

AN ELECTROCHEMICAL STUDY ON THE CORROSION OF STEEL IN CONCRETE STRUCTURES IN SEVERE MARINE ENVIRONMENT BASED ON LONG-TERM EXPOSURE TEST

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<https://hdl.handle.net/2324/4496041>

出版情報 : Kyushu University, 2021, 博士 (工学), 課程博士
バージョン :
権利関係 :

(様式2)

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論 文 名: AN ELECTROCHEMICAL STUDY ON THE CORROSION OF STEEL IN
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BASED ON LONG-TERM EXPOSURE TEST

(長期暴露試験に基づいた厳しい海洋環境におけるコンクリート中鋼材の腐食
に関する電気化学的研究)

区 分 : 甲

論 文 内 容 の 要 旨

Concrete is a long-established manufactured material in the civil engineering field worldwide. Concrete is popular due to its extensive versatility, its adaptability, and its relatively low cost. Moreover, the idea of sustainability is a growing appeal in construction fields. Due fast global population growth, the overconsumption of resources along with overproduction of waste have increased. Chloride-induced corrosion is one of the underlying reasons for the deterioration of reinforced steel concrete structures. The financial implications of concrete deterioration are considerable that a sustainable and durable method of prevention and protection is of heightened needs.

In this study, the mechanism of chloride-induced corrosion in concrete is studied. In the first part, the effect of long-term exposure of concrete to a chloride environment is presented. Prevention and repair method are presented in the second half of the thesis. This work will contribute to a comprehensive understanding of the mechanism of corrosion in concrete construction, and to give more insight into the method for repair and prevention of corrosion in concrete construction.

Chapter 1 introduces the background of the research, states the research problem, shows the objectives and the limitation of the study, and finally gives the research contribution and the outline of the dissertation.

Chapter 2 summarizes previous work related to the deterioration of concrete due to chloride attacks. This chapter summarizes the behavior, the mechanism, and the parameters affecting the corrosion of reinforcing steel in concrete. In addition, this chapter considers prevention and repair methods introduced in the past years. Finally, monitoring and assessment methods on steel corrosion in concrete are also detailed.

Chapter 3 presents the research related to concrete in the realization stage. The effectiveness of joint in severely damaged pre-stressed concrete exposed to the marine environment for more than 30 years was investigated. The visual assessment of the specimen without joint treatment reiterated the significance of the use of appropriate joint treatment. From the electrochemical and

destructive tests, the outcome showed that both mortar and epoxy resin is effective in treating joints. As cracks of 0.1mm and 0.2mm were targeted for each kind of joint treatment, the results suggest that the fine cracks at the joint could be the reason for the lower performance of the treated specimen with 0.2 mm crack width. A non-uniform formation of corrosion or macro-cell corrosion was observed with an average distance between the anode and the cathode of about 5 to 10 cm.

Chapter 4 deals with the study of the effect of concrete bleeding on the corrosion of horizontal steel bars, which is a form of deterioration that often occurs in fresh concrete. The results confirmed that the formation of interfacial gaps between the concrete and the steel bars by bleeding. In addition, from the void area measurement, it was found that the void areas are more significant on the upper section and in the axial direction of each specimen as the water rise and evaporates from the concrete. The mentioned areas were more prone to corrosion, as per the electrochemical results and the visual observation. To enhance the long-term durability of reinforced concrete under severe marine environments, it is necessary to prevent the formation interfacial gap between steel surface and cement paste.

Chapter 5 proposes a solution to the corrosion of reinforcement and investigates the effectiveness of the use of calcium nitrite in the coating of reinforcement. In the case of the OPC specimen, the effect of the different concentrations of calcium nitrite in seawater mixed concrete is distinguished, unlike the GGBFS specimen. From the half-cell potential results, it is understood that the specimen with steel coating (Series 2) shows more noble potential compared to the specimen without coating (Series 1). From the polarization resistance measurement, Series 2 showed the lower current density than Series 1. In the anodic polarization curve, the effect of calcium nitrite in Series 1 and Series 2 is not distinguished. However, from the cathodic polarization curve and the oxygen permeability, the supply of oxygen in Series 2 is limited than in Series 1. From the experimental work described in this chapter, it became clear that mortar coating system on steel surface before concrete casting could prevent the gap formation and eventually contributes to the corrosion prevention of steel bars in concrete.

Chapter 6 describes the monitoring of repairs method of 40 years severely damaged reinforced concrete beams. The combination of Sacrificial Anode Cathodic Protection (SACP) in the non-patch repair area and polymer mortar in the patch repair area were used. Corrosion inhibitor was added in one of two specimens to check its effectiveness. After three years of monitoring, the results show that the depolarization in cathodic protection still reaches the 100mV criterion, which suggests that the addition of inhibitor has a good effect on the recovery of the potential. Most of the steel surface, with inhibitor showed a potential between -200 mV and -300 mV classified as in an "Uncertain" corrosion zone. On the contrary, the steel without inhibitor showed a less noble potential around the patch repair classified "Uncertain" to "90% corrosion" zone. The potential of steel bars became constant after three years. From three years monitoring of repaired reinforced concrete beams, it is clear that the steel inside concrete became stable condition even in chloride contaminated concrete.

Chapter 7 summarizes the main finding of the study described in Chapter 3 to Chapter 6 and advances recommendations for future works.