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Simulation of Corrosion of Rebar in Concrete by Impressed Current Technique

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Abstract: *Marine structures are adversely affected by corrosion of rebars. In order to assess the structural health, prediction of the amount of mass loss of rebars is important. In this context, an experimental investigation was done to find a relationship between crack width and level of corrosion. An impressed current technique was employed to accelerate the corrosion process. The crack width was measured by image analysis. In this research, a linear relationship was found between the crack width and mass loss. 32 mg/cm^2 corrosion level was found to be needed for the appearance of surface cracking.*
Keywords: *Corrosion of rebar, impressed current technique, crack width, level of corrosion*

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I. Introduction

In the coastal region, due to a high concentration of chlorides present in the environment, corrosion of rebar in concrete becomes a major durability problem for reinforced concrete structures. Level of corrosion has a significant effect on structural health like flexural strength, deformation behavior, surface cracking, bond strength, ductility [1]. Due to corrosion of rebar, products of corrosion occupies larger volume resulting formation of surface crack along the rebar (Shakib and Zakir morshed 2018). The width of surface crack is a good parameter to predict the condition of structural health.

An impressed current technique is used to accelerate the corrosion so that tests can be completed within a reasonable period of time in the laboratory. In this method, Faraday's law is used to determine the mass loss of metal. The Faraday's law is as follows

$W = MIt/zF$ ……………………………………………………………………………………………….(1)

Where, W is the mass of steel losses (gm); M is the atomic mass of steel (56 gm); I is the current flowed (A); t is the duration of tests in seconds; z is the ionic charge (2); and F is the Faraday's constant (96500 A/sec).

An electrochemical potential is applied between the reinforcing steel (anode) and a cathode in this method. In the previous studies, a good agreement is found on using an impressed current technique to predict the level of corrosion [1,3–5]. Although a huge amount of works is found regarding the corrosion of rebar and cracking due to corrosion, there is a limited information in the studies on the relationship between the crack width and the level of corrosion. The current research work aims to study the effect of corrosion level on the surface crack width and find a relationship between the level of corrosion and crack width.

II. Experimental Procedures

2.1 Material Properties

A C30grade normal weight concrete was used in this study. The proportion of concrete mix is shown in Table 1. Ordinary Portland cement was used as a binder material. A 19 mm downgrade stone chips and river sand with fineness modulus of 2.8 were used as coarse aggregate and fine aggregate in concrete respectively. In order to permit the corrosion, 3.5% NaCl by weight of water was added to the mixing water prior to the casting. The average compressive strength of concrete was found as 32.4 MPa. Two types of steel reinforcement were used in this research. 12 mm diameter Grade 60 MS plain bar was used to represent as an anode and 4 mm diameter wire as a cathode.

Table 1: Mix proportions for the concrete

Materials (kg/m^3)					w/c ratio
Water	Cement	Fine Aggregate	Coarse Aggregate	Fresh density	
190	422	725	1008	2345	0.45

2.2 Test Specimen

The details of the test specimens are shown in Figure 1. The specimens were 250 mm in length and 100 mm x 100 mm in cross-section. The rebar (anode) to be corroded was placed at the corner maintaining a clear cover of 25 mm. The wire (cathode) was placed on another corner maintaining the same clear cover. The specimens were cured by immersing into the water for 28 days.

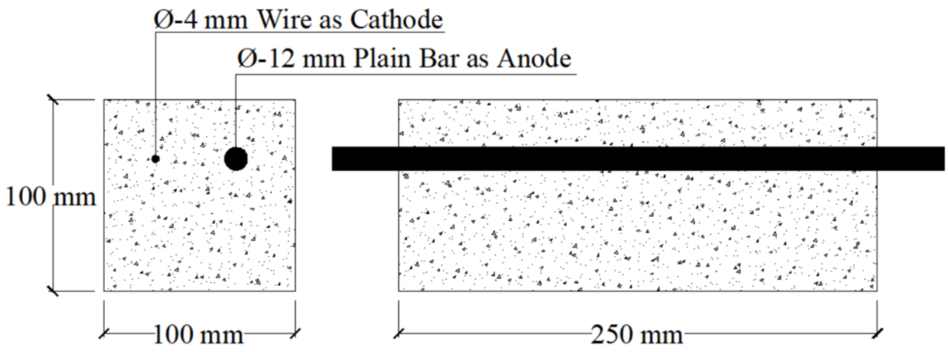


Figure 1: Schematic Diagram of Test Specimen

2.3 Test Setup and Procedure

An impressed current was supplied by means of a DC power supply. The positive pole of power supply was connected with the anode and negative pole was connected with the cathode as shown in Figure 2. A 12 V was applied across the circuit. The beam was immersed partially for 24 hours in 3.5% NaCl solution before starting the test. After 24 hours the current was allowed to flow through the circuit. An immersion for 24 hours before starting the test will saturate the concrete. The current flowed through the circuit was measured indirectly by the voltage drop across a fixed resistor of 4.7 Ω. The previous study states that the theoretical mass loss by Faraday's law can be used efficiently in this environment [1]. After formation of a crack, the width of crack was measured by a USB digital microscope.

