Engineered Maintenance of Newcastle Port Wharf Structures

Introduction
Exporting over 103 million tonnes per annum, the Port of Newcastle is one of the world’s largest single coal export ports. In addition to coal, the Port handles over 40 different non-coal commodities. Forecast estimates 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 per year, 24 hours per day. It has 18 operational berths, 7 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, 16km of roads, 4.5km of rail, 51 buildings, 2 breakwaters and over 7km of seawalls. Heritage structures near the entrance to the port also fall within the NPC asset register.

The Ports 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 sustain service lives of structural and building assets.

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. Figure 1 shows an aerial view of the Port of Newcastle.

The berth, wharf and jetty structures that NPC are directly responsible for are summarised at 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 design 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 of all structures so as to determine the mechanisms of deterioration, the extent of deterioration and to 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 utilised. 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.

Table 1. Newcastle Port Berth and Wharf Structures Summary

<table>
<thead>
<tr>
<th>Wharf or Berth Structure</th>
<th>Elements Description</th>
<th>Year Constructed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fitzroy Street Wharf</td>
<td>Reinforced concrete pile caps, headstocks and deck</td>
<td>1949 (south end)</td>
</tr>
<tr>
<td></td>
<td>Reinforced concrete piles</td>
<td>1956 (north end)</td>
</tr>
<tr>
<td>West Basin No. 3 (refer Figure 2)</td>
<td>Reinforced concrete crane beam, longitudinal beams and deck</td>
<td>1967</td>
</tr>
<tr>
<td>West Basin No. 4 (refer Figure 2)</td>
<td>Reinforced concrete crane beam, longitudinal beams and deck</td>
<td>1967</td>
</tr>
<tr>
<td>East Basin No. 1 (refer Figure 2)</td>
<td>Reinforced concrete longitudinal beams and deck</td>
<td>1964</td>
</tr>
<tr>
<td>East Basin No. 1 (refer Figure 2)</td>
<td>Reinforced concrete longitudinal beams and deck</td>
<td>1964</td>
</tr>
<tr>
<td>Channel Berth (refer Figure 2)</td>
<td>Reinforced concrete beams and deck</td>
<td>1978</td>
</tr>
<tr>
<td>Dyke 1 Berth (refer Figure 2)</td>
<td>Reinforced concrete dolphins. Reinforced concrete headstocks, prestressed planks and reinforced concrete slab for Road Bridges.</td>
<td>1971</td>
</tr>
<tr>
<td>Dyke 2 Berth (refer Figure 2)</td>
<td>Reinforced concrete dolphins. Reinforced concrete headstocks, prestressed planks and reinforced concrete slab for Road Bridges.</td>
<td>1971</td>
</tr>
<tr>
<td>Mayfield 4 Berth</td>
<td>Steel beams, reinforced concrete beams and deck</td>
<td></td>
</tr>
<tr>
<td>Kooragang No 2 Berth</td>
<td>Reinforced concrete longitudinal beams, end beams and deck</td>
<td>1965</td>
</tr>
<tr>
<td>Kooragang No 3 Berth</td>
<td>Reinforced concrete longitudinal beams, end beams and deck</td>
<td>1980</td>
</tr>
</tbody>
</table>

Figure 1: Aerial view of the Port of Newcastle.
Figure 2: West Basin, East Basin, the Channel Berth and Dyke Berths within the Port of Newcastle.
Figure 3: Kooragang K2 and K3 Berths.
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:

- Do nothing.
- 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.
- Petrolatum tape wrapping to mean low water level (MLW) of steel tubular or steel H-section (UC or UBP) piles.
- CP (galvanic or impressed current) for in-water steel pile sections.
- Combinations of the above.

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 utilised.

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 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 (Green et al., 2010; Green et al., 2011a).

For substructure beam or deck sofit elements, ribbon mesh and ribbon anodes grouted (cementitious) into slots refer Figure 4 or chases cut into the concrete surface have been utilised. At badly spalled areas the ribbon mesh anodes were suspended from the reinforcement using plastic fixings prior to application of shotcrete, refer Figures 5 and 6. The grouts and the 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) (Layzell et al., 1998; Green et al., 2010; Green et al., 2011a).

The above-water sections of concrete pile substructure elements have discrete anodes installed. The discrete anode systems are proprietary conductive ceramic-titanium based or tails 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 (Green et al., 2010; Green et al., 2011a).

Steel pile protection methods

Most of the NPC wharf, berth and jetty structures are steel piled including carbon steel tubular, H-section (UC or UBP) 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 4 - 5 years ago NPC maintenance staff observed "bright-orange" localised 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" localised corrosion at or near low tide is of the characteristic appearance of accelerated low water corrosion or ALWC, refer Figures 7 and 8 (Green et al., 2010). The "bright orange" localised corrosion evident to the below water pile sections has been assumed to be microbiologically influenced corrosion (MIC) (Green et al., 2011b).

Newcastle Port Corporation has an Asset Management Plan for their various structures and buildings. When ALWC and MIC was identified to steel piles of their wharf structures a specific ALWC/MIC Management and Remediation Strategy within the Asset Management 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 (Green et al., 2010; Green et al., 2011b).

Currently only steel tubular or steel H-section (UC or UBP) 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 (Green et al, 2010; Green et al, 2011b).

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 involving breakout of concrete to behind reinforcement and till 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.

Conclusions
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 can then be developed an Asset Maintenance Plan. 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 Newcastle Port Corporation for their wharf and berth structures including doing nothing.

The age of NPC wharf and berth structures varies from 32 to 63 years. Some are therefore at or beyond their design 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.

Acknowledgements
The authors would like to thank the Chief Executive Officer of the Newcastle Port Corporation for permission to publish this article. The views expressed in this article are those of the authors and are not necessarily of the companies that they represent.

References


Warren Green, Vinsi Partners Consulting Engineers, Sydney
Scott Bacon, Newcastle Port Corporation
Brad Dockrill, Vinsi Partners Consulting Engineers, Newcastle