

EFFECT OF PATCH REPAIR ON MACRO-CELL CORROSION IN REINFORCED CONCRETE MEMBERS

The University of Tokyo Graduate Student JSCE Member NANAYAKKARA, Ominda Prasad
The University of Tokyo Associate Professor JSCE Member KATO, Yoshitaka

1. Introduction

Reinforcement corrosion is one of the main deterioration problems of concrete structures. The deteriorated concrete part can be partially repaired by using a special repair material where it generally has low porosity relative to concrete to retard the diffusion of corrosive materials (chloride ions, Cl⁻). From an electrochemical point of view, the purpose of the patch repair is to remove the anodic reaction of corrosion cell of reinforced bar which existed before repair^[1]. However, the change of environment with respect to the corrosion cell cause to change the corrosion state and it become more complicated when the properties of repair material and concrete are different.

This research is, therefore, to investigate the locations of anodic reactions once the patching repair of chloride attacked concrete is completed.

2. Macro-cell corrosion current measurement

A divided steel bar is used to measure the real macro-cell corrosion current produced by a particular steel element^[2]. Method of measurement and calculation are represented in figure 1.

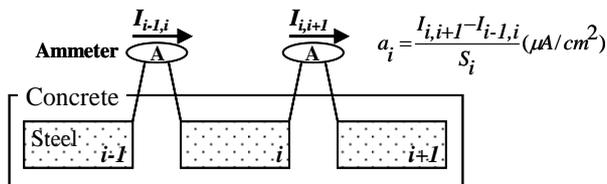


Fig.1. Measurement of macro-cell corrosion current

a_i – Macro-cell corrosion current density ($\mu\text{A}/\text{cm}^2$)

$I_{i-I,i}$, $I_{i,i+I}$ – Corrosion current (μA) flow from element $i-I$ to i and i to $i+I$ respectively

S_i – Surface area (cm^2) of the steel element i

3. Experimental program

3.1 Materials

OPC and Polymer modified cementitious mortar (EMACO® S98P) were used to make W/C of 0.55 concrete and repair material respectively. Concrete was mixed using fine aggregate of fineness modulus is 2.69 and coarse aggregate of maximum size is 15mm.

A divided steel bar was of diameter of 10mm plain steel. Smaller length steel elements were near the middle of the specimen and its view with their names is presented in the figure 2. Steel elements were connected using wires ensuring that macro-cell corrosion current passes through wires.

3.2 Preparation of specimen and exposure condition

Size of specimens was 100x100x376mm and it was made having side A (Repair material) and side B (Concrete) cast at different stages. Figure 2 represents a schematic view of the specimen. Chloride ions were deliberately added to concrete during mixing to represent deteriorated members and the variation of chloride ion in specimens is presented in table 1.

Specimens were kept for 7 days sealed curing and then epoxy coated except bottom surface. They were subject to cyclic wet (Relative Humidity-90%, Temperature-60°C, 3 days) and dry (RH-65%, T-15°C, 4 days) exposure condition per cycle (1 week) and totally for 24 cycles.

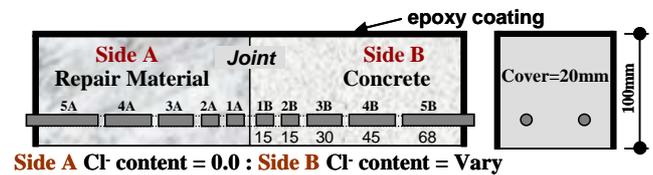


Fig.2. Schematic view of specimen

Table 1. Variation of chloride ion contents

No	Chloride ion content (kg/m^3)		
	Side A	Side B	Difference (B-A)
1	0	0.6	0.6
2	0	1.2	1.2
3	0	2.4	2.4
4	0	4.8	4.8

4. Results and Discussion

Measured periodic macro-cell corrosion currents were converted to the current density and hence total corrosion electricity (in Coulomb/ cm^2) was calculated for each and every element. These corrosion electricity values are graphically represented in the figure 3. It can be seen that the repair material section (Side A) has higher corrosion activity compared to the concrete section (Side B) for the specimens 1, 2 and 3. However, these results do not show any uniform

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Address: 4-6-1, Komaba, Meguro-Ku, Tokyo 153-8505, Japan. Tel. +81-3-5452-6098 (ext. 58090)

variation among specimens though specimen 1 and 3 shows their maximum corrosion activity in steel elements 1A and 2A in decreasing order. A higher corrosion activity in steel elements 1A and 2A occur due to the highest electrochemical potential difference occurs in the middle region of specimens. The specimen 4 which is having high chloride content (4.8kg/m^3) in concrete section shows a comparatively high corrosion activity in concrete part.

