STRATEGY FOR MONITORING THE LONG TERM CORROSION PERFORMANCE OF QUEENSLAND MAIN ROADS CONCRETE INFRASTRUCTURE

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SUMMARY: A range of Queensland Main Roads concrete structures have been instrumented with linear polarisation resistance (LPR) probes to determine the long-term durability performance of repair solutions in two cases and in another case put into a new tunnel roof subsequently buried under soil to assess the long term variation of corrosion activity of embedded reinforcement. The first structure instrumented in this manner was the Houghton Highway road bridge between Sandgate and Redcliffe near Brisbane built in 1979. Previous work has reported on the major repair program completed during the period 1996 to 2000 on the 500 prestressed concrete piles cracked due to alkali-silica reaction. The piles were concrete encased from 500 mm above water to 1000 mm below bed level. The additional pile section above water was wrapped in carbon fibre. The LPR probes were installed under the carbon fibre wrap at the connection to the concrete encasements and near the headstock on three piles at pier 96 in 1999. The monitoring of these piles has continued from 1999 to 2005. The second structure, Cattle Creek Bridge consisted of a prestressed deck unit bridge where a major repair was undertaken during the construction phase in 2000 to fix a large number of defective deck units. The repair of this structure has also been reported separately. As part of the repair strategy a number of LPR probes were installed in June 2001 in the repair zones of the deck units to look at the long-term performance of the rehabilitated bridge. The third structure is the Nundah Bypass Tunnel completed near Brisbane in 2001, which had 3 sets of four LPR probes installed, one near the Southern entrance, another at mid-section and the third set near the Northern exit. These 12 LPR probes were placed in the soffit of the roof slab to look at the long-term performance of the tunnel concrete in these areas. It has been concluded from all the installations that the use of the LPR technique has provided a new level of information previously not possible and given greater assurance that suitable repair techniques have been chosen and installed for the given structures. The current installations will be monitored over a longer term to provide valuable feedback to the asset owners in relation to effective repair strategies and the durability performance of these buried structures.

Keywords: concrete, corrosion, durability, linear polarisation resistance

1. INTRODUCTION

Queensland Main Roads owns and maintains a large network of concrete road bridge structures valued at several billion dollars. The stewardship of these structures involves decisions regarding repair or replace options. In the case of carrying out a repair strategy on a given structure it is usually the long term monitoring of the repair that determines the effectiveness of the particular repair strategy. Over the last 5 years several structures have been chosen for the installation of linear polarisation probes. The purpose of this work was to have a closer look at the performance of our repair solutions and be able to quantify the actual performance of repaired structures in relation to corrosion activity. In addition one new tunnel structure was chosen for the monitoring of the buried roof component which would be very difficult to access in the future for maintenance. The balance of this paper discusses the details of the three chosen structures and the short term data that has been collected over the last 5 years.

2. LINEAR POLARSIATION RESISTANCE THEORY

The relationship between the voltage response and applied current of a work electrode tends to be linear over a small range of deviation potential from the free corrosion potential of steel. Based on Ohm's Law, resistance is proportional to voltage and is inversely proportional to current. Thus, LPR of a material is defined in terms of the gradient of the potential-current graph at the free corrosion potential as illustrated in Figure I.

