(Microbial) Corrosion and cathodic protection of steel sheet pilings in a harbour in The Netherlands

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Introduction

MIC is the deterioration of metals as a result of metabolic activity of microorganisms. Different genera of microorganisms convert nutrients which are available in soil and water into for instance (organic) acids and other corrosive by-products which change local environmental conditions and may accelerate corrosion processes.

MIC can be recognized very well by its typical tubercles of corrosion products, being relatively soft, layered structures consisting of orange iron hydroxide products and black products containing iron sulfide. These layers are usually weakly attached to the steel surface and underneath the steel appears shiny, with pits, craters and holes of various dimension.

Aim of investigation

This poster describes the investigation of a MIC failure case in a marine/brackish harbour in The Netherlands. The quay wall consisted of an old part without and a new part with sacrificial anodes.
Aim of the investigation was to find the root cause of failure of sheet pilings in the old part.

To this end a comprehensive failure analysis package was carried out including coupon investigation on corrosion damage, microbial analysis for corrosive organisms, chemical analysis of corrosion products and potential measurements on the structure. Such approach will allow a thorough diagnosis and analysis for concluding if MIC is really the root cause of the damage observed. From this also proper recommendations can be given for mitigation of the problem.

Conclusion

Damage pattern and tubercles found on coupon sample strongly hint at MIC. Moreover, corrosion related microorganisms were frequently found in corrosion products. Sulfur was found in corrosion products indicating possible activity of SRB directly at the damaged surface and detection of gaseous sulfide from corrosion product samples confirmed this.

All this leads to the conclusion that MIC plays a key role in the observed damage of the quay wall structure.

Potential measurements showed variable values between -0.7 and -1.02 V. Sacrificial anodes were placed only on the new part of the structure.
Along the older part the potential was not low enough, resulting in severe corrosion damage and large perforations whereas the new part was adequately protected by the sacrificial anodes.

Results

What is the root cause of failure of the harbour structure?

