

Pros & Cons of Chemical & Electrochemical Corrosion Protection Techniques for Reinforced Concrete Structures

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1.0 Introduction

It is well known that one may make use of several electrochemical techniques in order to repair the concrete structures damaged due to reinforcement corrosion or to protect the new ones in highly aggressive environment. None of the techniques are universally applicable or completely foolproof or always economically viable. Hence a repair professional has to appreciate the merits and limitations of these techniques. The various pros and cons of the following methods that are quite prevalent in the construction industry are discussed herewith.

2.0 Corrosion inhibitors

Diffusing corrosion inhibitors into the concrete to protect the steel is a relatively new approach to concrete repair. The range of inhibitors is quite large, viz., several proprietary formulations of vapour phase inhibitors based on amino alcohols that create a molecular layer on the steel to block corrosion; monofluorophosphate that may create a highly alkaline environment as it hydrolyses in the concrete; calcium nitrite (an anodic inhibitor) in a mixture, to help penetration into concrete. The use of calcium nitrite as a corrosion inhibiting admixture in the concrete mix is well established. However, trials of inhibiting treatment in hardened concrete after corrosion damage are comparatively recent.

The main advantage of corrosion inhibitors is that the application is comparatively inexpensive and simple for any element with an accessible surface. However, the knowledge and understanding of the range of inhibitors is limited. The issues that need consideration in this context are their penetrability into concrete, uniform and effective spread along the rebar network, corrosion suppression capability, time-dependent effectiveness, the level of corrosion that can be countered, etc. Since answers to all these queries are not readily available, the use of corrosion inhibitors is restricted to concrete having carbonation or low-to-moderate chloride levels (less than one percent by weight of cement), low reinforcement cover (less than 20 mm), etc.

3.0 Cathodic Protection

Cathodic Protection has certain variants. The oldest and the most well established, is the "Impressed Current Cathodic Protection (ICCP)". The technique involves the application of a low voltage DC (typically 10V at 1A) from

a permanent anode usually positioned on the concrete surface to the reinforcing steel. There are a number of anode types which include conductive coatings, overlay system (coated titanium mesh in sprayed concrete), etc. New anodes are being continuously developed. It appears that if carefully designed, an ICCP system can provide a less invasive method of concrete repair than traditional methods. For long residual service life (say, 20 years or more) the life cycle cost analysis of ICCP often appears favourable. However, the ICCP system requires continuous monitoring for the life of the structure by suitably trained persons. Further, this method cannot be applied to elements containing prestressing steel or structures susceptible to ASR or with a lot of electrically discontinuous steel and so on.

Another variant of Cathodic Protection is the use of galvanic or sacrificial anode, often acronymed as GP. The sacrificial anodes, composed of a more reactive metal than steel (usually zinc), corrodes preferentially to the steel as a result of a difference in potential between the two metals, thus providing the necessary current required to maintain the reinforcing steel in a cathodic state. However, since concrete has a high resistance, galvanic systems are usually applied to structures in very wet conditions such as in tidal marine exposure. Recent developments are leading to trials of humectants, which humidify the concrete and lower the resistance, making galvanic cathodic protection more viable in a wider range of applications.

A third variant of Cathodic Protection, known as Discreet Galvanic Anode System (DGA), utilizes sacrificial anodes buried in a patch repair in order to provide localized protection to reinforcing steel. These galvanic anode units have been specifically developed to complement traditional patch repairs and consist of zinc anodes encased in a specially formulated mortar to maintain long-term galvanic activity of zinc. This is a simple and yet effective method of avoiding the transfer of corrosion to the previously protected region in which the incipient anode effect is observed.

4.0 Electrochemical Chloride Extraction

This method, often abbreviated as ECE, refers to a process of reducing chloride ions from the surroundings of reinforcing steel in contaminated concrete down to a level below the threshold limit for corrosion. In this process a temporary externally mounted metallic anode as shown in Fig. 1 is embedded into an alkaline electrolyte reservoir and a current (typically 1 A/m² of concrete) (Fig. 2) is applied to the reinforcing steel which becomes the cathode. The negatively charged chloride ions are repelled away from the negatively charged reinforcing steel and migrate towards the positively charged anodic mesh (Fig. 3). Simultaneously, the electrolytic production

of hydroxyl ions at the steel surface also results in the displacement of chloride ions and subsequent repassivation of the steel with an effective buffer zone.