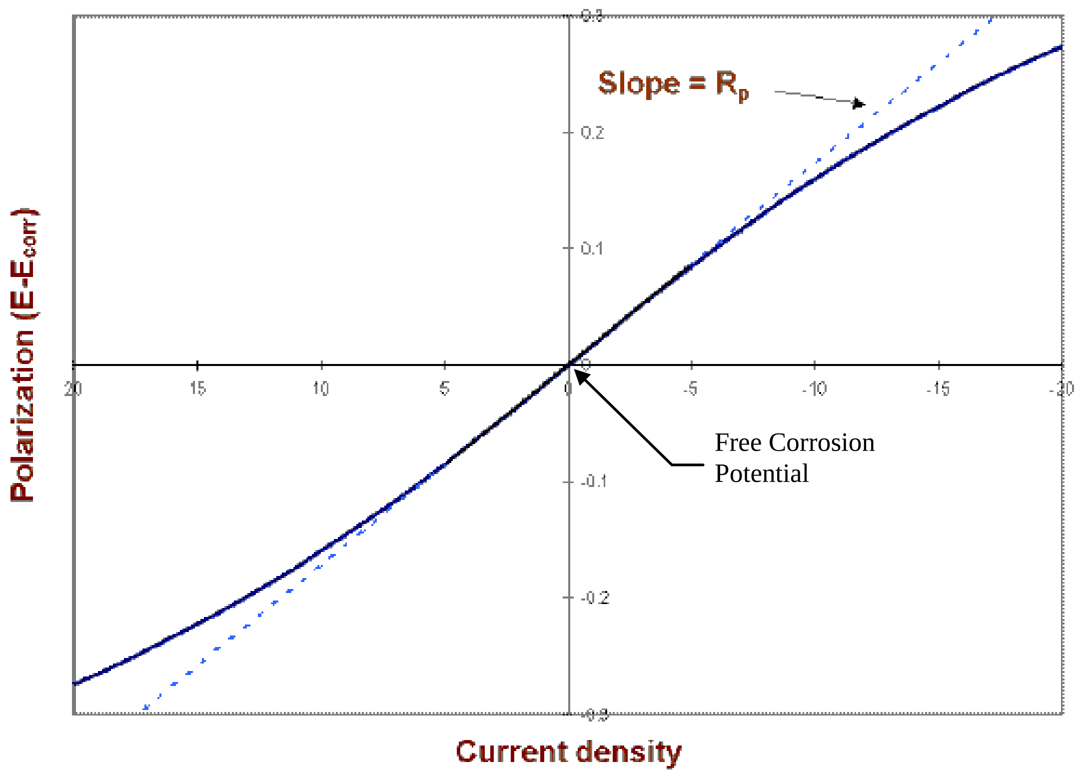


Figure I Polarisation in relation to current density

The deviation of polarisation/current density curve from the LPR slope is due to the exponential relationship between both the anodic and cathodic currents and the potential response. LPR results can be used to derive corrosion rate. It is critical to consider factors such as environmental exposures of steel in conjunction with the LPR analysis before corrosion rate is calculated.

3. HOUGHTON HIGHWAY BRIDGE

3.1 General Background

This bridge structure is 2716 metres in length and consists of 99/27.4 metre spans with 98 piers each supported on 5/560 mm octagonal prestressed piles (see Figure II). In 1992 approximately 210 of these piles were found to be cracked and in need of repair. Alkali-silica reaction in concrete was believed to cause the initial cracks, which were widened to a maximum measure of 8mm by steel corrosion at a later stage (see Figure II).

Figure II View of vertical crack in prestressed piles

Figures III shows the intervention strategy used to protect the piles on this bridge (1) at Sandgate near Brisbane. In this particular structure, the overall level of distress was generally low but would build (without intervention) within 5 years of discovery to be catastrophic. Hence, the intervention strategy adopted for this structure consisted of:

(a) Concrete encase all piles below water and to 500 mm above high water level
(b) Composite fibre encase all piles to the underside of the headstocks
(c) Insert linear polarization probes in selected piles under the composite fibre encasements for corrosion monitoring

