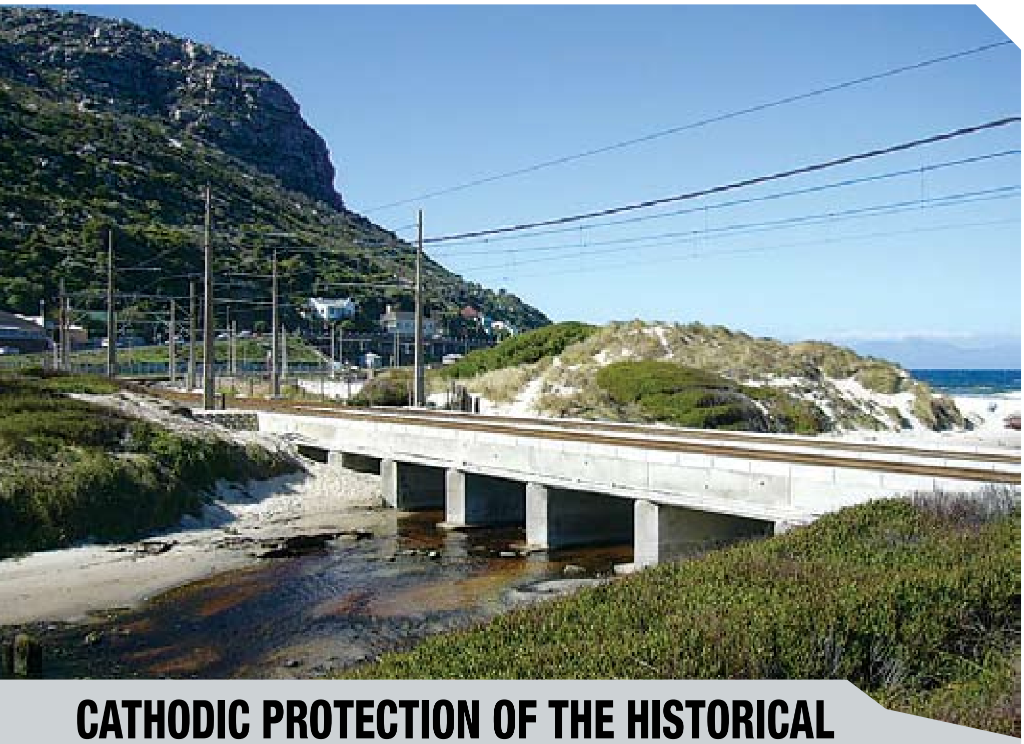
Cathodic protection of a historical rail bridge

THE RAIL BRIDGE over the Silvermine River near Clovelly, Cape Town, is a historically significant bridge structure. The seaside bridge was constructed in 1890 and an additional rail line and adjacent roadside bridge was added on the upstream side in 1926. The bridge is situated in the estuarine mouth of the Silvermine River and has been subjected to extreme marine environmental exposure conditions.

Below: The completed structure, with raised ballast retaining walls (May 2005)



CATHODIC PROTECTION OF THE HISTORICAL RAIL BRIDGE OVER THE SILVERMINE RIVER

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KEY PLAYERS
Client Metrorail
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Cathodic protection specialist Craig Stevenson & Associates cc
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Specialist subcontractor Guncrete (Pty) Ltd

The composite bridge deck consists of steel railway lines encased in concrete. Mass concrete piers and abutment walls support the bridge deck. Old rails (approximately 30 kg/m) appear to be the only reinforcing in the bridge deck. Seventeen rails, each with an approximate cross-sectional area of 3,85 x 103 mm^2, have been used at 177 mm centres. In addition, the 1926 bridge deck has four rolled steel joists in each span used as additional reinforcement, two 254 x 146 mm I-section profiles with an approximate cross-sectional area of 3,99 x 103 mm^2 at 305 mm centres positioned below the travelled rail line(s). There is also limited/restricted space available between the rail reinforcement, particularly near the flange sections of reinforcement.

TECHNICAL CONSIDERATIONS

Both bridges experienced advanced deck deterioration, evidenced by large cracks, spalled and delaminated portions of the bottom concrete cover and intense corrosion of the rail reinforcement, as a result of advanced chloride-induced corrosion. It appeared that only the bridge deck is reinforced and required protection (approximately 280 m^2), while the piers and abutments were constructed from mass concrete. Limited diagnostic testing revealed that chloride levels of 2% (by mass of cement) were determined in 2001 at the level of the reinforcing steel.