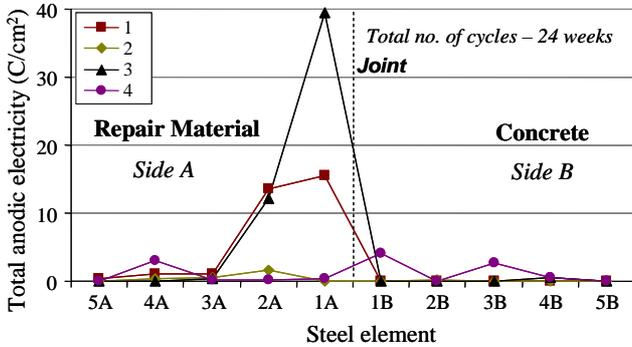


Fig.3. Variation of total anodic electricity

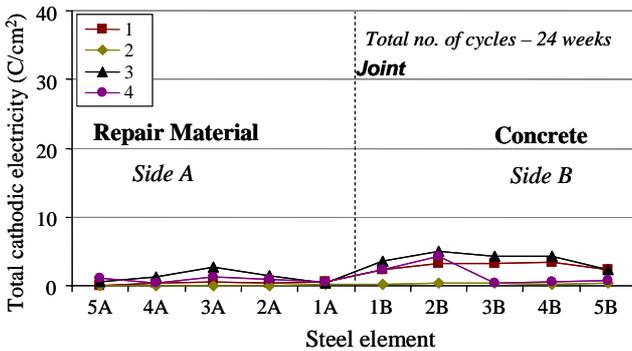


Fig.4. Variation of total cathodic electricity

This mechanism is different with the present knowledge of repair patching. To understand the mechanism properly, not only the investigation of anodic locations but also the coupled cathodic locations are required. Hence, the total cathodic electricity for each and every element was calculated and it is presented in the figure 4. From the figure 4, it can be observed that highest cathodic electricity is produced in concrete compared to repair material. Even for specimen 4, the cathodic electricity is higher in concrete section. Hence, it is clear that the cathodic electricity produced in concrete combine with the anodic

electricity produced in repair material for specimen 1, 2 and 3. From the fundamental of corrosion process, the cathodic reaction needs more oxygen (O_2) and moisture (H_2O) while anodic reaction absorbs them in a comparatively low rate. This confirms that a comparatively low rate of penetration of O_2 and H_2O occur into repair material which can be accepted as repair material has a low porosity compared to concrete. This phenomenon is graphically represented in the figure 5. The figure 5 explains that it may be seen the anodic region in repair material even when the concrete section is already attacked by chloride ions.

Considering the individual behavior of materials, the corrosion process inside repair material would clearly be less than the similar situation of concrete. Therefore, their individual role and the combined role create a completely different and more complex corrosion mechanism.

Also, though the corrosion occurred in repair material section as in this study, the breakage of passive oxide film in repaired section even without attacked by chloride ions cannot be clearly explained using the results of this study.

5. Conclusions

Corrosion of repaired concrete members generally visible in the vicinity of concrete section adjacent to the common region. However, this study found that the anodic reaction is activated in repair material section while coupled cathodic reaction is activated in concrete section when the concrete is attacked by low chloride content. This conclude that, when the concrete is repaired by a material with higher resistance for O_2 and H_2O penetration may cause for corrosion in repair at early stages. However, when a severely chloride attacked concrete member is repaired, the anodic reaction is activated in the concrete section.

References

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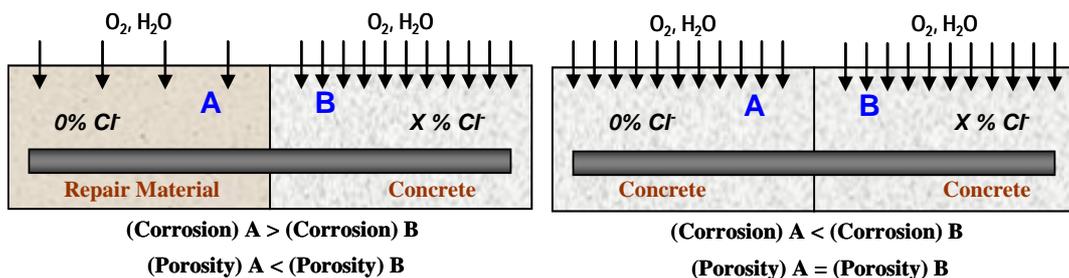


Fig.5. Schematic representation of the proposed corrosion mechanism in repair patch