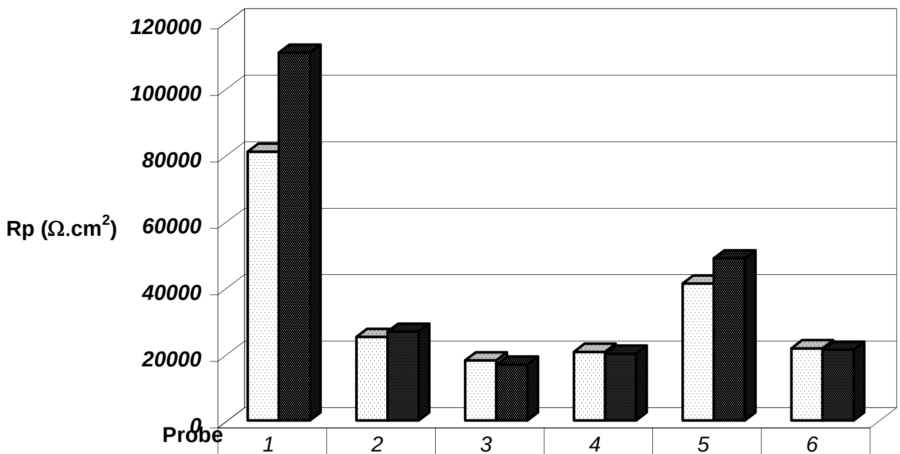
The main purpose of the wrapping carried out in (a) and (b) above was to provide a durability wrap rather than additional structural capacity. The concrete encasement was chosen for the section underwater as it would stay continuously wet and not be prone to excessive restrained shrinkage cracking. The composite fibre wrap was chosen for the section above the high water mark as it would be in a wind tunnel environment and needed to remain crack free. In addition, the appearance of the repair would be enhanced by having a slender top section leading into a thicker concrete repair in the water.

Figure III View of Concrete and Fibre Composite Encasement of Piles
Houghton Highway Bridge Sandgate-Redcliffe

3.2 Linear Polarization Probe Installation Details

Six LPR probes were inserted at pier 96 on the Northern side of the structure enabling easy access. Two probes were inserted in three separate piles underneath the composite fibre wrap. Within each pile one probe was set at the bottom of the wrap and the other near the top. The probes were installed and commissioned in August 1999 and will have been operational for 6 years at the time of this conference. Figure IV shows the general layout of the probes. Figure V shows the latest performance data.

Figure IV View of LPR probe locations



	1	2	3	4	5	6
Dec-2004 Rp (ohm.cm2)	80829	25096	18100	20624	41178	21688
Mar-2005 Rp (ohm.cm2)	110621	26654	16775	20051	48768	21237

Figure V Performance data at Houghton Highway Bridge

4. CATTLE CREEK BRIDGE

4.1 General Background

This structure consists of 12/20m spans of prestressed deck beams supported on octagonal prestressed concrete piles. In June 1999 construction was halted due to the detection of significant defects in the prestressed deck beams. This issue has been previously reported together with the method of repair (2). Figure VI shows a general view of the road and rail bridge structures. Each span of the bridge consisted of 15 roadway beams and 4 rail beams. The rail bridge had a separate superstructure but common substructure.

Figure VI General view of road and rail bridges (downstream on right)

4.2 Linear Polarization Probes Installation details

Figure VII shows a view of the installation locations for the four LPR probes inserted in the repair zones of 4 individual beams. The probes were installed by the owner to aid in the long term monitoring of the repaired beams. This bridge has a flood immunity frequency of 5 years and hence the repaired concrete beams will experience significant wetting over their design life of 100 years. The bottom surface of the beams were coated with a waterproofing material to help protect any minor shrinkage cracking that may occur in the repair grout. The probes were commissioned on the 18th June 2001. Fig VIII contains a summary of the data recorded since the probes were commissioned.

