**CORROSION EVALUATION WITH MEASUREMENTS OF MARITIME STEEL STRUCTURES IN COSTA RICA**

**by**

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1. **INTRODUCTION**

Due to the easiness of construction, many maritime structures, principally, foundation piles and earth retaining walls are made of steel. It is then normal that these structures are subject to corrosion that could be severe because of the direct contact with seawater or spray.

For such structures, some inspection and measurements, are performed as quality control during construction. However, in most cases, corrosion assessment, during service life, is negligible. Afterwards remediation countermeasures, are often costly and done with poor knowledge of which areas are critical. Nevertheless, there are some advantages in doing measurements for maintenance evaluations. Maybe the most important is to detect differences in the behavior of similar-type elements, and establish the priorities for maintenance.

This paper considers three study cases, located in the Pacific of Costa Rica with follow up after construction of maritime structures, including thicknesses and electrical potential measures.

1. **CASES OF STUDY**

**2.1 Cellular Cofferdam Breakwater at Quepos**

In 2010, it was constructed the first phase of a marina in Quepos, including two mix breakwaters, both with rubblemound and circular cells of sheet piles, on marine steel and filled with sand and gravel. Breakwaters are 956 meters long and have 25 circular cells from 12 to 18 meters in diameter, with interconnection arches, in water depths from 1-6 m below low water level (LWL). An over-thickness for sheet-piles was considered for corrosion purposes.

The maintenance plan for the marina, considers tracking the corrosion experienced by the steel sheet-piles, and comparing 'actual' against expected corrosion rates. An analysis is then required to check that the structural limits for the corrosion additional thickness are not exceeded. Update annual campaigns measurements, are from 2011 to 2013, and 2015 to 2017. Specific control sections, distributed along the breakwater, were considered both inside and outside the marina basin. In each section, thicknesses were measured, every meter from the top of the cell, about +4 m LWL to the seabed, using ultrasonic equipment and a special underwater transducer.

With measurements from different years, corrosion rates could be calculated, as an average for some structure sectors, or for each measured point. Differences on thicknesses loses and corrosion rates were identified for conditions of exposition, i.e. outside and inside basin, above and below LWL, and due to the location along the breakwaters. From the safe structural thickness for each sector, lifespans could be calculated. In general, these complies with the designed lifespan for the whole structure, however there are lower than required in specific sectors. Recommendations for these sectors regarding the barrier protection of the sheet-piles, had been issued. Measurements helps to spot the areas to protect and in turn minimize maintenance costs.

**2.2. Sheet-pile wall at Caldera Port**

The principal bulkhead of Port of Caldera, includes three berthing positions depths from -7.5 to -11 m LWL and a total length of 500 m. This is a steel sheet-pile retaining wall constructed in 1980. Above water, sheet-piles are protected by a concrete cap, meanwhile, below water sacrificial aluminum alloy anodes provide passive cathodic protection. Evaluations of sheet-pile thicknesses and electrical potential generated by the cathodic system were performed by others in 2003. Additional measurement campaigns, were executed from 2011 to 2015, and the last one in 2017.

Steel thicknesses measures, follows an analogous methodology as in the previous case study, with the difference that only measurements below water were executed, where there is no concrete cap. Despite this is a structure with 38 years of construction, steel thicknesses compared to sheet-pile original specifications remain similar, which is probably due to an effective cathodic protection.

Electrical voltage assessment is used as maintenance evaluation to detect areas with low potentials, in comparison with was is required to suppose corrosion inhibition. Measurements are performed in sections every 5-10 meters alongside the main and closure walls, and every 50-100 cm from top to sea-bed. If there are detected areas, with potentials outside specifications, additional anodes are welded to regain potential, and then new electrical measurements performed to confirm the protection. This approach minimizes maintenance costs since only the sections that need anodes would be re-protected with them, compared to replace anodes after certain mass loss despite the potential.

**2.2 Pier at Punta Morales**

The Punta Morales pier, principally for sugar export, was constructed in 1980, and is a dolphin-type pier with a loading platform, all on piles. The sugar is transported from a warehouse on land to the loading platform by means of a conveyor belt. This belt is supported on (9) concrete caps, each one with (4) H-beam steel piles. The piles of the conveyor support are protected from corrosion by painting and by an active cathodic protection.

During routinely inspections, sections losses were viewed on the belt support piles, mostly near LWL, and possible due to abrasion. However, extend of the damages were unknown, especially below water. In the five outermost supports, which pile does not discover on low tide with water depths from 1-9 m LWL, steel thicknesses at each pile were measured, every meter from top to sea-bottom.

Thicknesses measures helped to detect areas with severe losses, and showed some losses below water, not necessarily visible. Instead of prescribing substitution of the piles, which would probably be the recommendation without data, what was proposed was the reinforcement of them with steel plates, according to the distribution of evaluation measurements. This repair was implemented shortly after, and included underwater welding in difficult current and visibility conditions, but at low cost.

1. **CONCLUSIONS**

In all these study cases, thicknesses and electrical potential determination with maintenance measurements, helps to differentiate sectors of steel structures, where the phenomenon of corrosion and/or abrasion occurs with varied attack levels. With several campaigns of thicknesses measurements, along the years, it is possible to estimate corrosion rates and useful lives or lifespans, both general for structures, and specific for each level and section.

In turn, this allowed to identify maintenance priorities, defining possible sites where measures of corrosion protection should initiate, with barrier protection, or active or passive, cathodic protection systems, the need to apply other countermeasures as reinforcement or substitution of elements, as well in general, to have confidence in the structural capacity and safety of structures. Moreover, evaluation with discrete measurements along the structures had shown to be cost-effective reducing the costs for repairs and maintenance of the steel elements and cathodic protection systems.

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