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EXISTING STEEL COUPON EVALUATION AND ICE ABRASION SAMPLE INSTALLATION FOR DULUTH HARBOR CORROSION STUDY

DULUTH-SUPERIOR HARBOR

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AMI Projects #081087

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Purpose of Inspection and Installation

AMI Consulting Engineers, P.A. (AMI), was contracted to document existing conditions in place, remove, visually inspect, and return sample steel coupons in the 14 corrosion trays located in the Duluth-Superior Harbor. Also, as part of this study, AMI was contracted by the ACOE to install 16 ice abrasion samples within the Duluth-Superior Harbor to help determine which coatings will be the most effective in protecting the steel structures in our environment.

Steel Coupon Evaluation

The corrosion trays were previously installed in 2006 and 2007 so that corrosion at various locations within the harbor could be monitored. In 2006, AMI was contracted with the Duluth Seaway Port Authority (DSPA), to install 6 sample trays within the harbor containing 8 sample steel coupons each. In 2007, AMI was contracted with the Army Corps of Engineers to install 8 trays containing 8 sample steel coupons each, 4 of which were plain steel and 4 coupons were to be coated steel samples. These steel plates were cut from A328 sheet piling by Superior Steel then returned to AMI to be weighed and recorded. The coupons which were to be coated were sent to the Al Beitelman at the ACOE to be etched with a coupon designation and coated. Once the coupons were returned they were installed at the predetermined sites within the Duluth-Superior Harbor.

AMI was contracted to inspect and document the conditions of a total of 100 steel coupons that were previously installed in the Duluth-Superior Harbor. AMI was to document the condition of each coupon through a visual description of each coupon, photos of both sides of each coupon, take ultra sonic thickness measurement of each coupon and collect on coupon from three of the trays, three total, and provide them in a sealed, watertight cooler to the Navel Research Laboratory in Mississippi.

These three coupons were to be chosen based on the maximum density of biological growth as observed by AMI. The collected coupons are to be kept stable, separated (to not disturb the growth on the coupons), and immersed in Duluth-Superior Harbor water while being transported to the Naval Research Laboratory.

Ice Abrasion Samples

The purpose of this contract is to install 18 coated steel samples on the face of existing steel sheet piling (SSP) in the water of the Duluth-Superior Harbor at the Duluth Seaway Port Authority. These coated steel samples were fabricated from C4x7.25 at 3'-0" lengths and attached to the SSP by welding steel plates and thru bolting the samples to the wall in the heavy ice zone. These ice abrasion samples will be monitored annually to determine which samples hold up the best under extreme ice conditions.

Accelerated corrosion of the steel structures within the Duluth-Superior Harbor has been an ongoing problem with the cause of the problem being unknown to date. For this reason various coatings are being tested to see how they hold up within the harbor and the plain steel samples are being monitored to determine rates of corrosion.

Diving Procedures Used for Underwater Inspections and Installation

The AMI Engineers 4-man dive team consisted of one dive supervisor, one underwater welder/diver, one standby diver, and one dive tender. Surface supplied diving techniques were utilized during all phases of the installation process to meet OSHA, Coast Guard and ACOE standard regulations for commercial diving. AMI's dive plan and schedule was submitted to Ed Parzych, the local dive coordinator, for approval and review. Pertinent video clips, photos and tables (links are in blue text) will be used in the report to illustrate the current conditions of the existing sample trays.

Field Descriptions of Existing Steel Coupons

On October 8, 15, 21, and 22, 2008 the AMI Engineers dive team evaluated the existing steel coupons at 14 different sites within the Duluth-Superior Harbor. The 6 sample trays which were installed in 2006 contained 8 sample steel coupons each. Drawings of the sample trays and coupons can be seen in Appendix A. These steel sample coupons were cut from ” thick, A328 sheet piling. All of the steel samples installed in 2006 were installed with the mill scale left on the steel coupons. Before the steel sample trays were installed each of the sample coupons was measured and weighed with each of the measurements being recorded. This data can be seen in Appendix A.

