in the October 2012 issue of MP, will discuss the results of the evaluation.

Sixteen miles (26 km) of carbon steel (CS) sheet piling (12-mm thick A328¹ cold rolled; used for docks, bridges, and bulkheads in the Duluth Superior Harbor (DSH) in Minnesota and Wisconsin are corroding at an accelerated rate of 3 mm/y or higher. Piling 30 years old or older are riddled with through-wall pitting (Figures 1[a] and [b]).

The corroded pilings have an orange, rusty appearance characterized by tubercles (i.e., corrosion products and deposits covering areas of localized corrosion [Figures 2(a) and (b)]).

Divers reported that tubercles were randomly distributed from the waterline to ~3 m below the surface. Tubercles varied in diameter from a few millimeters to several centimeters and when removed, large and often deep pits were exposed. Divers also reported that the attached zebra mussel (*Dreissena polymorpha*) population was dense and few tubercles were observed below 3 m. Zebra mussels are small, fingernail-sized mussels native to the Caspian Sea. They were first observed in Lake St. Clair, Minnesota in 1988 and have since spread to all of the Great Lakes.

DSH, located at the extreme western end of Lake Superior, is a fresh water harbor with mg/l concentrations of sulfate (SO_4^{2-}). DSH is polymictic (i.e., seiches or free-standing wave oscillations are almost always present, suspending particulates into the water column). DSH is icebound from mid-December to mid-April and during that time has a durable, well-defined ice cover. DSH experiences freeze ice thicknesses that range from 0.5 to 1.4 m, as well as snow ice, stack ice, and ice from wave and splash action along harbor walls.

Ray, et al.² reported that a combination of biological, chemical, and physical events contributed to the corrosion of CS pilings in DSH. Dense deposits of iron-



FIGURE 1
 Corrosion of pilings in DSH. Photos courtesy of Gene Clark, Wisconsin Sea Grant Program.

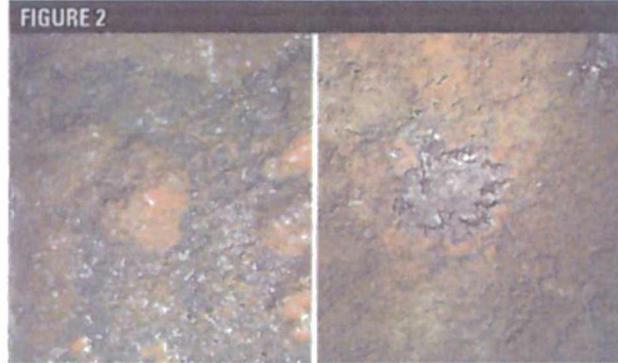
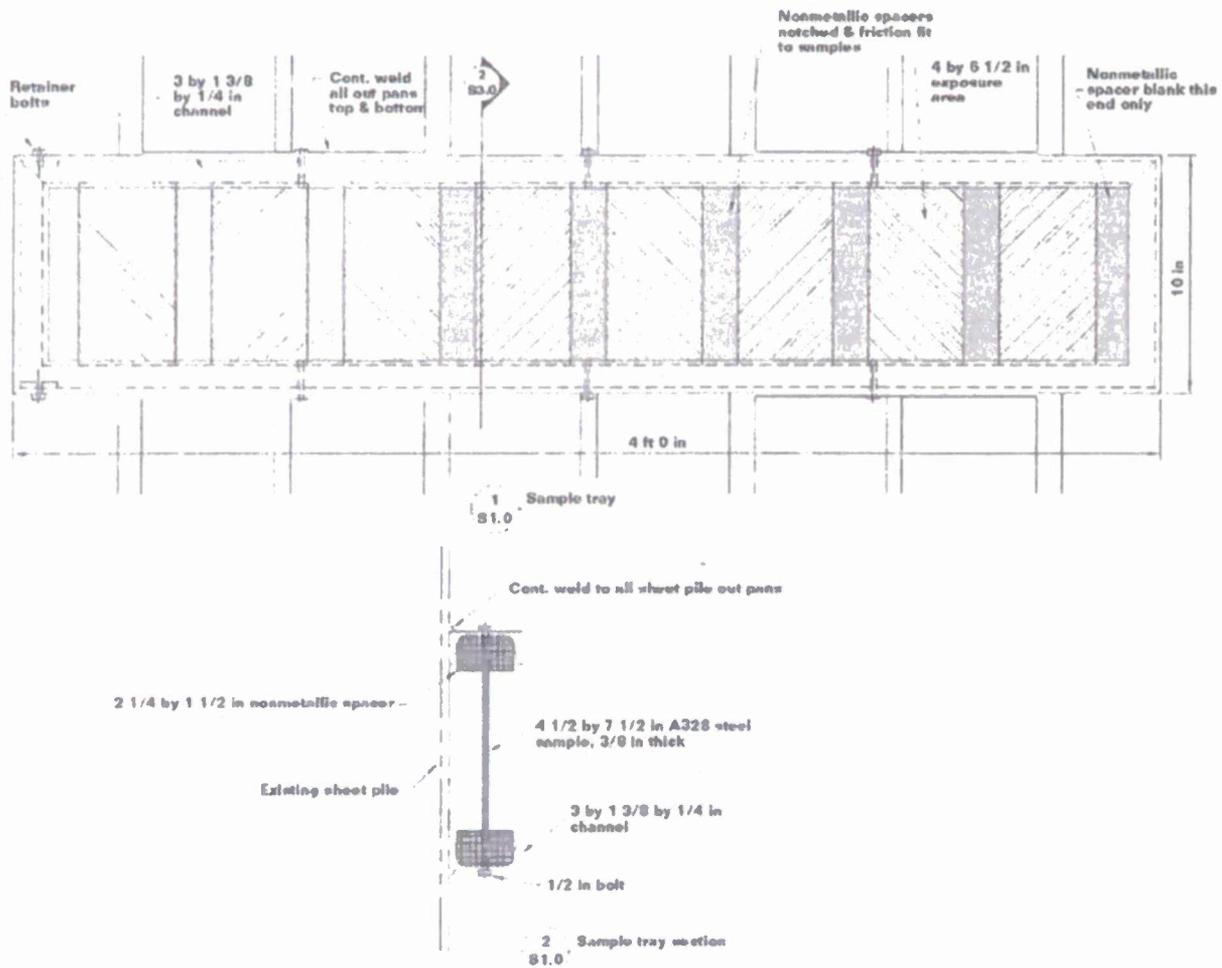


