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Evaluation about Electrochemical Measurements for Mortar Applied Silane Type Surface Penetrant

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ABSTRACT

There is preventive maintenance using a silane type surface penetrant as a method not to penetrate deterioration factors into the reinforced concrete. This method is easy to observe after countermeasures. Therefore, it is increasingly used. In the electrochemical measurement for confirming the effect after the countermeasure, measurement is performed with various electrodes from above the penetrant layer. However, because of the influence of the penetrant layer, there is a possibility that the electrical response value from the internal steel bar is not accurately measured. Therefore, the purpose of this study is to develop the electrochemical measurement method which is not affected by drying and wetting of external environment using the surface penetrant for mortar. That is, the influence of the penetrant layer on the measurement result is examined by comparing the case where the mini sensor is embedded near the steel bar and the case where the electrodes are set on the mortar surface which is over the penetrant layer. As a result, it is confirmed that the potential increase when the electrodes are set on the mortar surface. On the other hand, it is confirmed that the polarization resistance is almost equal in both measurement methods.

1. INTRODUCTION

Deterioration factors such as anti-freezing agent sprayed on the road in the winter season and airbone salt penetrate into the reinforced concrete. Then, the passive film on the surface of the steel bar is destroyed and rusted. Therefore, the corrosion of steel bar is suppressed by not penetrating deterioration factors from an environment into a concrete. As a countermeasure, preventive maintenance using silane type surface penetrant is increasing. This reason is that visual inspection is easy to confirm the effect after application. The effect after countermeasure is often confirmed by the

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electrochemical measurement. The measurement is made by placing various electrodes on concrete to which surface penetrant is applied. Here, an equivalent circuit is shown in Fig. 1. As shown in Fig. 1 (2), it is considered that the electric resistance of the concrete surface layer part is increased by the surface penetrant material (S, Komatsu 2014), and a circuit of a two-layer having different resistances is formed in the penetrant part and the no-penetrant part. Also, the moisture content decreases and there is a possibility that the electrical response value from the internal steel bar has not been measured correctly. Therefore, the purpose of this study is to develop the electrochemical measurement method which is not affected by drying and wetting of external environment using mortar coated with surface penetrant material. That is, the influence of the penetrant layer on the measurement is examined by comparing the case where the mini sensor is placed near to the steel bar and the case where the electrodes are placed from above the penetrant layer.

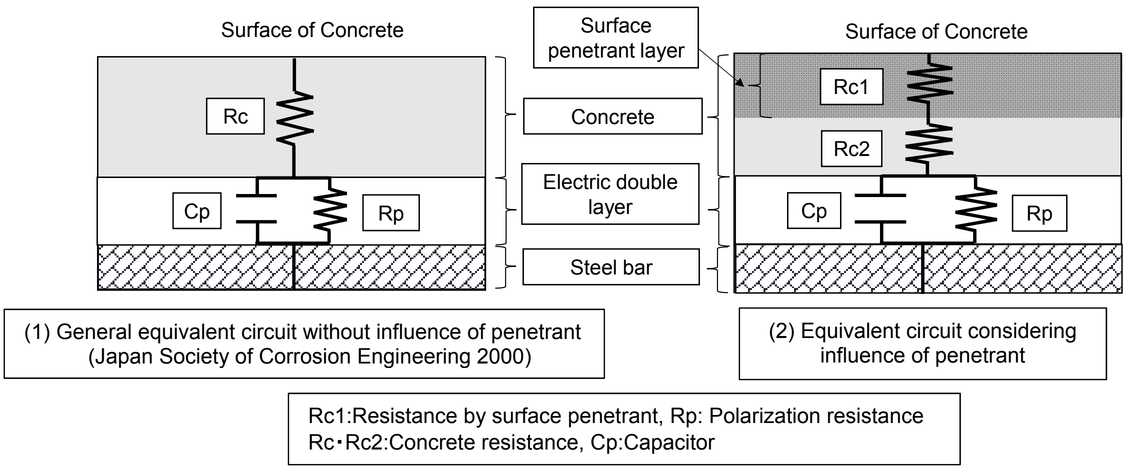

Fig.1 Equivalent circuit

2. THEORETICAL STUDY ON MEASUREMENT OF POTENTIAL

Eq. (1) is constituted by extending Ohm's law.

$$V = IR \qquad \therefore I = \frac{V}{R} \tag{1}$$

V : Voltage (V), I : Current (A), R : Resistance(Ω)

An example of the circuit at the measurement is shown in Fig.2. Here, Is is the current flowing through the concrete surface layer, and Iin is the current flowing in the potential electrometer.