The 8 sample trays which were installed in 2007 also contained 8 sample steel coupons each. The sample coupons were cut from a section of ½” thick A328 cold rolled sheet pile. The coupons were then sand blasted to SP5 White Metal Blast Cleaning specification. Half of the coupons were then sent to Al Beitelman at the U.S. Army Corps of Engineers, ERDC-CERL in Champaign, IL to be coated with various marine coatings. Al Beitelman is the Director of the Paint Technology Center at CERL for the ACOE. The coupons were each labeled with an etched identification mark, coated then an etch was then made down to the bare steel in each of the coated steel samples to help determine how the coatings will hold up if damaged. A list of these coatings with coupon identifications can be seen in the Coating Information Data Table located in Appendix A. The remaining half of the coupons were etched with the site delineation and coupon number. The uncoated samples were then weighed and recorded as can be seen the Coating Sample Tray Information Data Table located in Appendix A. A list of each of the sites with GPS coordinates and maps showing locations of each sample tray is included in Appendix A.

At each site the diver carefully removed each of the steel coupons and brought them to the dive boat where they were visually inspected and a picture of the front and back of the sample was taken. These pictures are also included in Appendix A. As per Andrew Wadysz instructions, who is Chief of Geotechnical and Structural Engineering Branch in the Detroit District of ACOE, ultra sonic thickness measurements were not taken on the samples because the marine growth would have to be removed from the sample which in turn would remove any corrosion causing bacteria from the steel samples. The samples were then reinstalled into the trays taking particular attention not to disturb or remove any of the marine growth.

During the evaluation 6 uncoated sample coupons were saved, submerged in a water tight container filled with harbor water, and given to the University of Minnesota Duluth (UMD) for analysis and to be weighed. The weighing process included first cleaning the sample coupons in a bath with 500 mL of hydrochloric acid (HCl, sp gr 1.19), 3.5 g hexamethylene tetramine, and reagent water to make 1000 mL for 10 minutes at 20 to 25˚C. The samples were then weighed on a digital scale and recorded to a 10^{th} of a gram. This data can be seen in the Corrosion Sample Tray Information Table located in Appendix A. Also, 3 uncoated sample coupons were saved, submerged in a watertight plastic box filled with harbor water, and shipped overnight to the Naval Research Laboratory (NRL) for analysis.

DSPA Berth 4

There were 6 plain steel samples remaining in this sample tray which was installed in 2006. Sample coupon #3 was removed and given to UMD for analysis. Once the sample was cleaned and weighed it was found to have a loss of 3.23 mils of loss per year. There was heavy corrosion present on the steel coupons and they were covered with a light coating of algae. The nodules ranged from ⅜” to ¾” diameter on these coupons. Pictures of each of these sample coupons can be seen in Appendix A. The video of the tray with the installed coupons can be seen by clicking here.

Hallett Dock 5

There were 5 plain steel samples remaining in this sample tray which was installed in 2006. Sample coupon #4 was saved and given to UMD for analysis. Once the sample was cleaned and weighed it was found to

have a loss of 3.23 mils of loss per year. There was heavy corrosion on the steel coupons and they were covered with a light coating of silt and some mussels. The nodules ranged from ⅜" to ¾" diameter on these coupons. Pictures of each of these sample coupons can be seen in Appendix A. The video of the tray with the installed coupons can be seen by clicking here.

Hallett Dock 7
There were 6 plain steel sample coupons remaining in this tray which was installed in 2006. Sample coupon #3 was saved and given to UMD for analysis. Once the sample was cleaned and weighed it was found to have a loss of 3.23 mils of loss per year. The samples in this tray were heavily corroded with a light coating of silt and algae on the samples. The nodules ranged from ⅜" to ¾" diameter on these coupons. Pictures of each of these sample coupons can be seen in Appendix A. The video of the tray with the installed coupons can be seen by clicking here.

Oliver Bridge
There were 6 plain steel samples remaining in this tray which was installed in 2006. One sample coupon was saved and given to both UMD and NRL for analysis. Sample coupon #3 which was given to UMD when cleaned and weighed was found to have a loss of 2.53 mils per year. Sample #5 was stuck in the tray because it was larger than the others and could not slide out easily like the other samples. This sample was removed using ratchet tie-down straps which disturbed the sample and removed the marine growth from the sample. This sample was re-installed at the opening of the sample tray so it will be easy to remove in the future. The samples in this tray were heavily corroded with a light coating of silt on the samples. The nodules ranged from ⅜" to ¾" diameter on these coupons. Pictures of each of these sample coupons can be seen in Appendix A. The video of the tray with the installed coupons can be seen by clicking here.

