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Assessment and Repair of a Concrete Dockyard

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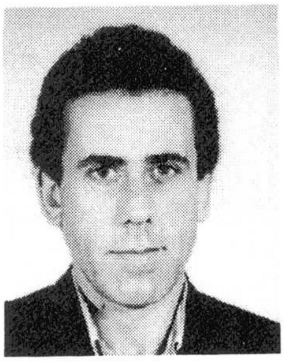

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Summary

Chloride induced corrosion is the main cause of distress of concrete structures exposed to the marine environment. This deterioration mechanism is very fast and often leads to a reduced service life. In this paper, results are presented of the condition survey and the repair methodology of a concrete dockyard, localised in the west coast of Portugal. The dock, with dimensions of 350 x 55 m, was built in 1974-75 and exhibits severe deterioration due to reinforcement corrosion. Some evidence of chemical attack on concrete has also been observed. Several tests including concrete chloride content analysis, concrete resistivity, potential mapping, corrosion rate measurements, petrographic analysis and scanning electron microscopy have been performed to allow a careful diagnosis and a full understanding of the deterioration process.

Keywords: reinforcement corrosion; concrete deterioration; marine environment; concrete repair; concrete dockyard

1. Introduction

This paper presents a condition survey and the repair methodology to be implemented on a concrete dockyard presenting significant deterioration. The structure (dock 22) is integrated in a large complex belonging to a shipyard, located in the estuary of river Sado, in the west coast of Portugal.

The shipyard has three reinforced concrete docks (docks 20, 21 and 22) built during the 1973-1975 period. The quick deterioration of the structures led to a first intervention in 1984. At the time, 3.600m^2 of the internal face of the walls of dock 20 have been repaired. In 1988, 5.600m^2 of the internal face of the walls of dock 21 have also been repaired. The other part of the walls of docks 20 and 21, corresponding to a total area of 23.400m^2, has been repaired in 1991.

Dock 22 has been built with a low quality concrete. The concrete mix used presented a quantity of cement of 300 Kg/m^3 and a water/cement ratio of 0.7. The concrete covers specified for the structure were 4 cm for the walls and 6 cm for the bottom slab. Tests have been done to determine the concrete behaviour. As regards the compressive strength, a characteristic value of 17.6 MPa has been obtained for the walls and 20.6 MPa for the bottom slab. The concrete of the walls presented a water permeability coefficient of 14x10^{-11} m/s and the concrete of the bottom slab exhibited a value of 0.6x10^{-11} m/s. The open porosity measured on the concrete of the walls and slab was 17.8 and 16.4% respectively.

2. Assessment of deterioration

To assess the deterioration condition of the structure a survey plan has been established, which involved the following phases: visual inspection and in situ and laboratory tests.

The main type of deterioration observed in the visual inspection has been the delamination and spalling of the concrete cover caused by reinforcement corrosion. It has been verified that the deterioration presents significant differences in the various zones of the dock associated to different exposure conditions. The walls of the dock exhibited a deterioration rate much higher than the one observed on the bottom slab. Generally, it has been verified that the walls presented a delamination higher than 30 % of their area, whereas on the bottom slab the area of delaminated concrete was about 10%.

The chloride contents measured at the reinforcement level range usually from 2 to 4% of the cement mass. The carbonation depth of the concrete is comparatively low. The maximum values measured are about 20 mm, values less than 10 mm having been usually obtained.

Tests on the electrical potential of reinforcement at the zones without delamination showed values ranging from 300 to 400 mv, reaching values of about 500-600 mv on some places. The values measured for the resistivity of the concrete range generally from 1.5 to 3 KΩcm on the walls and are below 1.5 KΩcm on the bottom slab. The values of the instantaneous corrosion rate measured on the bottom slab are within 17 to 23 μm/year.

The petrographic and microscopic analysis showed that the superficial concrete layer with thickness of about 10-40 mm presented evidence of chemical attack of concrete by magnesium salts and sulphates from seawater.

3. Repair methodology

In view of the high deterioration level of the dock, the extensive contamination of the concrete by chlorides as well as the deterioration of the superficial layer of the concrete by chemical attack, a repair methodology has been selected. This consists of the total removal of the superficial concrete layer and its replacement by a new high quality concrete surrounding the reinforcement. The minimum cut depth of the concrete is 10 cm, thus ensuring the cut of the concrete of at least 2 cm beyond the reinforcement. The specified concrete cover is 6 cm.

The owner intended a service life for the work of about 20 years. This period can be ensured using this repair methodology, as indicated by the results obtained through monitoring of repairs performed on other docks of the shipyard in 1990-92.

The specifications imposed as regards the concrete to be adopted for repair were as follows:

Composition:	$A/C \leq 0.4$		
	Cement	$350 \leq C \leq 400$ Kg/m^3	
	Micro silica	$15 \leq C \leq 30$ Kg/m^3	
Properties:	Water permeability	$d \leq 20$ mm (ISO 7031)	
		$K_w \leq 1x10^{-12}$ m/s	
	Capillary absorption	$a \leq 0.1$ mm/min$^{0.5}$	
		$h \leq 10$ mm (4 hours)	
	Chloride diffusion	$D \leq 1x10^{-12}$ m^2/s	

The specification of these properties is related with the transport mechanisms into the concrete that occur inside the dock: permeation, absorption and diffusion. A monitoring system has been specified for the repair works to follow the evolution of the penetration of the critical chloride content and assessing the parameters having highest influence on the corrosion rate: resistivity, temperature and concrete moisture.