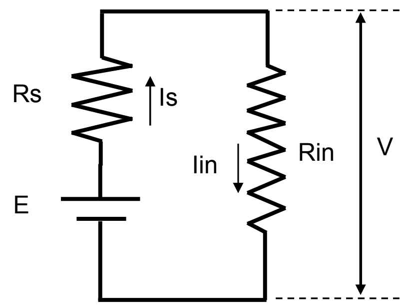

Fig.2 Circuit at measurement

When these are applied to Eq. (1), Eq. (2) and Eq. (3) are established.

$$Is = \frac{E}{Rs + Rin} \tag{2}$$

$$Iin = \frac{V}{Rin} \tag{3}$$

Since Is equals Iin, Eq. (4) is obtained by expanding Eq. (2) and Eq. (3).

$$V = \frac{E \cdot Rin}{Rs + Rin} \tag{4}$$

If Rs << Rin, Eq. (4) becomes Eq. (5).

$$\frac{Rin}{Rs + Rin} \fallingdotseq 1 \qquad \therefore V \fallingdotseq E \tag{5}$$

While if Rs almost equals Rin, Eq. (4) becomes Eq. (6).

$$\frac{Rin}{Rs + Rin} \fallingdotseq 0.5 \qquad \therefore V \fallingdotseq 0.5E \tag{6}$$

Therefore, as Rs increases, V decreases.

That is, there is a possibility that the measured value of the potential may be displayed small because the resistance of the concrete surface increases.

3. EXPERIMENTAL PROCEDURES

3.1 Specimen outline

The specimen is shown in Fig.3. The dimensions are 2 levels of 100×100×60mm and 100×100×100mm. The distances from exposed face (construction joint surface) to a steel are each 30mm and 70mm. A penetrant depth measured by JSCE K-571 here is 6 ~ 7mm, and it is shallower than the cover depth. The mini sensor shown in Fig.4 is set to a steel bar in a unity band and embedded in mortar. In addition, W/C of mortar is 50% and its S/C is 3.0. After the cast, a specimen is cured in the wet environment (20°C, 90%RH) for four weeks. Then, it makes dry (20°C, 60%RH) for more than one week. After surface penetrant materials show in table 1 applied to a construction joint, the specimen is cured under dry air for one week. Afterwards, five surfaces without an exposure face are coated with epoxy resin, and a specimen is exposure under an accelerated chloride attack environment with wet and dry repetition cycles. This 1 cycle is an immersion (3.0% NaCl water solution) for 12 hours, and a dry air (60%RH) for 72 hours. And their temperatures are 30°C before 80th cycle and 40°C from 81st to 100th cycle.

Table 1 Surface penetrant materials

Surface penetrant	Main component	Sub component	Application uantity
α	Alkyl alkoxy silane	Corrosion inhibitor	350 g/m^2
β		-	