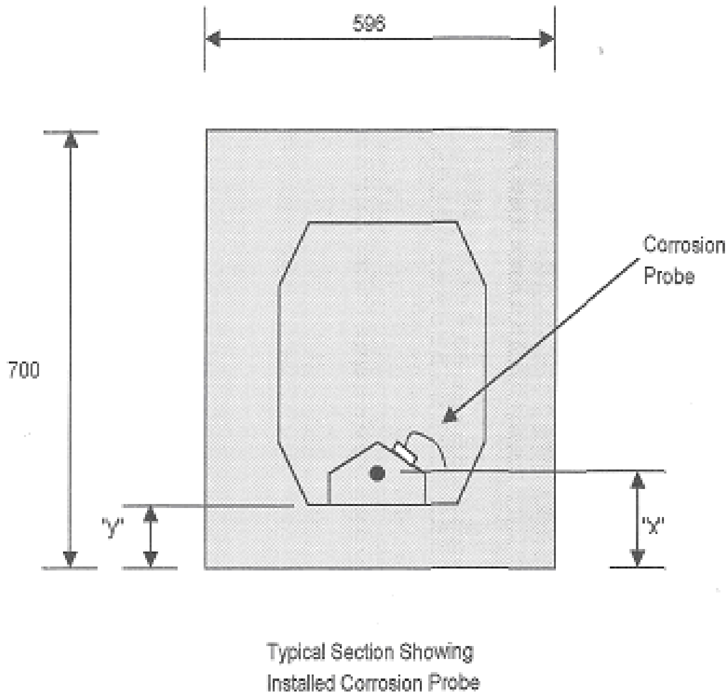
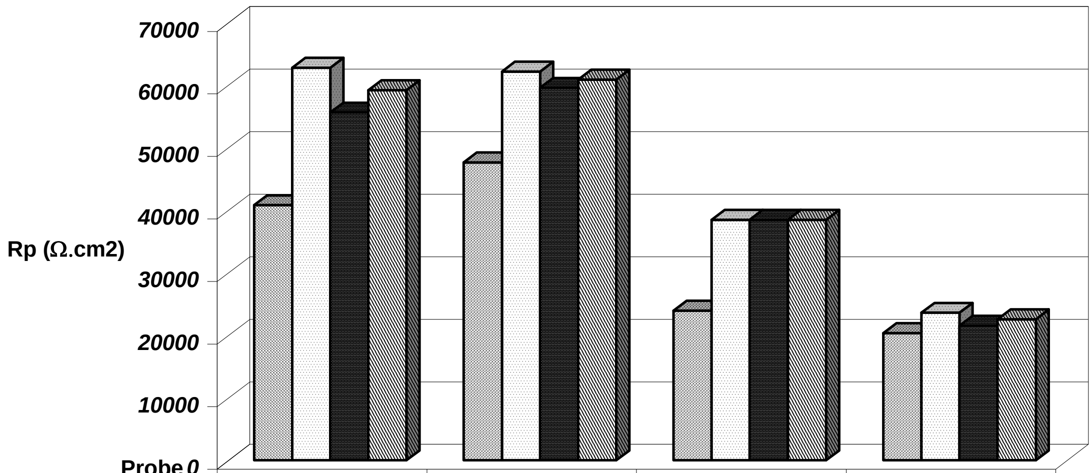


Figure VII Location of LPR probes in beam soffits



Probe	1	2	3	4
2001 Rp (ohm.cm2)	40803	47647	23959	20332
2003 Rp (ohm.cm2)	62780	62164	38461	23606
Mar-2005 Rp (ohm.cm2)	55637	59583	38450	21537
Aug-2005 Rp (ohm.cm2)	59209	60874	38455	22571

Figure VIII Performance data at Cattle Creek

4. NUNDAH TUNNEL

4.1 General Background

The Nundah Tunnel project was undertaken to provide a bypass of the local shopping area for the significant traffic on Sandgate Road. The tunnel is approximately 300 m in length and was constructed during 2000 and 2001. The first base slab pour was on the 28th November 2000. Figure IX shows a general view of the tunnel during construction.