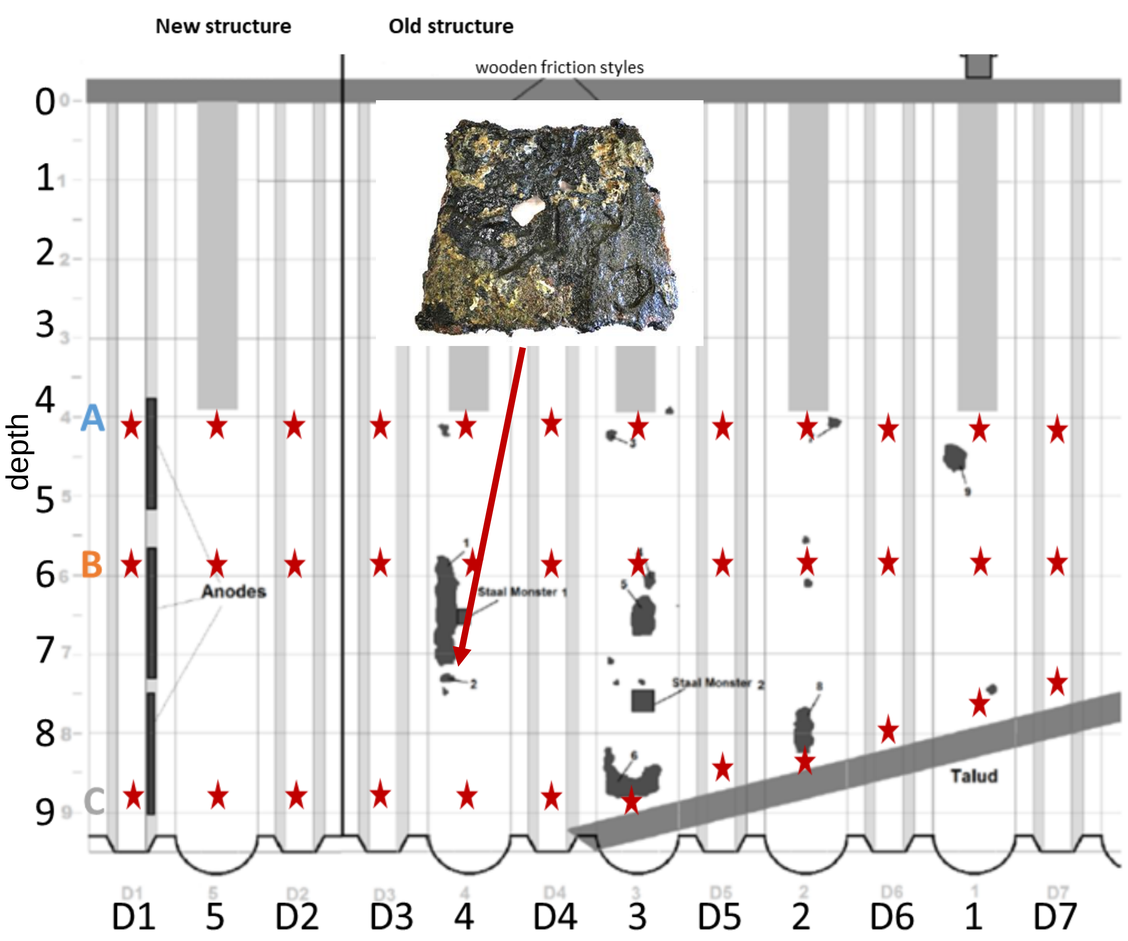

Figure 1: Overview of damaged quay wall. Red arrow shows location of sampled coupon taken out; red stars indicate locations for potential measurements and wall thickness measurements at different depths (A, B, C). Results of potential and wall thickness measurements are shown in the diagrams at the right.