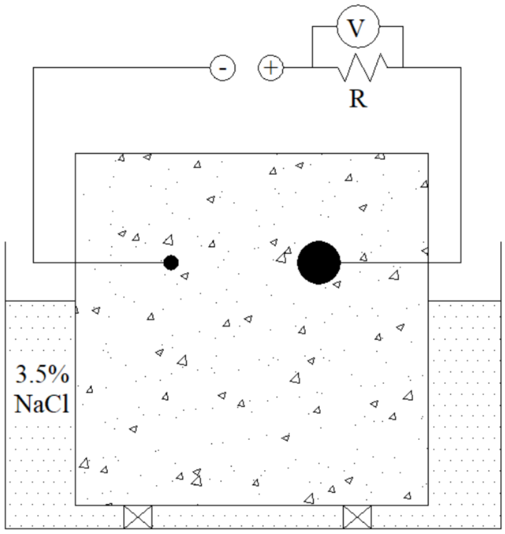


Figure 2: Schematic Diagram of Test Setup

III. Results and Discussion

3.1 Crack Width

As a potential difference was applied to the reinforcement, different oxides are formed in the presence of water, oxygen and chloride ions. The oxides occupy a larger volume than the parent material [2]. These oxides pressurize the cover concrete which results cracking of cover. The width of the crack was measured by a USB microscope. The pictures of crack were captured at an interval of distance throughout the beam along the crack. The width of crack is plotted against the predicted mass loss shown in Figure 3. At each corrosion level, the variation of crack width along the beam is shown in the Figure 3. From the figure, it is seen that the major crack appeared on the surface at a corrosion level of 32 mg/cm^2. The width of crack was linearly increased with the level of corrosion. The previous study showed both linear relations [6] as well as nonlinear [7]. They showed an average crack width but it's quite difficult to find a uniform crack width along the beam. Along with the time the amount of corrosion products was increased and only soluble part was leached out through the crack. As a result, the pressure induced part was accumulated around the rebar and the opening of the crack was increased as well.

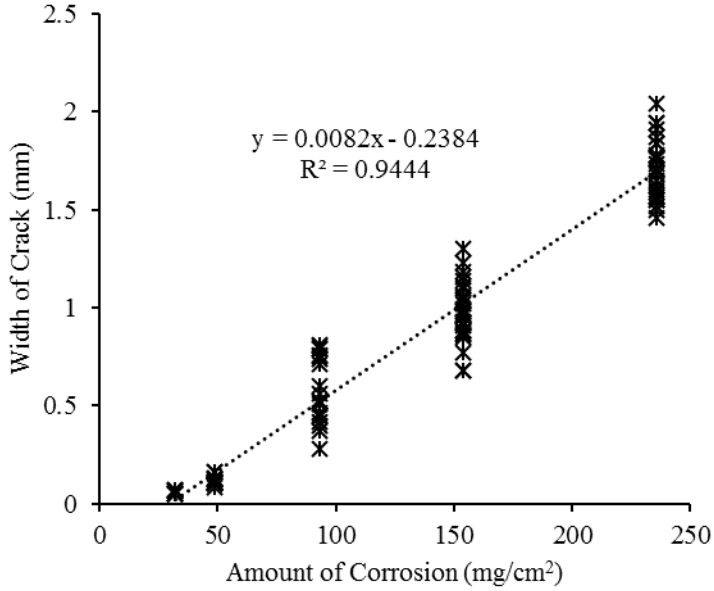
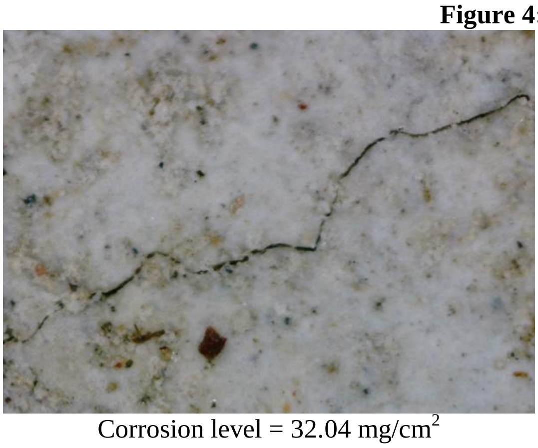


