Transactions of the SAEST VOL. 38 No. 2 Apr.-June 2003 53–56

Corrosion of Reinforced Concrete Exposed to Marine Atmosphere

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The reinforced concrete exposed to marine atmosphere deteriorates very fast resulting in the corrosion of reinforcement. Corrosion of reinforcement reduces the life of the structure. It is impossible to estimate accurately the loss resulting from corrosion. In 1925, FRANKN. Speller estimated roughly that the renewal of iron and steel products such as roofing, wire, tubes and pipe, oil-well equipment, steel coal cars and many other steel or iron structures subject to corrosion because of inadequate or no protection amounted annually to about 2 percent of the total tonnage of such products in use.

In this paper the corrosion, the facts established with respect to corrosion, the nature and mechanism of corrosion, typical chemical reactions of the corrosion process; corrosion measurements, corrosion control methods:- cathodic protection methods, protective coatings, admixtures and incubations; The corrosion measurement techniques are presented. Wherever possible the examples are given. The corrosion in the Tuticorin marine environment is presented.

Key words: Corrosion, cathodic protection, incubator, coating, marine environment.

Introduction

The reinforced concrete structures located near the seashore behave differently. The durability of RCC structures exposed to marine atmosphere affected very fast leading to decrease in the service life of the structure to a great extent. The corrosion of reinforcement is very much predominant in the RCC structures, subjected to marine environment.

The replacement cost (due to corrosion), loss of time and production, and consequent damages are usually many times the cost of the new metal required for replacement [1].

In the 1938 an American coordinating committee on corrosion was organized with official representatives from 17 national technical societies or organizations. In 1944 the National Association of Corrosion Engineers (NACE) was organized and in 1948 took over the formal coordinating committee and appointed a special inter-society committee. Thus the corrosion problem taken is of importance.

Corrosion

All metals when exposed have tendency to change to another form. The example is rapid formation of iron rust, when the metal is brought in contact with air and water. The rusting of irons is a simple reaction, creates a complicated problems in RCC structures especially located in marine environment.

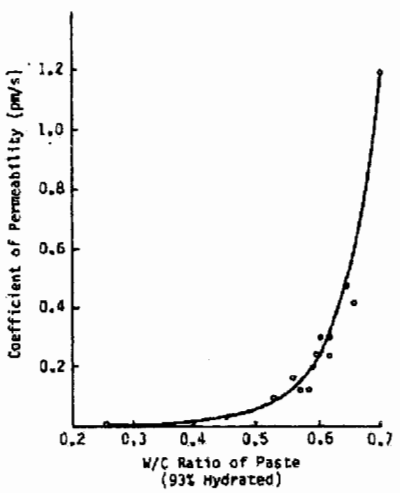

Fig. 1. Effect of water/cement ratio on permeability of cement mortar specimens.

Natural mechanism of corrosion

Theories of corrosion

Corrosion may be defined broadly as the destruction or deterioration of metal by direct or electrochemical reaction with its environment.

Facts established with respect to corrosion particularly of iron:

1. Iron requires the presence of moisture, oxygen to corrode at normal temperature. In acid solutions corrosion is more rapid.

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2. Usually hydrogen gas is evolved.
3. The rate and distribution of corrosion is controlled by formation of surface films.
4. The initial rate of corrosion is much greater than the rate after short period of time.
5. The electrochemical processes of corrosion influenced by biological organism.

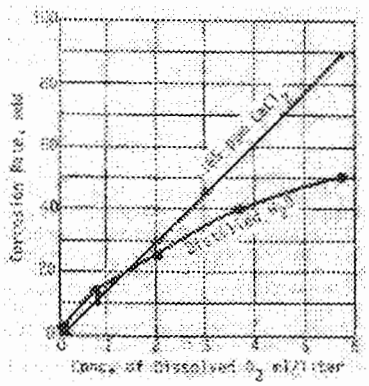

Fig. 2: Effect of oxygen concentration on corrosion of steel in water of two purities.