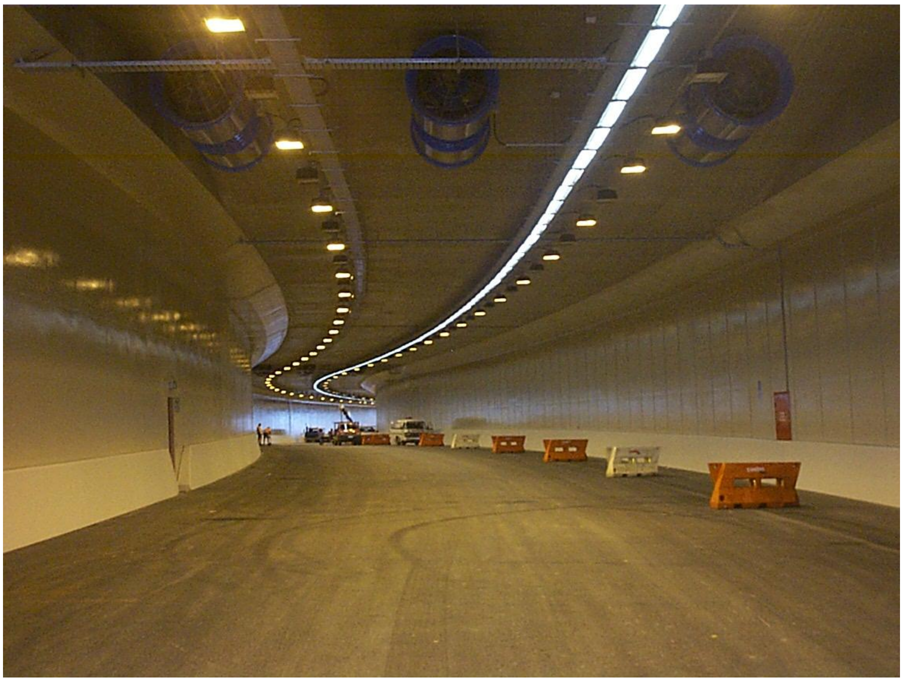


Figure IX General view of tunnel during construction in 2001

4.2 Linear Polarization Probes Installation details

Linear polarization probes were inserted at the entry, middle and exit locations of the tunnel. The probes were inserted in the soffit section of the tunnel roof during construction. The main reason for taking this action was to monitor the condition of the soffit section of the roof slab over the first 10 years of the tunnel operation. Since the roof of the tunnel was covered with fill, the monitoring was undertaken to provide the owner with the required level of confidence in the performance of the buried roof slab. Figure X shows a view of the LPR probes being installed in the roof slab and Figures XI and XII show design details. Figure XIII shows performance data. Large variations of polarization resistances at probe locations 1 to 4 were observed between the two monitoring sessions. These were attributed to the difference in moisture content in the concrete.

