Realkalisation Technology for the Restoration of Multiple Bridges in Tasmania

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ABSTRACT

In Australia's rural regions, road bridges are often subject to aggressive environmental conditions. For reinforced concrete bridges, carbonation is a common mechanism of deterioration. The traditional method of repair involves the removal of all carbonated concrete followed by reinstatement using polymer modified repair mortars.

As part of a strengthening program for three bridges for The Department of State Growth in Tasmania, concrete carbonation was identified as the main cause of existing and potential corrosion problems on the bridge decks. In conjunction with bridge strengthening, and to meet the design requirement of 50 years design life, rectification of all carbonated concrete was required.

For these structures, the removal of sound (but carbonated) concrete would have been overly destructive. Concrete realkalisation treatment was considered as an alternative non-destructive option for the full restoration of the alkalinity of the concrete and for improving the corrosion resistance of embedded rebar by electrochemical means. Following a successful trial application, full realkalisation treatment was successfully completed for the three subject bridges.

This paper will outline the theory of concrete realkalisation, provide details of the realkalisation treatment for the three bridges, and will highlight how innovative technologies can successfully be adopted for extending the service life of infrastructure.

1. INTRODUCTION

The two most common causes of concrete deterioration are concrete carbonation and chloride contamination of concrete. From the moment concrete is poured, it is attacked by contaminants from the environment. These external contaminants can penetrate the concrete by diffusion through the bulk concrete, or by entry through cracks and defects. As a result, over time these contaminants can reach the surface of the steel reinforcement at which point the concrete may no longer adequately protect the embedded steel from corrosion initiation. The attack can lead to reduction in concrete alkalinity, corrosion of the steel reinforcement and further concrete cracking and deterioration.

1.1 Concrete Carbonation

Carbonation can occur when carbon dioxide from the atmosphere penetrates a concrete element. In this scenario, the capacity of the environment to attack the concrete is dependent on the permeability of the concrete. The net effect of carbonation is the reduction of alkalinity of the pore water in the concrete which is essential for the maintenance of a passive layer of film on the surface of the embedded steel. Once the carbonation front reaches the depth of the steel, the steel may no longer be protected, and the mechanism of steel corrosion and propagation can occur.

Testing for carbonation can be carried out by spraying a pH solution at breakout locations on the concrete to determine the existence and depth of carbonation. It is important to know the amount of concrete cover in a structure in order to estimate the amount of steel reinforcement which is likely located in carbonated concrete and to determine the most appropriate method of repair. If the carbonation front is limited to only a few areas with low concrete cover, the remediation work can be localised by carrying out patch repairs using a polymer modified repair system and the application of an anti-carbonation coating to the concrete surfaces to reduce the ingress of further carbon dioxide to the concrete.

In cases where the bulk of reinforcing steel is located in carbonated concrete, electro-chemical treatment such as concrete realkalisation is the only option for consideration.

1.2 Chloride Contamination

In the case of chloride attack, the chloride ions cause the passive layer to deteriorate at the location at which they come into contact with the steel. This point then becomes the anodic area on the steel and the remaining area becomes the cathodic area. In this scenario, an electrolytic cell exists because the steel is placed in different environments. The environments are connected by the reinforcing steel which acts as an electrical conductor allowing ionic transfer between the electrolytes. The anodic area (in relation to the relatively large cathodic area) can sometimes experience the rapid development of pitting corrosion on the steel at that location.

The electrochemical nature of chloride attack requires an accurate assessment of the corrosion process in order to determine the most appropriate repair method. A combination of various tests including assessing the level of chloride content in the concrete at the vicinity of the steel, concrete resistivity testing, cover to reinforcement measurement and half-cell potential mapping (1) are some the most common techniques used for the assessment of the extent of reinforcement corrosion.

Cathodic protection is the most common technique used for the protection of chloride contaminated concrete structures.

1.3 Practical Application of Realkalisation Treatment

Concrete carbonation was identified by the Department of State Growth as a corrosion risk for the embedded rebar in the deck soffits of three bridges in Tasmania. The structures were B907 Blanchards Creek Bridge, B898 Tullochgorum Creek Bridge, and B2852 Rostrevor Rivulet Bridge.

In conjunction with the planned strengthening of these bridges, concrete realkalisation treatment was selected as a method to increase the alkalinity of the concrete and restore the passive protective layer around the embedded steel in the soffits of these bridges.

In order to verify the viability of realkalisation treatment for the concrete deck soffits, concrete testing of the deck soffits was performed. The testing included cover-to-reinforcement measurement, carbonation testing, electrical continuity testing and inspection of rebar at breakout locations. In addition, realkalisation trials were undertaken at B907 Blanchards Creek Bridge and B898 Tullochgorum Creek Bridge. The testing indicated that a large percentage of the first layer of reinforcing steel in the soffits of the three bridges was located in carbonated concrete. The trial work confirmed a suitable realkalisation reservoir for the proposed realkalisation treatment and the viability of the realkalisation treatment to restore the alkalinity of the concrete and re-passivate the embedded rebar for these bridges based on NACE SP0107-2021, *Electrochemical Realkalization and Chloride Extraction for Reinforced Concrete*”.

2. REALKALISATION TREATMENT

Concrete realkalisation is a method used to stop and permanently prevent reinforcement corrosion in carbonated concrete structures by increasing their pH to a value greater than 10.5 which is sufficient to restore and maintain a passive oxide film on the steel.

Realkalisation involves a technique whereby a current is passed through the concrete to the steel reinforcement by means of an externally applied anode which is temporarily attached to the concrete surface. A paste of sprayed cellulous fibre or textile cloth with a solution of potassium or sodium carbonate is used as the electrolyte covering the concrete surface.

