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Repairing to Extend the Lifespan: the Multi – Strategy Criteria

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The paper aims to describe the story of the "APS Terminal Petroleiro Access Viaduct", located at Sines, south of Portugal, some ten metres distant from sea, a prestressed reinforced concrete structure with a very low thickness of concrete cover that has been exposed, since its construction, to a heavily aggressive marine environment.

The careful survey that has taken place before the rehabilitation works showed that the main cause for the decay of the concrete in the viaduct was the reinforcement corrosion due to the high chloride content at the reinforcing steel, as shown in the Table bellow:

Minimum reinforcement cover		Depth of carbonation	
Piers	1,8 – 3,0 cm	Piers	0,1 – 0,6 cm
Deck	1,1 – 2,3 cm	Deck	0,1 – 2,3 cm
Abutment	2,1 – 3,5 cm	Abutment	0,5 – 1,8 cm
Chloride content referred to weight of cement around reinforcements		Probability of active corrosion	
Piers	0,11 % - 1,26 %	Piers	Minimum
Deck	0,42 % - 1,12 %	Deck	50 % - 95 %
Abutment	0,52 % - 0,81 %	Abutment	Minimum to 50 %

The adopted repair system has favoured the removal of the aggressive substances from the concrete (desalinisation) instead of using surgical treatments (concrete removal), that has been used only when indispensable (spalling).

As this work involved removal of a lower volume of contaminated concrete than initially foreseen as well as the elimination of the cause for the deterioration of the structure, the final cost was much smaller than the amount initially foreseen.

Desalination of concrete is an electrochemical treatment intended to stop and avoid corrosion of steel in reinforced concrete when it is contaminated by chlorides and to reduce the chloride content to permissible values by applying an electric field (a current with a density nearly equal to 1 A/ m_) between the concrete reinforcement and an external anodic system, a titanium mesh fastened to the structure by insulating nails in plastic material and coated through projection of cellulose fibres, forming the electrolyte as the fibres are kept damp.

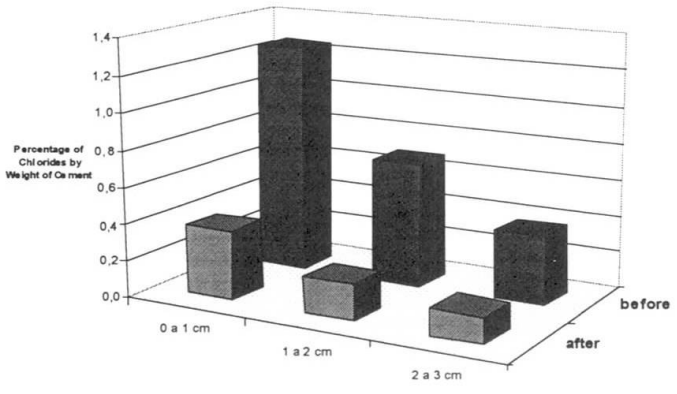
During the treatment, the negative chloride ions migrate to outside the concrete whereas an electrolysis phenomenon occurs on the reinforcement surface to produce alkaline environment and re-passivation. Moreover, the attraction of positive ions towards the reinforcement zone leads to compactness and imperviousness of concrete around the reinforcement steel.

Since the reinforcement cover was less than 10 mm in some zones, the thickness of the cover was improved by shotecreting (dry mix procedure), in order to ensure a minimum cover of 40 mm. The defective zones of the structure were repaired with similar procedures.

An automatic system has been used to monitor desalination, which includes a computer-controlled rectifier unit controlling each cell. In real time the control system informs the operator of any failure or of anomalies that can be solved so that the process may reliably and efficiently go on. This system also allows the operators to control the indicators of the evolution of the process, such as resistance, intensity of current, quantity of Amperes $\times$ hour per m_ of reinforcement so far supplied to the cells.

Each desalination cell shows differences in concrete resistivity (depending on moisture in concrete or on the extent of repaired areas), reason why drawings are previously prepared to indicate location of the cell, its designation and the zones repaired are mapped as well as the control points for chloride content. This information is of utmost importance during the work, to permit to interpret both messages pointing to error of the system and the values that indicate the evolution of the treatment.

About once in a week, the structure' s concrete is sampled for the determination of the chloride content and to support de decision of concluding the treatment, if the required level (less than 0,3 % of the cement weight) is achieved. Now, desalination is in progress and the removal of chlorides has already been successfully performed on 1400 m_. Values of about 0,2 % of cement weight were obtained at reinforcements, against the initial values of about 0,6 % (see figure bellow).



Subsequently it was decided to perform the protection of the structure by applying an appropriate painting structural rehabilitation, thus characterising a multiple strategy of interventions regarding the durability of the construction.