Engineered maintenance of port wharf structures

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Introduction

Exporting over 103 million tonnes per annum, the Port of Newcastle, New South Wales, Australia is one of the world's largest single coal export ports. In addition to coal, the port handles over 40 different non-coal commodities. Forecasts indicate that Newcastle Port Corporation (NPC) can expect to exceed 180 million tonnes per annum by 2015 in coal trade alone.

Newcastle Port Corporation operates 365 days a year, 24 hours a day. It has 18 operational berths, seven dedicated to the handling of coal and 11 allocated to the handling of non-coal trade. NPC also owns, operates and maintains 195 navigation aids, 16 kilometers of roads, 4.5 kilometers of rail, 51 buildings, two breakwaters and over 7 kilometers of seawalls. Heritage structures near the entrance to the port also fall within the NPC asset register.

The port's assets are located in an aggressive marine environment so the corporation is acutely aware of corrosion-induced deterioration and the need for corrosion management and maintenance approaches to sustaining the service lives of structural and building assets.

Figure 1: Aerial view of the Port of Newcastle, New South Wales, Australia.

Figure 2: West basin, East basin, the Channel berth and Dyke berths within the Port of Newcastle.

Port of Newcastle wharf and berth structures

The wharf and berth structures of the Port of Newcastle are of reinforced concrete construction (decks, substructure beams and rear walls) supported on reinforced concrete or steel piles.

The berth, wharf and jetty structures that NPC are directly responsible for are summarized below (see Table 1). Other berth and wharf structures within the port are leased and are the responsibility of the tenants. The age of the NPC wharf and berth structures varies from 32 to 63 years, some are therefore at or beyond their designed lives. However, decades of future service lives are required of the structures so pro-active, engineered, maintenance and corrosion management is necessary.

Condition assessment of structures

Condition surveys have been necessary for all structures so as to determine the mechanisms and extent of deterioration and enable prognoses of future deterioration. Structural assessments and structural capacity checks have also typically been undertaken. Scenario analyses of remedial, maintenance and corrosion management options have been utilized. Informed decisions have therefore been possible by NPC.

Various consulting engineers have worked with the corporation to undertake the condition surveys, structural assessments and remedial options analysis. The independence of these consulting engineers has been paramount as conflicts of interest associated with the supply of materials, equipment or laboratory testing services would compromise recommendations.

Figure 3: Kooragang K2 and K3 berths.

TABLE 1: NEWCASTLE PORT BERTH AND WHARF STRUCTURES SUMMARY.

Wharf or berth structure	Elements description	Year constructed
Fitzroy Street wharf	Reinforced concrete pile caps, headstocks and deck Reinforced concrete piles	1949 (south end) 1956 (north end)
West basin no. 3 (see Figure 2)	Reinforced concrete crane beam, longitudinal beams and deck Reinforced concrete piles	1967
West basin no. 4 (see Figure 2)	Reinforced concrete crane beam, longitudinal beams and deck Reinforced concrete piles	1967
East basin no. 1 (see Figure 2)	Reinforced concrete longitudinal beams and deck Reinforced concrete piles	1964
East basin no. 2 (see Figure 2)	Reinforced concrete longitudinal beams and deck Reinforced concrete piles	1964
Channel berth (see Figure 2)	Reinforced concrete beams and deck HP2 steel piles	1978
Dyke 1 berth (see Figure 2)	Reinforced concrete dolphins. Reinforced concrete headstocks, prestressed planks and reinforced concrete slab for Road Bridges. HP2 and H section steel piles	1971
Dyke 2 berth (see Figure 2)	Reinforced concrete dolphins. Reinforced concrete headstocks, prestressed planks and reinforced concrete slab for road bridges. HP2 and H section steel piles	1971
Mayfield 4 berth	Steel beams, reinforced concrete beams and deck HP2, H section tubular and sheet steel piles	
Kooragang no 2 berth	Reinforced concrete longitudinal beams, end beams and deck Reinforced concrete piles and tubular steel fender piles	1965
Kooragang no. 3 berth	Reinforced concrete longitudinal beams, end beams and deck Tubular steel piles	1980

Maintenance and corrosion management approaches

The maintenance and corrosion management approaches being adopted by NPC for substructure elements of wharf and berth structures have been engineered and tailored to meet required future structure service lives, budgetary constraints, release of maintenance funding and lowest life cycle costs.

The maintenance and corrosion management approaches being adopted include:

doing nothing in some cases; penetrant treatment (and re-application) of select concrete elements to prevent reinforcement corrosion initiation; conventional concrete repair; impressed current Cathodic Protection (CP) of select concrete elements and petrolatum tape wrapping to mean low water level (MLW) of steel tubular or steel H-section (UC or UBP) piles. Also, CP (galvanic or impressed current) for in-water steel pile sections or various combinations of these methods.

These approaches have only been applied to those wharf and berth substructure elements that need them. For example, there is not a need to cathodically protect the whole reinforced concrete substructure sections of any berths, only those elements that need CP. Combinations of remedial options are routinely utilized.