Factors influencing the corrosion rate

The moisture content, the temperature, the chemical composition, the porosity, the concrete cover.

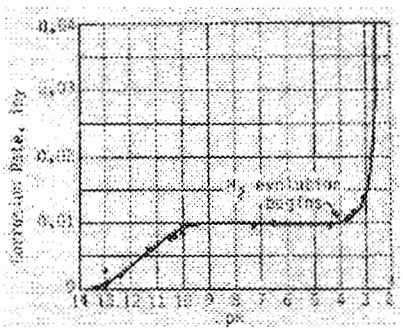

Fig. 3: Effect of pH on corrosion rate of iron in aerated soft water at room temperature.

General mechanism of corrosion

Typical chemical reactions of the corrosion process

$$Fe + 2H^{+} \Longleftrightarrow Fe^{++} + 2H \quad (1)$$

Metal ions — ion atoms

This is the typical primary reaction; it is followed by either the destruction of the film of hydrogen:

$$2H + \tfrac{1}{2}O_2 \longrightarrow H_2O \quad 2.(a)$$

atoms dissolved liquid or its removed as bubbles of gas.

$$2H \longrightarrow H_2 \quad 2(b)$$

atoms — gas

These permit reaction (1) to proceed with the accumulation in the solution of Fe^{++} which is oxidized and precipitated as rust by

$$2Fe^{++} + \tfrac{1}{2}O_2 + H_2O \longrightarrow 2Fe^{+++} + 2OH^{-}$$
$$\longrightarrow \text{insoluble ferric hydroxide (rust)} \quad (3)$$

Lewis and copenhagen: (1959)
(macrocell action) [2]

Steel (Anode)	Permeable concrete (low pH, high Cl^{-})	Less permeable concrete (high pH, low Cl^{-})	Steel (cathode)

Steel (cathode)	High Oxygen Availability	Low Oxygen Availability	Steel (Anode)

The volume change in the concrete manifests into cracks, the crack promotes more permeability. The higher permeability is the fundamental cause of further volume change and bigger cracks, which lead to deterioration, degradation, disruption, and eventual failure of concrete structure [3].

The organization for economic cooperation and development (DECE), Paris carried out a survey in 1986 on 80,00,000 bridges with an average age of 18 – 27 years located in North America, Western Europe, Japan and Australia. 18% of these bridges were of pre-stressed concrete. It has been reported that the durability of many of those bridges is suspectable [4].

In Germany, use of high alumina cement is reported to have caused hydrogen embrittlement.

In marine environment, the ingress of chloride is the primary cause for the breakdown of passivity and the onset of severe corrosion.

Measuring the rate of corrosion

Weight loss method

This method has been described by inter alia, Mercer, Butler and Warmer (1979) and has also been described as an ASTM. Standard, ASTM E1-67 (5).

In this method the weight loss is measured. Pickling or cleaning agents (Clark's solution), removes the metal oxide. It is possible to record corrosion attacks of no more than a few tenths of a mg/cm^2. Suitable for investigating the corrosion rate after initiation and for determining the depth of corrosion that gave rise to cracks in the concrete cover.

Rate of corrosion-practical case histories

Balcony slabs

Top reinforcements in a number of balcony slabs with a standard (ie. According to the applicable code of practice) concrete strength of 25 Mpa was found to have corrected an average about 1 mm in 20 years. The concrete cover was 20 mm. This gives a rate of corrosion of 50 mm/year. The slabs were carbonated.

Concrete building with chloride admixture

The Swedish Cement and Concrete Research Institute investigated a residential area with an age of about 10 years in Stockholm after reports were received that serious corrosion attacks could be seen. The corrosion rate was estimated to lie on a level of 0.1-0.5 mm/year.

