A STUDY ON CORROSION EVALUATION OF STEEL REINFORCEMENT IN CONCRETE DURING INITIATION AND PROPAGATION STAGE DUE TO CHLORIDE ATTACK

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https://doi.org/10.15017/2534439

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論 文 名　　：A STUDY ON CORROSION EVALUATION OF STEEL REINFORCEMENT IN CONCRETE DURING INITIATION AND PROPAGATION STAGE DUE TO CHLORIDE ATTACK
(塩害の潜伏期および進展期における埋設鉄筋の腐食評価に関する研究)

区　　分　　：甲

論 文 内 容 の 要 旨

Deterioration of RC structures due to harsh environmental conditions lead to performance degradation of RC structures, and premature deterioration before completing expected service life is a major concern for engineers and researchers, maintainers, and infrastructure owners. Considering marine exposure conditions and use either sea sand/seawater for heavy construction in many countries, chloride-induced corrosion is one of major causes of deterioration of RC structures. In the literature, reliable chloride threshold for both new structures design and condition assessment of existing structures is important as the remaining service life is often considered as the time required to reach the chloride threshold value at a depth of steel bar. Several critical disasters due to steel corrosion have been reported, including the collapse of building and bridge. The total estimated direct cost for repairing or preventing corrosion is reported to be expensive. For these reasons needs to be increasing consideration of optimum durability design. Different mineral admixtures are often added in concrete to improve the durability, rheology of fresh concrete, and mechanical properties of hardened concrete. Optimal design necessary advances in the knowledge base relevant to the durability evaluation of RC structure in marine environments, including the role of mineral admixture for durability, the methods of measuring, and design for long-lasting of RC structures in marine environments. Therefore, this study aims 1) to propose a reliable detection method to determine the chloride threshold value to corrosion initiation of steel bars in various mineral admixtures such as fly ash, silica fume, metakaolin, and BFS; 2) to determine the performance of OPC mortar with difference chloride contaminated from moderate to high corrosion rate under certain period of exposure; 3) to determine the better performance of concrete mixed with seawater after 36-years exposure; 4) to propose a reliable assessment method to predict corrosion activity in RC structure; and 5) to determine some consideration regarding durability of seawater in RC structures. Further, this study expected to contribute for necessary information and may guide engineers in the development of longer-lasting RC structures, because it provides a demonstration of the long-term behavior of a commonly used construction material, permitting the prediction of the behaviors of existing structures and the more informed design and study of structures to be built. This dissertation consists mainly seven chapters.

Chapter 1 describes the background of this study, research objective, research contribution and dissertation outline.

Chapter 2 describes the brief background to chloride-induced reinforcement corrosion, literature review of previous studies about utilization of mineral admixture for resistance against chloride-induced corrosion and report on seawater-mixed concrete in performance and corrosion issue. The results of previous researches on investigation of seawater in concrete mixture are reviewed. Some factors affecting the durability of sea water mixed concrete are viewed also. The issues to be addressed in this study were discussed.

Chapter 3 describes the OPC mortar contaminated chloride was tested during the propagation period of corrosion from moderate to high corrosion rate. The main objective of this study is to identify and determine

corrosion behavior and the extent of corrosion of OPC mortar during the early period of the propagation stage by using several corrosion measurement methods. From the present test results, the factors influence of corrosion behavior of OPC mortar with difference chloride contaminated from moderate to high corrosion rate is proposed. The sensitivity of the corrosion potential against chloride content tends to be decreased after a certain period of exposure. The value is 13~15% of corrosion area can be defined as high corrosion degree and categorized into propagation stage. Therefore, from moderate to high corrosion rate, after 8-years exposure of OPC mortar has increased the probability from pitting to generate corrosion.

Chapter 4 describes the chloride threshold value to corrosion initiation by using mineral admixtures such as fly ash, silica fume, metakaolin, and BFS. Corrosion potential and corrosion current density were conducted to examine the threshold chloride concentration. The amount of chloride was determined according to the added amount of chlorides, type of mineral admixtures and W/B ratios. The specimens were stored in the laboratory atmosphere condition room and after one year, specimens were exposed in accelerated carbonation chamber until the sign of corrosion initiating. From the present test results, the factors influencing threshold chloride concentration are investigated, and the reliable ranges of threshold chloride concentration causing active corrosion of steel bar are proposed. In performance-based design determined by chloride attack and carbonation, it is possible to use seawater and if mortar mixed with BFS and fly ash with W/B ratio of 0.4 and 0.5 with minimum cover depth 5 cm. Therefore, establish the threshold total and free chloride content using mineral admixtures for the initiation of corrosion steel bars in concrete structures become the main contributions of this study.

Chapter 5 introduces several investigations on concrete mixed with seawater and tap water. Ten number of RC beams have been evaluated. The specimens were exposed to a tidal pool utilizing seawater directly from the sea. The major test variables include mixing water, various of cover depth, water to cement ratios, various bending load and exposure condition. The study aims to evaluate the effect of seawater mixing and exposure condition (tidal and splash) on deterioration and steel corrosion of RC beam under service load after 36-years of exposure. Visual observation, some electrochemical and physical evaluation were evaluated. From the present test results, the use of seawater as mixing water improved concrete strength, concrete resistance, oxygen permeability resistance and maintained very dense microstructure. And, the results of 36-years exposure test of concrete mixed with seawater with concrete cover 50 mm demonstrated high possibility of using seawater as an alternative and sustainable material of reinforced concrete, especially in marine tidal environment. The results will be very useful to provide notable information regarding the long-term performance of concrete mixed with tap water and seawater under marine environment. The information expected to assist future optimum design of seawater mixed.

Chapter 6 presents the importance reinforcement corrosion monitoring and describes the different methods for evaluating the corrosion state of RC structures. The main objective of this study was to compare the corrosion level of long-term exposure of RC beam using several corrosion measurement methods and discuss an overview of utilization of seawater in concrete structures. The data of corrosion level were taken from Chapter 5 then analysis and categorized into deterioration and degradation stage level. This study proposes a reliable assessment method to predict corrosion activity of steel corrosion caused serious damage of RC structure. Additionally, a potential correlation of actual corrosion and corrosion measurement was explored. From the present test results, after long-term exposure, chloride ion content, grade passivity of steel bar and visual observation method estimated the lowest correlation corrosion level, while corrosion potential, corrosion current density, electrical resistivity and oxygen supply methods predicted the highest correlation corrosion levels. And for performance reduction, corroded area, cross-sectional loss and maximum ultimate methods predicted the highest corrosion activity levels. Some considerations regarding durability of seawater mixing in RC structure particularly in marine environment were also proposed.

Chapter 7 conveys summary, conclusion, and recommendation for research works in the future.