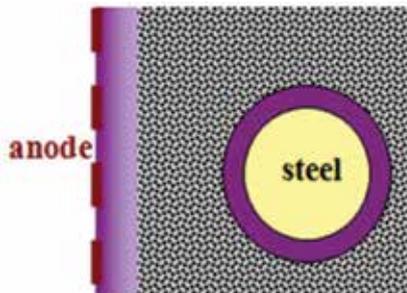


Fig. 1: Installation of metallic anode for electrochemical chloride extraction

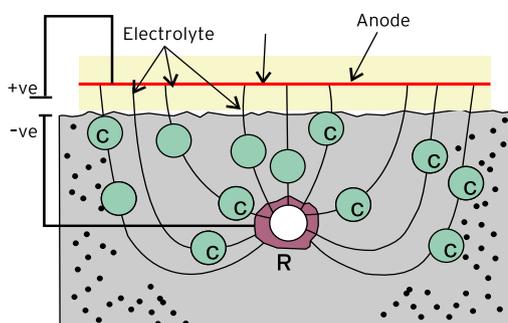


Fig. 2: Making rebar as cathode by installation of external current

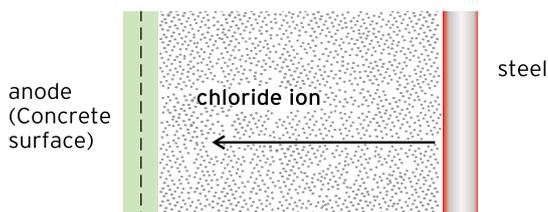


Fig. 3: Negatively charged chloride ions being migrated towards the positively charged anodic mesh

ECE is observed to be at its best where the steel is reasonably closely spaced, where the chlorides have not penetrated too far beyond the first layer of reinforcing and where future penetration of chlorides can be excluded. The treatment reportedly takes about 8 weeks. On completion the current is switched off, and the external anode with its electrolyte reservoir is removed and discarded, as there are no ongoing monitoring requirements. Thus, one may take it as a one-off treatment. But it might be worthwhile to consider that the problems with isolated steel, prestressing, ASR, etc., mentioned for ICCP, are exacerbated for ECE owing to the higher voltages and current densities.

5.0 Electrochemical Realkalization (ERA)

This is generally regarded as the equivalent of ECE for structures where the carbonation has progressed to unacceptable depths. ERA works on the basis of electro-

osmosis and is used to realkalise carbonated concrete by making the existing reinforcement as the negative electrode or cathode and by installing a temporary external metallic anode mesh embedded in a disposable electrolyte mass containing a molar potassium carbonate based solution. On applying a voltage between these electrodes, the electrolyte is drawn towards the reinforcement. The movement results in ionic migration under the influence of the applied current and electro-osmosis. This action pulls the ERA electrolyte into the concrete pores. In the course of 7 - 10 days the concrete gets saturated to beyond the cover zone with the alkaline solution reinstating the pH level to the desired extent. The schematic representation of electrochemical realkalization is shown in Fig. 4.

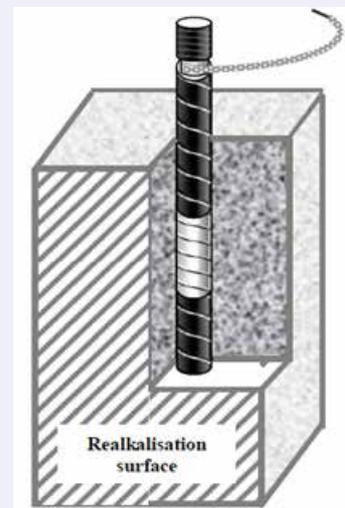


Fig. 4: Schematic representation of electrochemical realkalization process

6.0 Conclusion

From the above discourse, it is evident that adequate knowledge of the electrochemical process of reinforcement corrosion is necessary in order to understand, assess, and specify the most appropriate repair technique. It is well known that since 1980s the main focus of concrete repair research has been on the electro-chemical methods to protect the reinforcement against corrosion. These research efforts have yielded different options as narrated above with varying advantages, disadvantages and applicability. But the practices have shown that in the case of chloride induced corrosion that it is more prudent to undertake the prior diagnosis of the whole concrete surface than taking discreet samples from certain selected points. The potential mapping in close parallel lines over the entire surface gives the information of the probability of corrosion over the whole investigated surface. The potential maps are a basis to decide which repair methods should be used in which areas.