FIGURE 2
 (a) Wet corrosion tubercles and (b) dry corrosion tubercles on pilings in DSH.

FIGURE 3



CS coupons in a sample tray at DSH.



DSH sample locations, CGB-1, CGC-1 (coupons), and the Duluth Seaway Port Authority Facility (I-beams).

TABLE 1
Coupon coating descriptions

Tray Number: 5 Location: CGB-1			
Slot	Sample Designation	Product	Product Chemistry
1	CGB-1-01	Bare steel	
2	CGB-1-02	Bare steel	
3	CGB-1-03	Bare steel	
4	CGB-1-04	Bare steel	
5	CGB-1-05	1	White two-part solvent-free polyamine epoxy
6	CGB-1-06	6	White epoxy amine (one coat)
7	CGB-1-07	7	Black glass flake reinforced epoxy
8	CGB-1-08	4	Green two-part polyamine epoxy
Tray Number: 6 Location: CGC-1			
Slot	Sample Designation	Product	Product Chemistry
1	CGC-1-01	Bare steel	
2	CGC-1-02	Bare steel	
3	CGC-1-03	Bare steel	
4	CGC-1-04	Bare steel	
5	CGC-1-05	4	Green two-part polyamine epoxy Red urethane micaceous iron oxides/refined coal tar
6	CGC-1-06	5	Blue/grey zinc primer/vinyl copolymers
7	CGC-1-07	9	White two-part solvent-free polyamine epoxy
8	CGC-1-08	1	

oxidizing bacteria produced tubercles, creating conditions for Cu precipitation on CS surfaces. Ice scoring disrupted the tubercles and exposed localized areas of Cu-covered CS to oxygen (O₂). The resulting galvanic cell produced aggressive localized corrosion. Barrier coatings provide one option for protection of extensive structures in fresh water. Al Breichman (retired), former director of the Paint Technology Center at the U.S. Construction Engineering Research Laboratory (CERL) (Champaign, Illinois), selected the following coatings for this evaluation (hereafter referred to by their corresponding numbers):

- 1 Aquapure HR[†]
- 2 Chevron Phillips 179043[†]
- 3 Coal tar epoxy
- 4 Humidur MI[†]
- 6 Wasser MC-zinc/MC-tar
- 6 Sherwin-Williams Fast clad ER[†]
- 7 Sherwin-Williams Sher glass epoxy[†]
- 8 Standard epoxy
- 9 Zinc-rich primer VZ108/V766

Methods and Materials

Divers from AMI Consulting Engineers (Superior, Wisconsin) installed trays for coupons and I-beams. Eight sample trays containing eight 4.5 by 7.5 by 1.2-in (114 by 190 by 30-mm) thick A328 steel sample coupons per tray (Figure 3) were prepared.