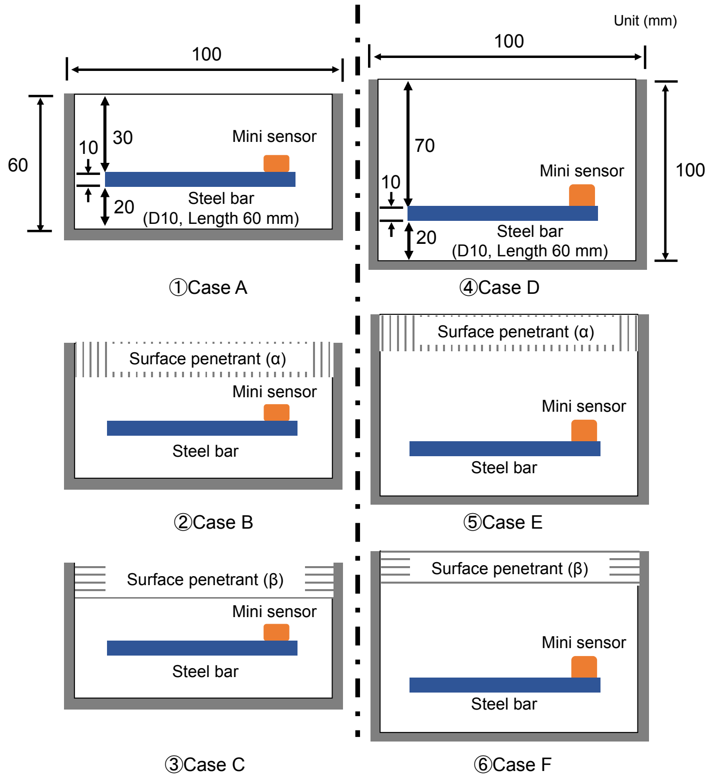

Fig.3 Specimen

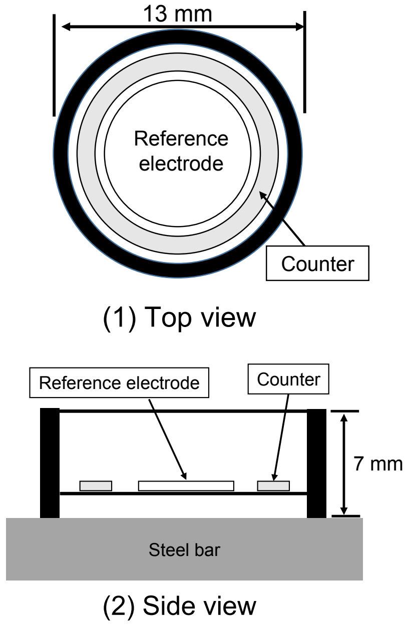

Fig.4 Mini sensor (K, Shimozawa 1998)

3.2 Experiment cases

Experiment cases are shown in Table 2. Whether or not the penetrant material was applied, the types of penetrant material, and cover depth were set as parameters. That is, total cases set 6 levels.

Table 2 Experiment case

Case	Surface penetrant		Cover depth(mm)
	α	β	
A	-	-	30
B	◯	-	
C	-	◯	
D	-	-	70
E	◯	-	
F	-	◯	

3.3 Measurement methods

Potential and polarization resistance were measured in a room at 20°C, at 20th, 50th, 80th and 100th cycle. The polarization resistance was measured by an alternating current impedance method in which the frequency was set in the range of 10 kHz to 1 mHz. Here, examples of measurement results are shown in Fig.5 and Fig.6. The polarization resistance was calculated using bode diagram and Cole-Cole plot. Also, the potential was measured using a device having an internal resistance of 1000 MΩ. A method of measuring from the mortar surface using the counter electrode plate and a method of measuring with the mini sensor embedded in the mortar are shown in Fig.7. For the counter plate, a stainless steel plate wrapped with wet tissue paper was used to increase conduction with the mortar.

