LIFE-EXTENSION OF RC STRUCTURE BY CATHODIC PROTECTION USING ZINC SACRIFICIAL ANODE EMBEDDED IN CONCRETE

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論 文 名　：LIFE-EXTENSION OF RC STRUCTURE BY CATHODIC PROTECTION USING ZINC SACRIFICIAL ANODE EMBEDDED IN CONCRETE
（コンクリート中に埋設された亜鉛犠牲陽極方式の電気防食による RC 構造物の長寿命化）

区　　分　：甲

論 文 内 容 の 要 旨

Reinforced concrete (RC) structures damaged by concrete degradation or steel corrosion need maintenance or repair interventions aiming at restoring the safety and serviceability of the structure to the required performance level and providing reasonable residual service life of the structure. The repair strategies may include conventional patch repair and electrochemical treatments. One of the electrochemical techniques applied for controlling corrosion of steel in concrete is cathodic protection system. Cathodic protection (CP) is rapidly being accepted as a repair option for steel-reinforced concrete structures deteriorated by steel corrosion caused by chloride attack. This technique requires the permanent application of a small direct current to protect the steel. One system of this protection is a sacrificial anode type cathodic protection.

Galvanic anode made of zinc has some beneficial features such as simple to install, no power supply is needed, no wiring or no conduit is necessary, suitable for all rebar size, quality of patch repair material is not compromised, performance can be easily monitored and no long-term maintenance is necessary. However, the anode ability to achieve cathodic protection over a usable distance (throwing power distance) under realistic service conditions and the number of anodes needed are still unclear. Anode life and protective current delivery function on the boundary of partially-repair concrete are also indistinct. Related to the CP system by sacrificial anodes embedded in concrete, some issues were addressed in this study in order to observe durability and effectiveness of zinc sacrificial anode to increase life-span of RC structures.

In **Chapter 1**, the background of the study, its problem and limitation of this study is described.

In **Chapter 2**, previous studies on deterioration of RC structure and utilization of sacrificial anode as corrosion protection of steel in concrete is reviewed. Some factors affecting durability of concrete and sacrificial anode were clarified. The issues to be addressed in this study were discussed.

In **Chapter 3**, deterioration condition of 77-year-old RC structure exposed under severe marine condition was investigated. Field survey and experimental research by destructive and non-destructive methods were conducted to evaluate long-term performance of the open type wharf structure. Repair strategies for extending the service life of this structure are also presented in this study. The inspection results showed that the principal mechanism responsible for the deterioration of the structure is chloride-induced reinforcement corrosion. The main damages are broad delamination, spalling, cracking and loss of cross-section of steel reinforcement. The macro and micro strata layer of corrosion products are clearly observed on teh steel surfaces.

In **Chapter 4**, the effective length of embedded steel element on partially-repaired concrete protected by sacrificial anode against macro-cell corrosion under non-homogeneous chloride environment is discussed. From the macro-cell corrosion and protective current density test results, it was observed that macro-cell corrosion was formed coupling the boundary between chloride free concrete and its surrounding chloride contaminated concrete for all specimens since in the early age of exposure period. The effective length is differed according to the chloride content in concrete.

In **Chapter 5**, the effect of steel surface conditions on the performance of anode in patch repair concrete is presented. From this research, it can be concluded that non-rusted rebar condition in repair concrete (non-chloride contamination) is the most desirable initial condition when CP is applied on it to protect corroded steel bar in existing concrete (chloride contamination).

In **Chapter 6**, performance of zinc sacrificial anode to protect steel bar in concrete from corrosion under two extreme ambient conditions, namely, freeze temperature (-17°C, RH 4-5%) and hot temperature (40°C, RH 96-99%) was investigated. Based on the results of experimental study, it was observed that anode produce higher levels of current in wet or humid environments compared to the dry and low temperature conditions. Moreover, aging of anode is faster in high temperature condition than in freeze condition. Even in very low temperature, the sacrificial anode is still active and works as anode of cathodic protection for reinforcement in concrete.

In **Chapter 7**, this chapter presents the estimation of the service life of zinc sacrificial anode with and without steel embedded in chloride-contaminated concrete and free-chloride concrete exposed to dry or wet-dry condition. In addition, current acceleration method was also carried out in order to observe the service life of anode. Based on the results, it was observed that moisture and humidity of environment generates protective ability of the anode, also, it can be said that the potential value of the sacrificial anode was also affected by the moisture and oxygen content in the concrete. High moisture content in concrete enhance the zinc sacrificial anode activity to provide large protection current. It was predictd that zinc sacrificial anode reaches over 100 years' service life.

In **Chapter 8**, this chapter presents the application of sacrificial anode to 40-year old deteriorated RC beam as a repair. It was observed that corrosion risk of steel bars in the parent concrete (non-repair area) of deteriorated RC beams are still high. Sacrificial anodes are effective to protect steel bar in patch repair area and also surrounding area.

In **Chapter 9**, conclusions and recommendations for future works is presented.