Each sample tray contained four coated and four uncoated steel coupons. A report³ prepared for the U.S. Army Corps of Engineers provides details about tray and coupon installation. Trays and coupons were installed on November 7, 8, and 13, 2007. Coupons were retrieved from two locations, U.S. Coast Guard Cell B (CGB-1) and U.S. Coast Guard Cell C (CGC-1) (Figure 4), in September 20, 2011. Table 1 presents coupon coating descriptions.

Trays designed to contain I-beams, 6 by 7 1/4 by 36 in (152 by 184 by 914 mm), were prepared (Figure 5) and installed at the Duluth Seaway Port Au-

[†]Trade name.

thority Facility (Figure 4) in September 2008. Table 2 provides I-beam coatings descriptions.

I-beams were retrieved from the original location at the Duluth Seaway Port Authority Facility in late August 2010 and submerged in plastic barrels for outside storage through one more winter. They were sent to the U.S. Naval Research Laboratory at Stennis Space Center (Mississippi) in October 2011.

Summary

A combination of biological, chemical, and physical events have contributed to accelerated corrosion of 15 miles of CS sheet piling in DSH. A series of coatings were tested on CS coupons and I-beams to evaluate their effectiveness in preventing the localized corrosion. Part 2 of this article, to be published in October 2012 *MP*, will detail the results of the coatings evaluation.

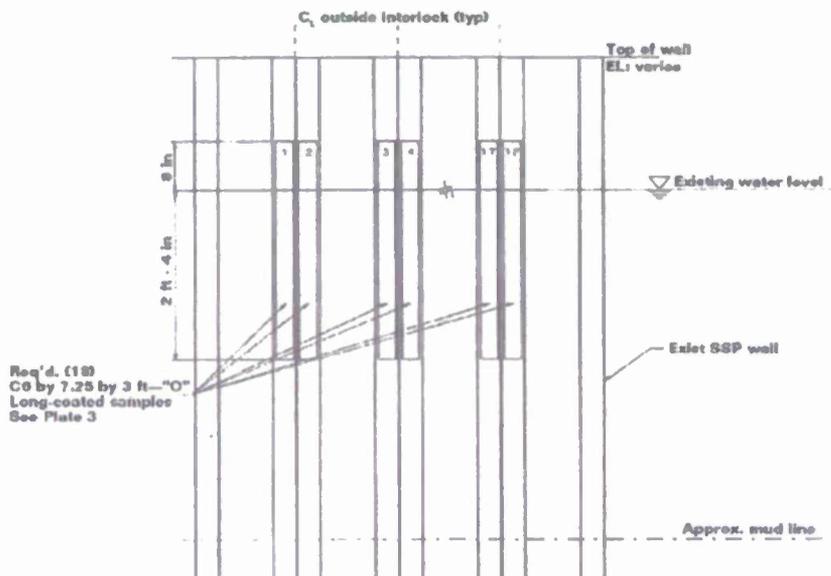
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- 1 ASTM Standard A328/A328M-07, "Standard Specification for Steel Sheet Piling" (West Conshohocken, PA: ASTM International, 2007).
- 2 R. Ray, J. Lee, H. Little, "Factors Contributing to Corrosion of Steel Piling in Duluth—Superior Harbor," *Corrosion* 65 (2011): pp. 707-717.
- 3 "ACOE Sample Tray Installation," AMI Consulting Engineers, Project #071017, December 2007.

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FIGURE 5



I-beam sample tray design and installation.

TABLE 2

I-beam coating descriptions

Sample No.	Product	Product Chemistry
1	1	White two-part solvent-free polyamine epoxy
10	1	
2	2	Light green/white two-part epoxy
11	2	
3	3	Grey two-part coal tar polyamide epoxy
12	3	
4	4	Green two-part polyamine epoxy
13	4	
5	5	Red urethane micaeous iron oxides and refined coal tar
14	5	
6	6	White amine epoxy (one coat)
15	6	
7	7	Black glass flake reinforced epoxy
16	7	
8	8	Black two-part polyamide epoxy/zinc primer
17	8	
9	9	Blue/grey zinc primer/vinyl copolymer
18	9	

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The Beachside Corrosion Test Site at NASA's John F. Kennedy Space Center (KSC) Beachside Atmospheric Corrosion Test Facility includes 600 ft (183 m) of test racks located 100 ft (30 m) from the Atlantic Ocean and ~1 mile (1.6 km) from KSC's rocket launch sites. The NASA Corrosion Technology Laboratory at KSC launched a study of corrosion exposure testing to determine if a correlation could be made between marine atmospheric exposure tests and accelerated corrosion tests. See the feature article on p. 28. Photo courtesy of NASA.



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