Midwest Energy
There were 6 plain steel sample coupons present in this tray which was installed in 2006. One sample coupons was saved and given to both UMD and NRL for analysis. Sample coupon #4 which was given to UMD when cleaned and weighed was found to have a loss of 2.73 mils per year. The samples in this tray were heavily corroded with a light coating of silt and several mussels on the samples. The nodules ranged from ⅜" to ¾" diameter on these coupons. Pictures of each of these sample coupons can be seen in Appendix A. The video of the tray with the installed coupons can be seen by clicking here.

Cutler Magner
There were 6 plain steel sample coupons present in this tray which was installed in 2006. One sample coupons was saved and given to both UMD and NRL for analysis. Sample coupon #3 which was given to UMD when cleaned and weighed was found to have a loss of 3.73 mils per year. The samples in this tray were heavily corroded with a light coating of silt on the samples. The nodules ranged from ⅜" to ¾" diameter on these coupons. Pictures of each of these sample coupons can be seen in Appendix A. The video of the tray with the installed coupons can be seen by clicking here.

Duluth Entry, DE-6
There were 8 coated and uncoated steel sample coupons in this tray which was installed in 2007. There was heavy rust nodule growth on both sides of the uncoated samples. These nodules were ⅜" to ¾" diameter on the coupons with the domes being softer than nodules on the upstream samples. All coating samples were in good condition with no signs of loss of adhesion anywhere including around the etch mark. Pictures of each of these sample coupons can be seen in Appendix A. The video of the tray with the installed coupons can be seen by clicking here.

Vessel Yard, VY-1
There were 8 coated and uncoated steel sample coupons in this tray which was installed in 2007. There was heavy rust nodule growth on both sides of the uncoated samples with the front side of the coupon being

covered with a heavy coating of algae. These nodules were ⅜" to 1½" diameter on the coupons with the domes being very soft under the algae. There was almost no crust on the nodules on the front side of the coupon with the nodules being very soft but much harder on the backside with no algae covering them. All coated samples were in good condition with no signs of loss of adhesion anywhere including around the etch mark. Pictures of each of these sample coupons can be seen in Appendix A. The video of the tray with the installed coupons can be seen by clicking here.

Erie Pier, EP-1
There were 8 coated and uncoated steel sample coupons in this tray which was installed in 2007. There was heavy rust nodule growth on both sides of the uncoated samples. These nodules ranged from ⅜" to 1" diameter and were flatter then other areas or less dome like and spread out more. These nodules were hard to the touch. All coated samples were in good condition with no signs of loss of adhesion anywhere including around the etch mark. Pictures of each of these sample coupons can be seen in Appendix A. The video of the tray with the installed coupons can be seen by clicking here.

Coast Guard Cell A, CGA-1
There were 8 coated and uncoated steel sample coupons in this tray which was installed in 2007. Sample #1 was saved, cleaned, weighed and was found to have a loss of 2.44 mils per year. There was heavy rust nodule growth on both sides of the uncoated samples. These nodules ranged from ¼" to ½" diameter on the back side of the coupons and ½" to 1" diameter on the front side. These nodules were also hard to the touch. All coated samples were in good condition with no signs of loss of adhesion anywhere including around the etch mark. Pictures of each of these sample coupons can be seen in Appendix A. The video of the tray with the installed coupons can be seen by clicking here.

Coast Guard Cell B, CGB-1
There were 8 coated and uncoated steel sample coupons in this tray which was installed in 2007. There was heavy rust nodule growth on both sides of the uncoated samples. These nodules ranged from ⅜" to ¾" diameter on the coupons. All coated samples were in good condition with no signs of loss of adhesion anywhere including around the etch mark. Pictures of each of these sample coupons can be seen in Appendix A. The video of the tray with the installed coupons can be seen by clicking here.