Concrete CP systems overview

Impressed current anode systems include catalysed titanium ribbon mesh, mixed metal oxide coated ribbon and discrete anodes (proprietary and tailor-made). Transformer rectifier units (TR units) vary in number and type. Remote monitoring and control systems (RMCS) were installed to some TR units. The RMCS units had

Figure 4: Ribbon mesh anode installation into slots.

Figure 5: Ribbon mesh anode suspension from reinforcement at spalled areas.


Figure 6: Shotcrete reinstatement over ribbon mesh anode.


Figure 7: ALWC of tubular pile.


Figure 8: ALWC corrosion of sheet pile.

operational reliability issues from commissioning and no remote monitoring and control of the CP system has been performed (and the RMCS units have subsequently been discarded). Monitoring has been easily and cost effectively undertaken by manual means throughout the life of the CP systems.

For substructure beam or deck soffit elements, ribbon mesh and ribbon anodes grouted (cementitious) into slots (see Figure 4) or chases cut into the concrete surface have been utilized. At badly spalled areas the ribbon mesh anodes were suspended from the reinforcement using plastic fixings prior to application of shotcrete (see Figures 5 and 6). The grouts and shotcretes used were proprietary cementitious and CP compatible with known electrical resistivity characteristics and increased alkalinity (buffering capacity) to resist acidification (since the electrochemical reactions at the anode to grout interface are oxidising, producing acidity).

The above water sections of concrete pile substructure elements have discrete anodes installed. The discrete anode systems are proprietary conductive ceramic-titanium based or tailor-made catalysed titanium, installed into drill holes, which are then in turn grouted with proprietary cementitious grouts. As for the ribbon mesh and ribbon anodes, the proprietary cementitious grouts used were CP compatible.

Steel pile protection methods

Most of the NPC wharf, berth and jetty structures are steel piled including carbon steel tubular, H-section and sheet. In the past, the rate of corrosion of carbon steel piles in Newcastle harbour has been so low that corrosion protection methods have not always been necessary. Some four to five years ago NPC maintenance staff observed bright orange localized corrosion of some steel piles at around low water level, within the lower half of the tidal zone and within the in water sections. The bright orange localized corrosion at or near low tide is of the characteristic appearance of Accelerated Low Water Corrosion (ALWC) (see Figures 7 and 8). The bright orange localizsed corrosion evident to the below water pile sections has been assumed to be Microbiologically Influenced Corrosion (MIC).

NPC has an asset management plan for its various structures and buildings. When ALWC and MIC was identified to the steel piles of the wharf structures, a specific ALWC/MIC management and remediation strategy within the plan was considered necessary. A literature search was the first step so that an appreciation could be gained for how others have dealt with ALWC and MIC. Readily available literature and major databases were searched.

The literature search identified that the corrosion protection and maintenance strategies that are applicable to marine ALWC and MIC are those based on well established conventional methods, primarily cathodic protection (galvanic or impressed current), wrappings/tapes, coatings of various types and concrete encasement/jacketing.

Currently only steel tubular or steel H-section piles of wharf and berth structures in Newcastle Port are scheduled for protection. Sheet piles are to be repaired and protected at a later date. The protection methods considered appropriate from the literature search for Newcastle Port steel tubular and steel H-section piles were petrolatum tape wrapping to Mean Low Water level (MLW) and cathodic protection (galvanic or impressed current) for in water sections. Significant perforation of the tubular steel piles supporting dolphins of the channel berth occurred due to ALWC and MIC to the extent that the berth had to be closed. Structural repairs to the piles needed to be engineered to enable the berth to be re-opened and used.

Other maintenance and corrosion management approaches

Penetrant treatment of select concrete substructure elements and substructure sections has been by silane. Re-application of silane is scheduled at 10 year intervals. Concrete repair of select concrete substructure elements has been by conventional means. This involves the breakout of concrete to behind reinforcement and until uncorroded, concrete surface preparation, reinforcement coating system application and reinstatement with proprietary cementitious repair mortars (polymer modified and shrinkage compensated). Silane treatment of repair areas is then undertaken. Sprayed zinc operating as a galvanic (sacrificial) CP system has also been applied to soffit reinforced concrete elements of a number of dolphins of the dyke berths. Year 1 performance results are most encouraging.

Conclusion

Not surprisingly, corrosion induced deterioration occurs to structural and building assets within the aggressive marine environment of the Port of Newcastle. It is necessary to assess the condition of assets from which an asset maintenance plan can be developed. All maintenance and corrosion management approaches need to be considered and scenario analyses of the same are most useful.

Combinations of maintenance and corrosion management approaches have been adopted by NPC for its wharf and berth structures including doing nothing in some cases. The age of NPC wharf and berth structures varies from 32 to 63 years. Some are therefore at or beyond their designed lives. However, decades of future service lives are required of the structures. Maintenance and corrosion management approaches can be engineered to achieve required future service lives and to meet budgetary constraints, maintenance funding timings and at lowest life cycle costs.

ABOUT THE AUTHORS

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ABOUT THE ORGANIZATION

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