해양 환경에서 매립형 고체 기준 전극을 사용한 철근 부식 조사

Investigation of the steel rebar corrosion using embeddable solid state reference electrode in marine environments

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Abstract
Reinforced concrete (RC) structures play a significant role in the construction industries. An embeddable solid-state reference electrode (ESSRE) was used to evaluate the corrosion status of steel rebar in the concrete of various cover thicknesses that exposed to the maritime environment (3.5 % NaCl) in this study. From the open circuit potential measurement (OCP), the passive state, the corrosion uncertainty, and the 90% probability of corrosion state of the steel rebars in the concrete were monitored by ESSRE. From the electrochemical impedance spectroscopy (EIS) method, severe corrosion was observed at the exposure period of 1510, 1847, 2350, and 3020 h for C10, C15, C20, and C30 concrete, respectively. The results confirm that the ESSRE can be useful to identify the corrosion occurrence and severe corrosion of steel rebar embedded in different cover depth concrete structures.

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1. Introduction

Reinforced concrete (RC) structures play a significant role in the construction industries. However, the service life of RC is frequently reduced when concrete constructions are exposed to a harsh environment. The reason for shortening the service life of concrete structures is the corrosion of reinforced steel rebar. The development of corrosion products on the steel rebar increases the diameter, which can result in cracking on the concrete surface. Hence, the corrosion monitoring in the RC structures is essential for maintaining and repairing the corrosion-affected area at the appropriate time. In the present study, the corrosion status of the steel rebars embedded in various cover depths of concretes which was exposed to 3.5% NaCl were monitored by ESSRE using electrochemical methods.

2. Materials and methods

2.1 Preparation of ESSRE and concrete specimens

The alkaline stable MnO2-based solid-state reference electrode was developed as per the literature, [1,2] and the fabricated SSRE was surrounded by stainless steel (SS) electrode for monitoring the corrosion. Here, the steel rebar used as a working electrode; the fabricated MnO2 and the SS acted as reference electrode and counter electrode, respectively. The whole assembly setup was called embeddable solid-state electrode (ESSRE).

For concrete specimen preparation, the mix proportion of 1:2:2.75 (cement:sand:coarse aggregate) and the water to cement ratio of 0.5 were used. The rectangular concrete specimens size of 20 ×10 ×10 cm were casted with 1.0 cm dia. and 20 cm length steel rebar embedded at various cover depths such as 10, 15, 20, 30 mm and along with the EESRE. After 28 days of curing, the concrete specimens were exposed to 3.5% NaCl and corrosion status was monitored by OCP and EIS using a high impedance voltmeter and potentiostat VersaSTAT (Princeton Applied Research, Oak Ridge, TN, USA) with a frequency range of 30 kHz to 0.01 Hz, respectively.

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3. Results and discussion

The measured OCP values of the steel rebars embedded in C10, C15, C20, and C30 concretes were plotted and shown in the Figure 1a From Figure 1a, the OCP values of the steel rebars embedded in C10, C15, C20, and C30 concrete samples have reached a potential of -476mV at the exposure period of 744, 1118, 1543, and 2619 h, respectively. As per the ASTM-C876-15, the obtained values indicates the 90% probability of corrosion occurring on the steel rebar surface. The different time durations were observed at different cover depth concretes are due to the time taken for penetrating of chloride ions to reach the steel rebar surface.

The charge transfers resistance (RCT) values obtained from the EIS data were plotted in Fig. 1b. It can be seen from Fig. 1b that the RCT of steel rebar in C10, C15, C20, and C30 concrete values initially increased. The increase of RCT values might be due to the hydration of the cement matrix and produce the passive layer on the steel rebar surface. Further increases the exposure periods, the RCT values gradually decreased, which was due to chloride ions reaching the steel rebar surface and corrosion reaction occurred. The RCT values of steel rebar embedded in C10, C15, C20, and C30 concretes were 17, 18, 18, and 19 kΩ.cm2 at the exposure period of 1510, 1847, 2350, and 3020 h, respectively. The results indicates severe corrosion occurs on the steel rebar surface.

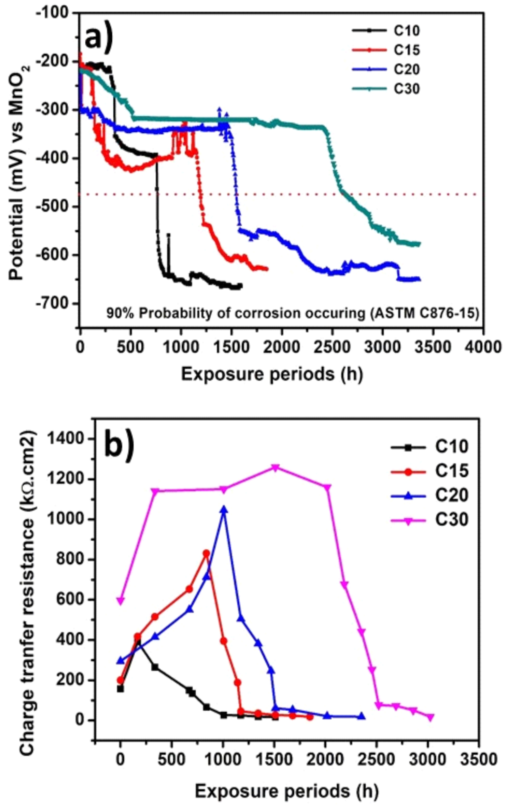

Figure 1. Open circuit potential measurement (a); and RCT values obtained from EIS studies (b).

4. Conclusions

We have studied the effect of corrosion in different cover depth of the RC with 3.5% sodium chloride. From OCP measurements, the time required for 90% probability of corrosion on steel rebar's which was embedded in the different cover depth of concrete under 3.5% NaCl with MnO2-ESSRE were 744, 1118, 1543, and 2619 h for C10, C15, C20, and C30 concretes, respectively. The EIS results confirms that severe corrosion was observed at exposure periods of 1510, 1847, 2350, and 3020 h (high corrosion region) for C10, C15, C20, and C30 concretes, respectively. The results confirm that the ESSRE can be useful to identify the corrosion occurrence and severe corrosion of steel rebar embedded in different cover depth concrete structures.

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