Various repair options, including desalination, structural strengthening and demolition and reconstruction, were considered but were found to be not feasible.

Cathodic protection was selected as the most suitable repair option to reinstate the rail bridge after considering the technical, environmental, historical and financial implications.

In view of the unusual nature of the strengthening option a complete design was also put to tender for pricing. It was found that the cost of this option would be roughly twice the cost of the cathodic protection option.

The one concern related to the cathodic protection system was ongoing monitoring and maintenance requirements, but in view of the nature of the rail maintenance which has a electrification component, the owner did not consider this a problem.

ENVIRONMENTAL CONSIDERATIONS

An environmental scoping process was conducted to identify issues and concerns related to the proposed activities. The main issues were as follows:

- The bridges are considered to be historically significant structures in view of their age. In addition the remains of an old wooden structure and other historical artefacts were identified in the construction area during the scoping study
- Several interest groups identified the Silvermine River as a sensitive river/estuarine environment

After due consideration and public participation processes, approval for construction was granted by means of a record of decision from the relevant environmental protection authority based on contractually binding regulatory mitigation measures. Key issues were that access to the sensitive areas had to be restricted and that the sensitive river environment had to be protected and suitable care had to be taken not to disturb the watercourse and riverbanks unnecessarily.

OVERVIEW OF CATHODIC PROTECTION

Tenders were called for the design, supply of materials, technical supervision during the installation phase and the commissioning of the cathodic protection system. Noteworthy requirements of the contract document were the assurance that the cathodic protection system could achieve the full protection to the embedded rail reinforcing and a minimum 25-year service/operating life.

The design made use of titanium ribbon mesh anode located 40 mm above the bottom flange of the rail reinforcement. Eighteen runs of anode were installed midway between the rail reinforcement for each span. The anodes were secured during installation using plastic clips

The cathodic protection system was designed in four sub-zones with each bridge having a design current of 3 A per bridge (for two sub-zones per bridge). This design current density is within the maximum current density of the anode to ensure a minimum operational life of 25 years. The operation current is at present set at 1,5 A per bridge – under these conditions the anode life will be at least double.

Monitoring of the system takes place via reference electrodes, mild steel coupons and structure/sense connections embedded within the concrete overlay at various locations in the structure while the system settings and outputs are controlled by the transformer-rectifier. The cathodic protection system will attempt to achieve a significant potential shift (to more negative than –800 mV vs Ag/AgCl) or polarisation, to attain theoretical immunity, that is, cessation of corrosion.

TENDER AND CONSTRUCTION

In view of the specialised nature of the installation the construction was facilitated by way of a two-phase process.

The impressed current-protection system was designed and the embedded materials supplied under a contract for the design, supply, commissioning, and monitoring of a cathodic protection system.

The various components of the cathodic protection system were installed under a separate contract using specialist repair contractors. This contract made provision for the demolition and reinstatement of the soffit (bottom cover to reinforcement) using a sprayed concrete overlay to encapsulate the cathodic protection system. The associated structural-grade sprayed concrete overlay had strict performance requirements to ensure appropriate functioning of the cathodic protection system. The sprayed concrete overlay was applied in two layers: the primary repair, about 50 mm thick, which encapsulated all the embedded CP components and cabling, and the finishing layer, some 25 mm thick, which received a trowelled, wood-floated surface finish.

In a similar fashion to refractory-type sprayed concrete applications, steel twigs were welded to the underside of the rail reinforcement at 600 mm centres to provide a physical key to the sprayed concrete overlay. Particular specifications were formulated for the sprayed concrete overlay at design stage, and included in the contract documentation, to effectively control the presaturation of the concrete substrate and curing of the overlay using a microjet spray system.

CONCLUSIONS

Technically sophisticated repair methods such as cathodic protection can provide appropriate solutions for structures in severe marine exposure environments particularly for historically significant structures in environmentally sensitive locations. The unique reinforcement configuration, comprising old rail track sections, complicated and reduced the available repair options for this bridge. An impressed current cathodic protection was selected as the most suitable repair option after due consideration of the technical, environmental, historical and financial factors. Despite the technical complexity of the project, the installation phase was completed within the approved budget. □