Coast Guard Cell C, CGC-1
There were 8 coated and uncoated steel samples present in this tray which was installed in 2007. There was minor corrosion with a light coating of silt on these coupons. These nodules ranged from ⅜" to 1½" diameter on the coupons. All coated samples were in good condition with no signs of loss of adhesion anywhere including around the etch mark. All of the steel coupons were reinstalled into this tray. Pictures of each of these sample coupons can be seen in Appendix A. The video of the tray with the installed coupons can be seen by clicking here.

Superior Entry, SE-1
There were 8 coated and uncoated steel sample coupons in this tray which was installed in 2007. There was heavy rust nodule growth on both sides of the uncoated samples. These nodules ranged from ⅜" to ¾" diameter on the coupons. All coated samples were in good condition with no signs of loss of adhesion anywhere including around the etch mark. Pictures of each of these sample coupons can be seen in Appendix A. The video of the tray with the installed coupons can be seen by clicking here.

Superior Entry, SE-10
There were 8 coated and uncoated steel sample coupons in this tray which was installed in 2007. There was heavy rust nodule growth on both sides of the uncoated samples. These nodules ranged from ⅜" to 1½" diameter on the coupons. All coated samples were in good condition with no signs of loss of adhesion

anywhere including around the etch mark. Pictures of each of these sample coupons can be seen in Appendix A. The video of the tray with the installed coupons can be seen by clicking here.

Ice Abrasion Sample Installation

The Ice Abrasion Samples were 3'-0" lengths of C6X8.2 channel fabricated from A36 steel. Steel tabs composed of ½" thick A36 steel were welded to the sheet piling at the top and bottom of the samples. 8" x ¾" bolts were used to hold the samples to the steel sheet piling during the study. The uninstalled samples with the top connector tabs are shown below in Picture 1.

Picture 1: Uninstalled Ice Abrasion Samples

On October 22, 23, 27, 28, and 29, 2008 the AMI Dive Team began installing the ACOE Ice Abrasion Samples. The installation of the ice abrasion samples included cleaning the steel sheet pile structures with a 4000 psi pressure washer to remove marine growth and any existing corrosion. This cleaning was equivalent to a SP7/NACE No. 4, Brush-Off Blast-Cleaning. This provided a clean surface with a few impurities to weld the steel tabs which hold the ice abrasion samples to the steel structure. The steel tabs were then welded to the clean steel structure using underwater welding techniques as described in AWS D3.6 utilizing Broco E70XX welding rods.

At the time of installation the water datum varied from 3" to 6" above mean low water (MLW) which is 601.1' above sea level. The coordinates that these samples were installed are at N46º45'23.94", W92º5'42.69"W at the Duluth Seaway Port Authority facility. The samples were installed so the top of the ice abrasion samples are located 6" above MLW. This elevation was chosen so the samples would be in the heaviest ice zone during the winter months. The samples in place when the water was approximately 3" above MLW can be seen below in Picture 2.

Picture 2: Installed Ice Abrasion Samples

There were 18 total ice abrasion samples installed in this study which were coated in pairs with 9 different coatings. A list of these coating can be found in Appendix B. Once the samples were installed the diver went from sample 1 to 18 and recorded video of the final installed product.

Conclusion

The inspection of the sample coupons went very well. All of the coatings that were inspected appeared to be holding up well. There was no loss of adhesion noted on any of the coated samples even around etch marks. The samples that were saved for analysis for UMD showed signs of loss between 2.29 and 3.73 mils per year which can be seen in the DSPA and ACOE Sample Data Tables located in Appendix A. AMI has not received any information regarding the 3 steel sample coupons which were sent to the NRL.

The installation of the ice abrasion samples also went very well. They are located in a heavy ice zone which will put the 9 different coatings to the test. This will help to better understand which coatings are best suited for our environment.

Respectfully Submitted,

Michael K. Weber, EIT
Structural Engineer/Commercial Diver

Reviewed By,
Chad W. Scott
Principal

APPENDIX A

STEEL SAMPLE COUPON FIELD DATA

SAMPLE INFORMATION:

APPENDIX B

ICE ABRASION SAMPLE FIELD DATA

SAMPLE INFORMATION: