DURABILITY AND REPAIR OF REINFORCED CONCRETE IN DESALINATION PLANTS

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Keywords : Corrosion, Passivation, Salt weathering, inhibitor, Reinforced

Contents

Summary

Reinforced steel in concrete in desalination plants is at great risk of corrosion due the presence in abundance of chlorides and moisture. To reduce the risk of corrosion, concrete of low permeability with a good cover to the steel must be used. However, this is not sufficient and additional protection systems are required. The most effective include cementitious crystalline waterproof systems, inorganic copolymer liquid waterproofing admixture and calcium nitrite corrosion inhibiting admixture. Once corrosion has occurred, a number of methods can be used for repair. Periodic monitoring of reinforced concrete structures helps in identifying problems at an early stage which makes repair less costly, less disruptive and more likely to be durable.

1. Introduction

Reinforced concrete is widely used throughout the world in all types of structures as a durable and cost effective construction material. Desalination plants are no exception.

Reinforced concrete structures in desalination plants include inlet and outlet structures, foundations supporting equipment, pipes and walkways, tanks, etc.

The reinforcing steel in these structures is at great risk of corrosion because they handle seawater and concentrated brine. The chloride salts and the presence of moisture promote both earlier initiation of corrosion and more rapid corrosion rates. For desalination plants in the Arabian Gulf, the risk of corrosion is even greater because of the highly saline atmosphere of the Gulf, the aggressive ground conditions, the contaminated concreting materials, and the high temperatures. Not surprisingly, severe corrosion has been reported in reinforced concrete structures in desalination plants (Bashenini et al. 1994).

In such environments, it is essential to produce a high quality dense concrete with sufficient concrete cover to the embedded steel. However, even this is not enough to ensure a long life for reinforced concrete in desalination plants. Additional protective systems are required.

2. Corrosion Mechanism

When steel is placed into an alkaline environment such as concrete the first reaction is:

$$Fe \rightarrow Fe^{2+} + 2e^{-}$$

Later reactions will convert the Fe^{2+} to $Fe(OH)_2$, $Fe_3O_4 \cdot nH_2O$, or γ-FeO·OH at the steel surface. In the absence of chlorides, all phases are stable in alkaline environments and the steel is passivated but γ-FeO·OH is most stable in the presence of chlorides or other depassivating ions (Schiessl 1988).

On a microscopic scale, there will be regions where γ-FeO·OH is not present and the chloride can complex with the Fe^{2+}. The resulting complex can migrate from the steel surface and then subsequently convert into an expansive corrosion product.

The presence of moisture in the concrete is essential for corrosion to take place because it acts as an electrolyte allowing ions to move between anodic and cathodic sites and it takes part in the cathodic reaction.

Desalination plants represent the most severe environments for reinforced concrete since both chloride salts and moisture are present in large quantities.

Another way in which corrosion can occur is through carbonation of the concrete. Carbonation is the penetration of carbon dioxide from the atmosphere into the concrete. This carbon dioxide reacts with the alkaline materials in the concrete and converts them to carbonates. This results in a lowering of the pH of the concrete to below the level that is necessary to maintain the passivating layer. When the concrete around the steel becomes carbonated, corrosion occurs. Generally, when the concrete cover to the steel is adequate, carbonation will not be a problem. In desalination plants, chlorides are a much bigger problem than carbonation.

3. Steps to Improve Durability

The first step in improving durability of steel reinforced concrete in desalination plants is to improve the concrete quality. The chloride contamination of the concrete constituents must be reduced to a minimum by proper controls and sourcing of materials. The water-to-cement ratio must be kept below 0.42 and proper placing, compaction, and curing procedures must be followed. The minimum concrete cover to embedded steel must be greater than 50 mm. However, there is a limit to the increase of the concrete cover. Excessive cover can be harmful in many cases, especially in beams. Figure 1 illustrates how the greater the cover or the better the quality of the concrete, the lower the chloride concentration at the steel level. However, even if concrete is produced to these stringent guidelines, extensive laboratory testing and field data indicate that chloride will ingress into the concrete and that corrosion will occur (Berke et al. 1992).

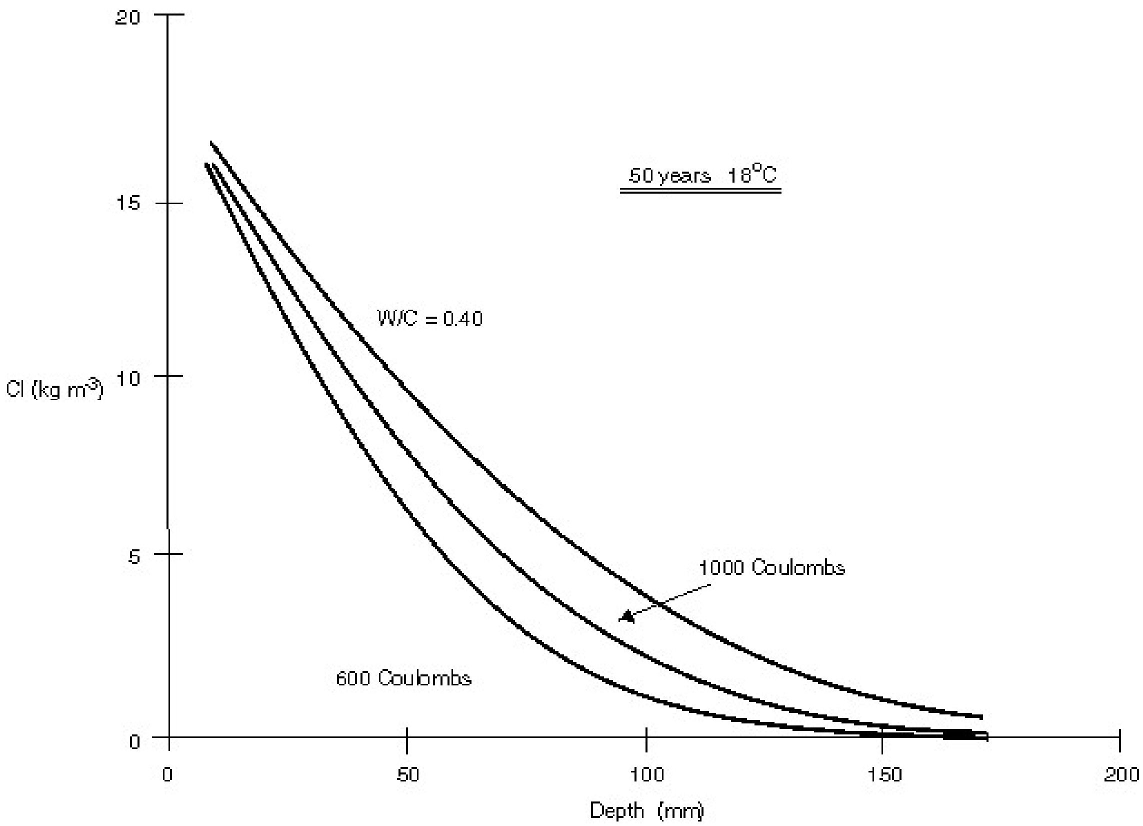

Figure 1. Sea wall profiles at the splash/tidal zone.

Corrosion of steel in concrete will be initiated when the acid-soluble chloride ion concentration exceeds about 0.20 per cent by weight of cement. In the Arabian Gulf, such a chloride level is exceeded through contaminated original concrete mix constituents in many cases and corrosion will occur even without additional chloride ingress (Matta 1992).

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