Figure X View of LPR probe installation

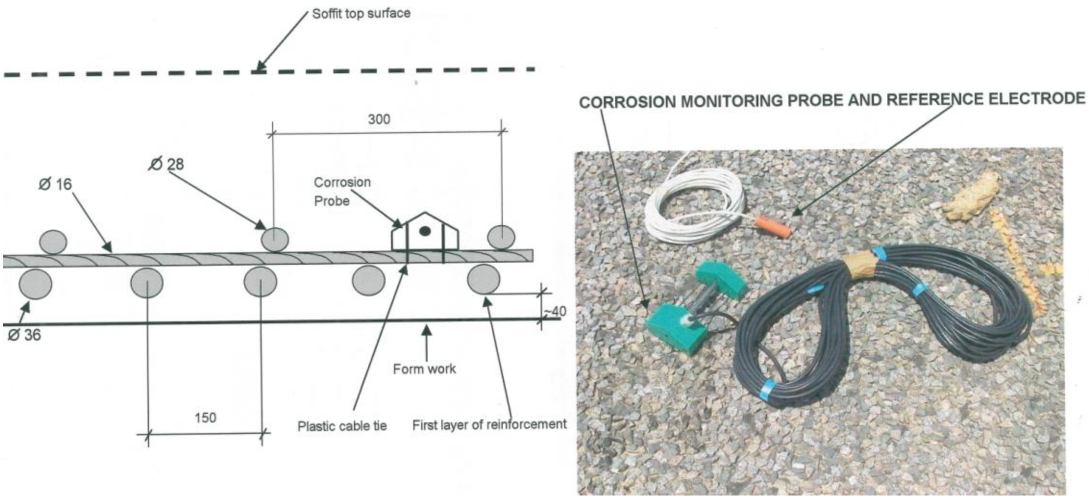


Figure XI Design details for probe locations

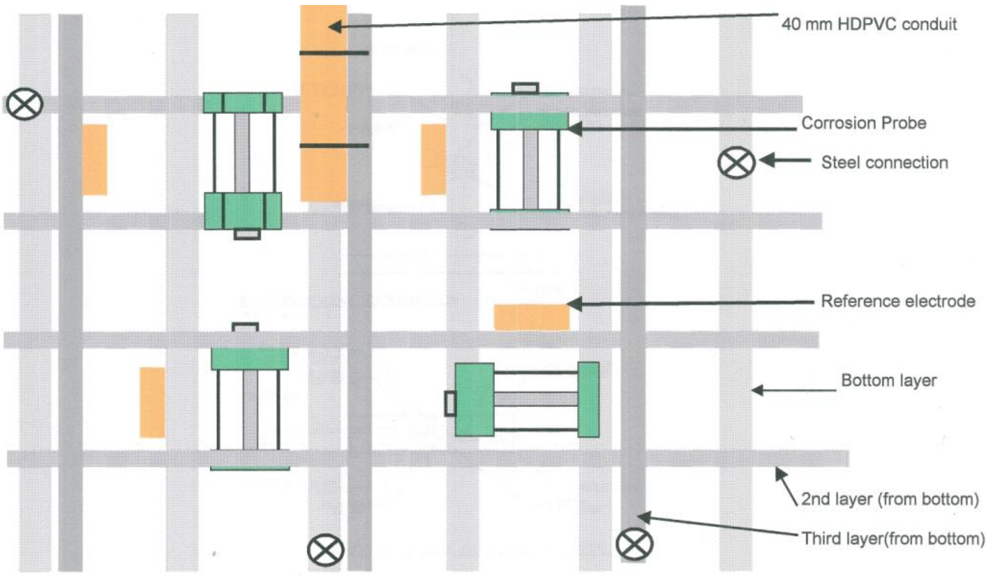
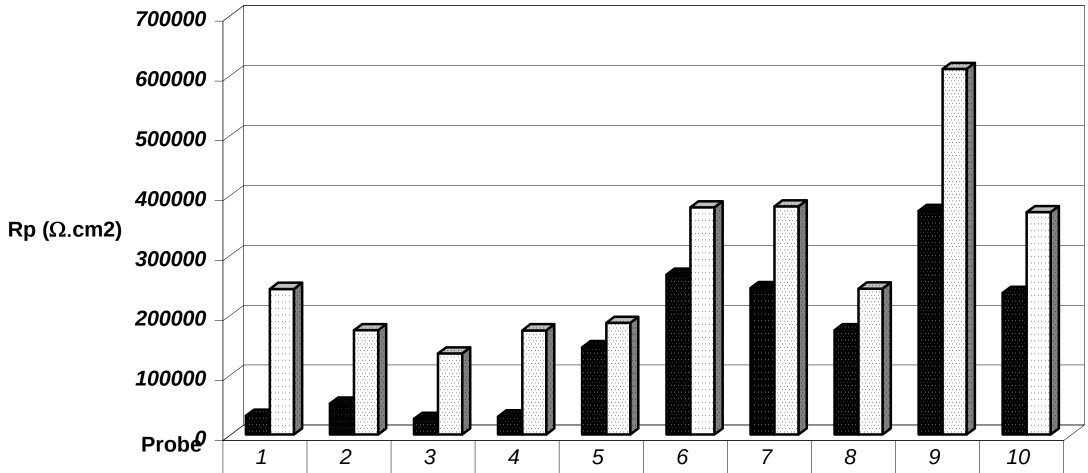


Figure XII Location of 4 LPR probes at each site



Probe	1	2	3	4	5	6	7	8	9	10
Dec-2004 Rp (ohm.cm2)	31651	51659	26252	30221	145556	266644	244352	174069	373182	236481
Aug-2005 Rp (ohm.cm2)	242963	174069	135271	173775	186364	378864	380682	243611	610000	370909

Figure XIII Performance Data at Nundah Bypass Tunnel

7. CONCLUSIONS

LPR is a continuing study and the probes shall be monitored over an extended period of time. The LPR parameters have been established and initial data has been collected at this preliminary stage, which will be reviewed and analysed when future results become available. The LPR measurements are greatly affected by the environmental exposure of the rebar. The variation of moisture content due to seasonal changes can be eliminated by taking LPR readings at both the dry and wet seasons to allow long-term comparisons. There is no doubt that corrosion monitoring using the LPR technique will provide valuable information regarding the corrosion activity of embedded reinforcement. In the future, this information can be used in conjunction with other assessment techniques for the planning of corrosion prevention measures.

8. REFERENCES

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