The net effect of realkalisation includes its effect on the concrete and steel reinforcement. The alkaline solution is transported into the concrete mass under the influence of a low voltage electrical current. This raises the concrete pH level to greater than 10.5. With regard to the effect on steel reinforcement, the alkalinity is increased at the steel surface by production of hydroxyl ions. This reinstates the passive film on the steel, which protects from further corrosion.

The realkalisation process requires minimal repair work of the concrete, especially the need to break out concrete behind the reinforcement, which is in itself a noisy, dusty and expensive exercise. The realkalisation process takes approximately one to two weeks to complete.

<u>Some of the other features of this technology are</u>:

- Environmentally friendly: For concrete remediation works using realkalisation treatment, there is a major reduction for concrete breakout.
- Low maintenance: There is no ongoing maintenance requirements.
- Long-term global protection: Realkalisation can provide effective treatment for the entire area of application.

2.1 The Realkalisation Process

For each of the bridge soffit areas subject to realkalisation, the work process included the following steps:

1. All paint and coatings were removed from the concrete surfaces.
2. Concrete delamination testing was performed to all areas subject to realkalisation treatment.
3. All spalled, cracked, and delaminated areas were marked out on the concrete surface and repaired before commencing the realkalisation process.
4. Any other defects on the concrete including open cracks and construction joints were also repaired prior to starting the realkalisation treatment.
5. Continuity of the embedded steel reinforcement in the realkalisation areas, and continuity of the embedded steel reinforcement with any metallic features located within the realkalisation zone were tested. Where required, continuity was established by welding a 4-6 mm diameter mild steel bar of suitable length between the isolated reinforcing bars and the nearest electrically continuous main reinforcement bar or ligature.
6. The minimum required cover for the realkalisation treatment was 10 mm. For any areas with exposed rebar due to low concrete cover, minor build-up was adopted to achieve the minimum cover.
7. Reference cores were extracted from the concrete prior to the realkalisation treatment.
8. Potassium carbonate and sodium carbonate were used for electrolyte.
9. pH strips were used to check the pH of the mixed electrolyte before spraying to ensure that the electrolyte had a pH reading above 12.
10. The realkalisation reservoir includes steel mesh sandwiched between two (2) layers of textile cloth.
11. The realkalisation reservoir was continuously wetted with electrolyte for the duration of the treatment.
12. The anode and rebar connections were extended to the temporary MicroNex power supply realkalisation unit.
13. The MicroNex power supply unit used for this project has the capacity of recording the A-h/m² delivered to the steel surface for each circuit.
14. Following the completion of the targeted 200 Ampere-hours/m², cores were extracted to perform pH testing using pH solution.
15. Subject to the verification of the achievement of the applicable protection criteria, the realkalisation reservoir and all cables were removed.

2.2 Protection Criteria

The protection criteria used were in accordance with NACE SP0107-2021, *Electrochemical Realkalization and Chloride Extraction for Reinforced Concrete (2)*. Based on the standard requirements, at least one of Criteria A or B below shall be used:

Criterion A - Ampere-hours per square meter of steel surface area: A treatment of 200 A-h/m^2 delivered to the steel surface is a suitable minimum target.

Criterion B - pH Level: The effectiveness of the ER process is demonstrated by pH testing using phenolphthalein solution in each anode zone with the extent of ER indicated by pink coloration surrounding the reinforcement to a minimum of 10 mm or the bar diameter, whichever is greater.

3. CONCLUSIONS

For the subject bridges affected by concrete carbonation, realkalisation treatment was selected as the most viable and the only practical remediation method. The only alternative option to realkalisation was the full removal of carbonated concrete and the reinstatement of breakout areas using polymer modified repair mortar which is generally a highly destructive procedure.

Realkalisation treatment was suitable for this project as full concrete breakout could only be performed in stages due to structural considerations and would require costly traffic control during the execution of the work. Therefore, a major reduction in concrete breakout and effective long-term global treatment was achieved by adopting realkalisation treatment.

The realkalisation treatment of these bridges is a typical example of how an innovative technology was used to extend the life of infrastructure assets.

4. REFERENCES

1. Chess P & Grønvold F, "Corrosion investigation - a guide to half-cell mapping" pub. Thomas Telford Service Ltd, (UK) 1996

2. NACE SP0107-2021, *Electrochemical Realkalization and Chloride Extraction for Reinforced Concrete*

5. BIOGRAPHIES

Atef Cheaitani is the Managing Director of Remedial Technology Pty Ltd. Atef's expertise is in the assessment and development of rehabilitation solutions for reinforced concrete structures using electrochemical applications. Atef has pioneered the introduction of cathodic prevention technology to Australia, China and India and has been involved in the development of various patented technologies associated with cathodic protection of concrete structures.

Duncan Murrell is a Site Engineer at Pensar Structures and has delivered multiple projects across Tasmania and Queensland. These projects involved concrete rehabilitation, coating and strengthening on bridges, reservoirs, and promenades.

Craig Mc Phillips is the Rehabilitation Manager at Pensar Structures and has over 16 years of experience in concrete remediation and specialist coatings. His experience varies from large marine infrastructure rehabilitation projects through to concrete rehabilitation of water treatment plants. In recent years Craig has held management/leadership roles which have allowed him to lead his team from the tender stage right through to project delivery

Jamie Horan is the Operations Supervisor at Pensar Structures and has over 25 years of experience in structural remediation, strengthening and protective coatings. Jamie has delivered complex solutions for numerous reinforced concrete structures including marine, rail and road infrastructure as well as high rise buildings, reservoirs, water and wastewater assets. Jamie has also been involved in several landmark projects both nationally and internationally.