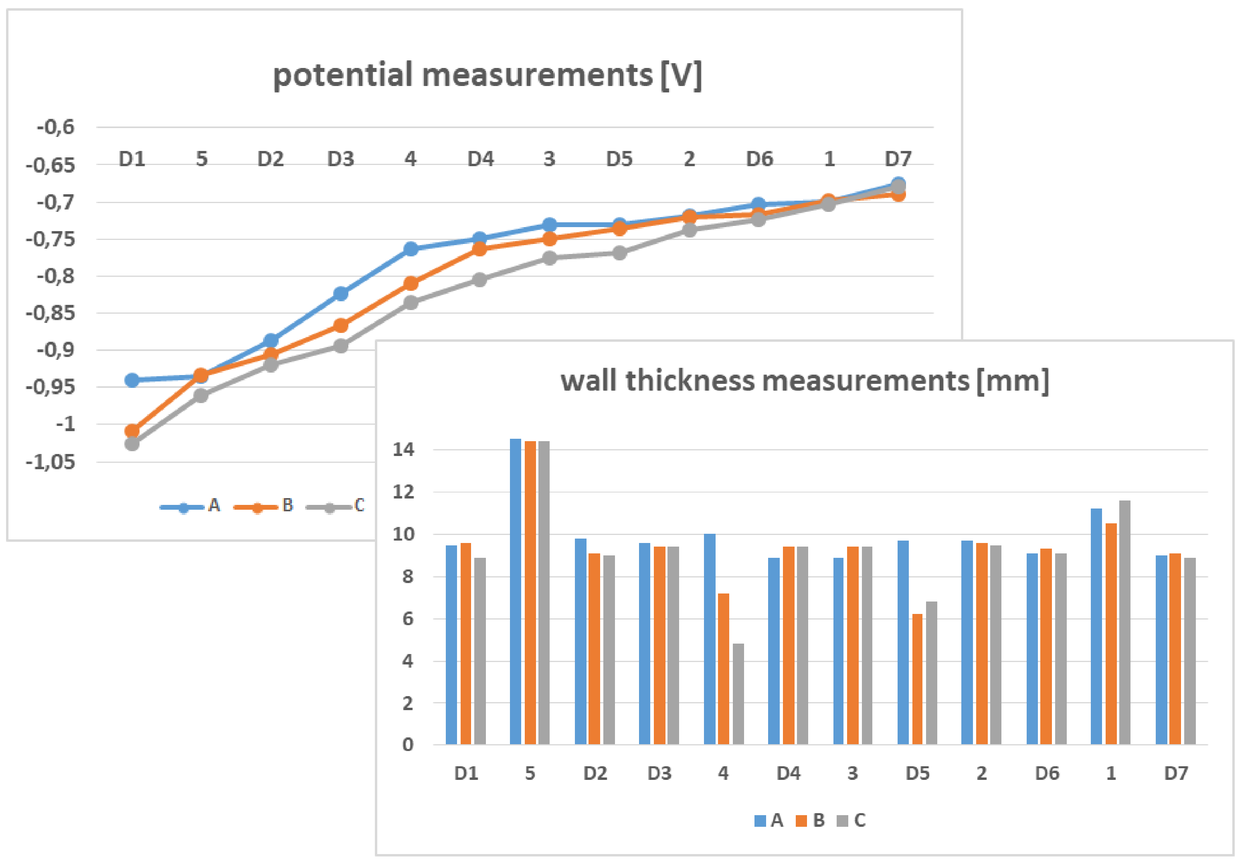

Table 1: Results of quantification and activity of corrosion related microorganisms in corrosion products using qPCR and MPNs.

	Type of microorganism or metabolism						
Sample	**Total bacteria ***	**IRB*,****	**SRB*,****	**SOB****	**IOB****	**APB****	**SFB****
Corrosion products	**+**	**-**	**(+)**				

* detection by qPCR: + = high numbers, (+) = moderate numbers, - =not detected.
** detection by MPN, colour code red = high activity, orange = moderate activity, yellow = low activity, grey = not detected.
IRB = iron reducing bacteria, SRB = sulfate reducing bacteria, APB = acid producing bacteria,
IOB = iron oxidizing bacteria, SOB =sulfur oxidizing bacteria, SFB = slime forming bacteria

Figure 2: Volatile sulfide determination from corrosion product sample.

Acid was added dropwise to the corrosion product sample. Gaseous sulfide was trapped in the headspace and then measured using the Dräger tubes.

A negative control (right tube) was used as reference for visual evaluation of the Dräger tube readings.

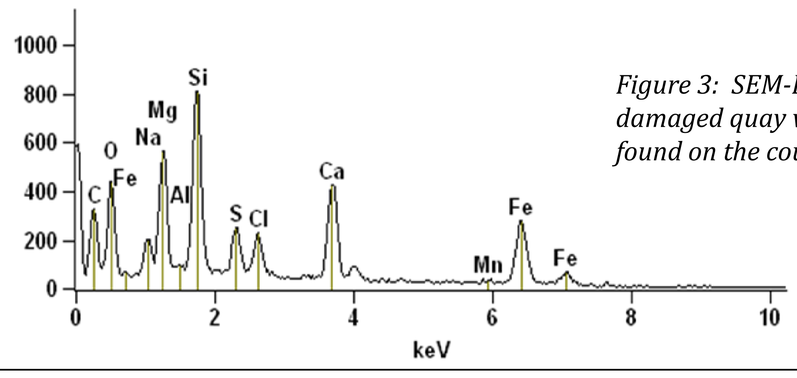

Figure 3: SEM-EDX results of metal coupon from the damaged quay wall structure. Sulfur was frequently found on the coupon surface.

Experimental

The fractions of total microorganisms with potential corrosive activity are determined by the Most Probable Number (MPN) method in selective growth media and in some cases by qPCR. Growth media are used for the specific enrichment of MIC relevant microorganisms including:
→ IRB, SRB, APB, IOB, SOB, and SFB.

Quantitative polymerase chain reaction (qPCR) is a genetic level-based technique which can provide information on microbial populations without the need of cultivation. The same sample as for culture methods was analyzed by qPCR for 3 target organisms:
→ total bacteria, sulfate reducing activity and iron reducing bacteria.

Potential measurements were carried out using the Bathycorrometer. It is an advanced, hand held, diver operated unit providing a consistent way of determining the corrosion potential of subsea structures. The potential is measured against a silver/ silver- chloride electrode.

Afterwards wall thickness measurements were carried out by a diver operated unit.

Scanning electron microscopy (SEM) from metal samples and corrosion products was done in combination with Energy-dispersive microanalysis (EDX). For this, a Jeol JSM 5800LV instrument equipped with a Noran instruments EDX system was used. EDX provides semi- quantitative information on the elementary composition of the samples.

For qualitative determination of presence of precipitated sulfur at the metal surface (indication of microbial activity) a chemical detection method using commercially available sulfide detection tubes (Dräger) was applied. Acid (6M HCl) was added dropwise to the target surface and left to react for 5 min. Gaseous sulfide was trapped in the headspace and was measured using the Dräger tubes. Manufacturer's instructions were followed for the use of the sulfide sensitive tubes.