Figure 3: Variation of Crack Width with the Level of Corrosion

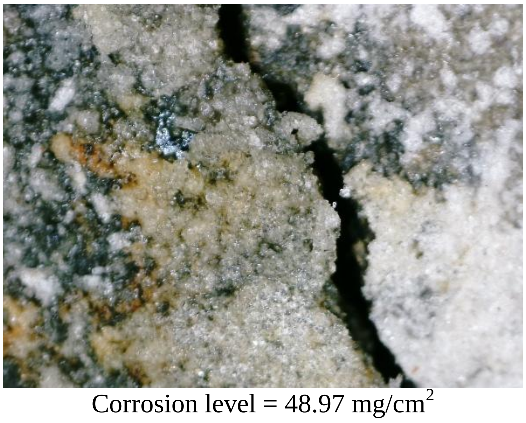
3.2 Crack Patterns

Since the expansive corrosion products induce an outward pressure, the crack is formed perpendicular to the rebar surface and along the rebar throughout the beam. The pattern of crack is shown in Figure 4. The photographs taken by the microscope at different level of corrosion is shown in Figure 5.

Figure 4: Pattern of Crack



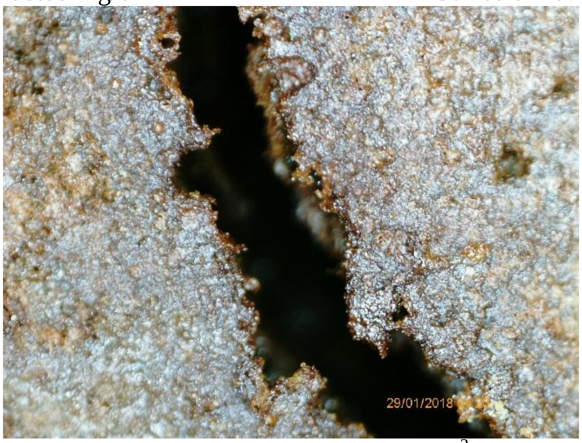
Corrosion level = 32.04 mg/cm^2



Corrosion level = 48.97 mg/cm^2

Corrosion level = 93.39 mg/cm^2

Corrosion level = 154 mg/cm^2



Corrosion level = 235.47 mg/cm^2

Figure 5: Cracks at Different Level of Corrosion

IV. Conclusions

In order to investigate the structural health exposed to saline environment, width of crack is an important parameter to predict indirectly the mass loss of rebar. In this research, crack width was successfully measured by image analysis taken by USB microscope. The width of crack followed a linear relation with the mass loss. 32 mg/cm^2 corrosion level was found to be needed for the appearance of surface cracking.

References

[1]. El Maaddawy, T. A. & Soudki, K. A. Effectiveness of Impressed Current Technique to Simulate Corrosion of Steel Reinforcement in Concrete. *J. Mater. Civ. Eng.***15,** 41–47 (2003).

[2]. Shakib, S. & Zakirmorshed, A. Initiation and Propagation of Crack Due to Corrosion of Reinforcement - An Experimental Investigation. **15,** 12–16 (2018).

[3]. Al-Sulaimani, G. J., Kaleemullah, M., Basunbul, I. A. & Rasheeduzzafar. Influence of Corrosion and Cracking on Bond Behavior and Strength of Reinforced Concrete Members. *ACI Struct. J.***87,** 220–231 (1990).

[4]. S, L. H., F, T. & T, N. Effects of rebar corrosion on the structural performance of singly reinforced beams. *Durab Build Mater Compon 7 Vol 1* 571–580 (1996).

[5]. Almusallam, A. A., Al-Gahtani, A. S., Aziz, A. R. & Rasheeduzzafar. Effect of reinforcement corrosion on bond strength. *Constr. Build. Mater.***10,** 123–129 (1996).

[6]. Vu, K., Stewart, M. G. & Mullard, J. Corrosion-Induced Cracking: Experimental Data and Predictive Models. *ACI Struct. J.***102,** 719–726 (2005).

[7]. Tran, K. K., Nakamura, H., Kawamura, K. & Kunieda, M. Analysis of crack propagation due to rebar corrosion using RBSM. *Cem. Concr. Compos.***33,** 906–917 (2011).

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