V.Kucera and E.Mattsson based on the investigation says electrochemical techniques prove to be a useful tool for the investigation of atmospheric corrosion in the laboratory as well as on test sites out of doors and in industrial application [6].

Corrosion studies at CECRI have shown that the deformed bars are corroding slightly more than that of the plain round mild steel bars under accelerated and field conditions. Silicon can improve the general corrosion resistance. Small addition of nickel increases the resistance to atmospheric corrosion.

Protective measures of corrosion

A corrosion inhibitor is a substance, which when added in small amount to an environment normally corrosive to a metal or alloy in contact with it effectively reduces the corrosion rate [7]. For example, soluble oil emulsion type; chromates phosphates benzoates silicates are the anodic inhibitors and salts of metals such as zinc, magnesium, manganese or nickel are the cathodic inhibitors.

Vinod Kumar [8] has reported that the corrosion resistant Fe-Cr-Mn-Cu alloy through "white iron root" has higher strength and free from graphite corrosion.

Magnesium and calcium are invariably formed in seawater. There are three types of protection techniques:

1. Changing the environment around the reinforcing steel (by using admixtures to the concrete).
2. Changing the nature of the rebar (surface treatment or by bulk alloying).
3. Changing the electrochemical nature of the surface or the rebar (Cathodic protection).

Stratfull in California first applied cathodic protection to the problem of convention reinforcement deterioration in structure due to corrosion in concrete. Browne and Domone calculated that a splash – zone concrete with a water/cement ratio of 0.40 and concrete cover of 50.8 mm (2 inch) are needed. For concrete exposed to sea or brackish water, ACI recommends a water /cement ratio of 0.40 may be used provided the thickness of cover is increased 12.77 mm (0.5 inch). Pike et al showed that for epoxy coating of less than 10 mils thickness the bond strength under pull-out tests was only slightly less than for uncoated bars and within acceptable limits. High-build coatings (> 25 mils) suffered severe bond – strength problems, presumably due to "Wash-out" out of the deformations. For the recommended coating thickness (7±2 mils), however, the bond strength concern appears to be a "non-problem".

A series of evaluation conducted by the Portland cement association (PCA) on bridges containing galvanized reinforcement has been undertaken. For salt – contaminated bridges in Bermuda, which had been in service for (upto) 20 years, no corrosion damage was noted.

Corrosion studies at OPMEC, CECRI Unit at Tuticorin

Corrosion study of reinforced concrete blocks measuring 150 x 150 x 300 mm is planned at OPMEC, CECRI Unit at Tuticorin located in Gulf of Mannar. The proposed study involves using the four types of steel specimens (rebars) of 16 mm diameter, 200 mm in length. Three grades of concrete used. The unique facility available OPMEC, Tuticorin include carrying out the tests on RCC specimens by immersing them directly into the sea at six different levels namely atmospheric, flash zone, tidal zone, few meters below the tidal zone and the sea bottom including atmospheric exposure [9].

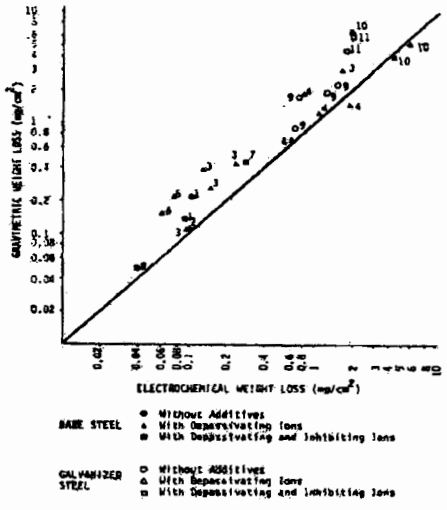

Fig. 4: Comparison between gravimetric weight loss and weight loss calculated from polarization resistance data from various steels in mortars.

It is proposed to collect data using polarization resistance method then it will be analyzed for durability aspects like corrosion.

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