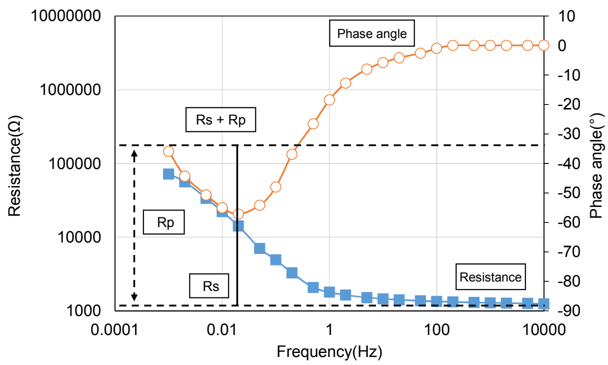

Fig.5 Bode diagram

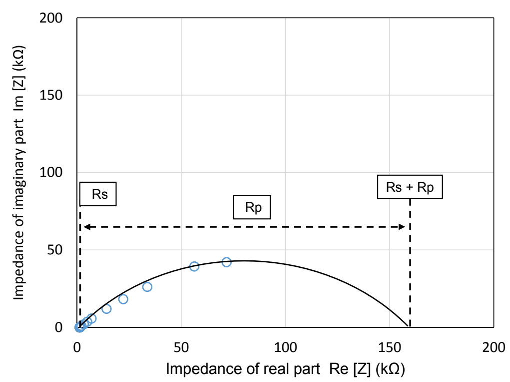

Fig.6 Cole-Cole plot

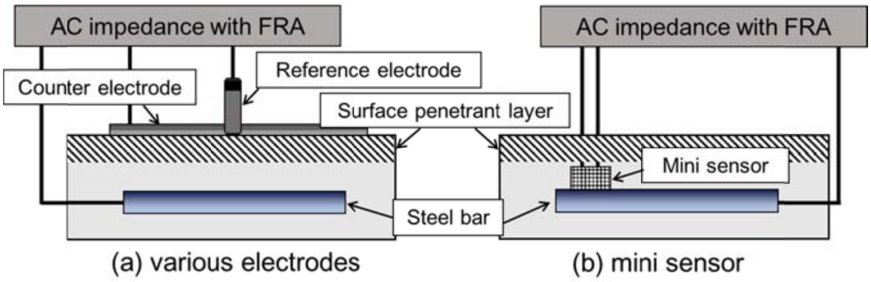

Fig.7 Example of measurement method

4. RESULTS AND DISCUSSIONS

4.1 Potential

Fig.8 and Fig.9 show the potentials measured with the counter electrode plate and the sensor. To compare these values, the relationship of the value measured with the counter electrode plate and the sensor is shown in Fig.10. According to this figure, the values of both are almost equal in case A and case D without the penetrant materials. On the other hand, the value measured with the counter electrode plate becomes higher than the value measured the sensor in the case where the penetrant material is applied. That is, it is thought that the result of a measurement of potential became high as described in section 2 because the electrical resistance in the mortar surface part increases by the penetrant material.

However, based on the internal resistance of the device of potential is 1000MΩ, the difference of the experimental data is larger than that of theoretical estimation data. To consider this, the water content in the surface part of mortar was measured with the high frequency capacity type moisture meter. As results, they were 8.1% in case A and case D. On the other hands in the case where the penetrant material was spread, they were around 4.0% which were small. Therefore, it was thought that high potential was measured (Y, Adachi 1995 and R, Suzuki 2007).

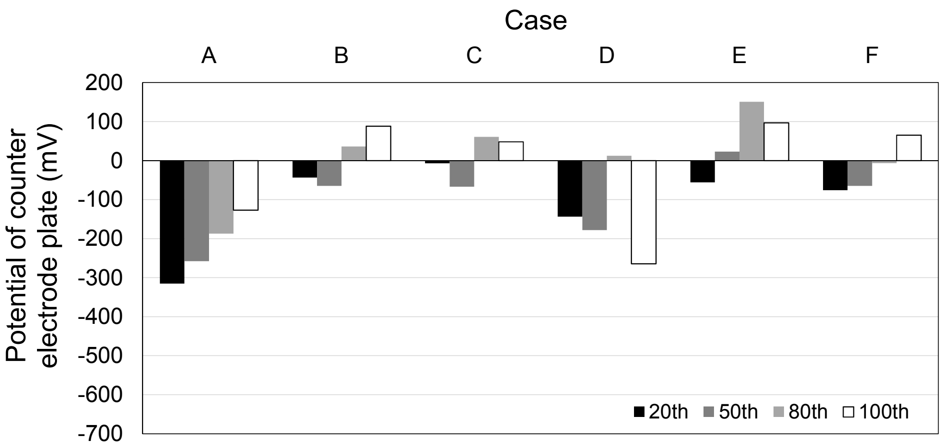

Fig.8 Potential of counter electrode plate

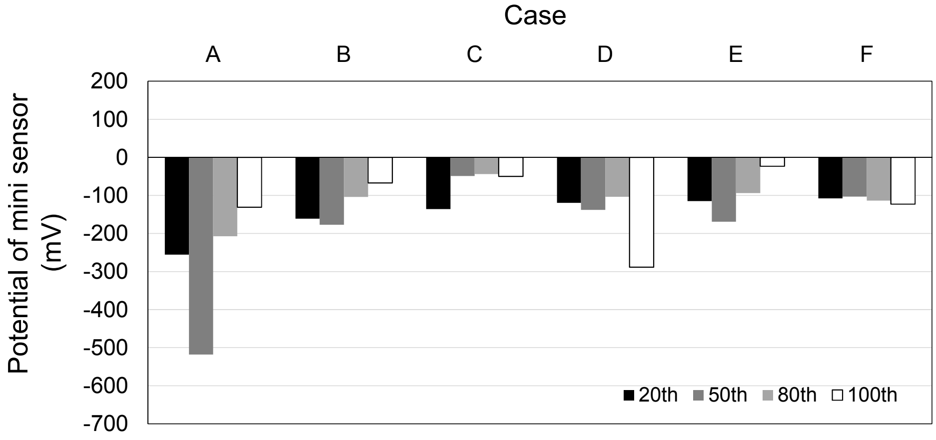

Fig.9 Potential of mini sensor

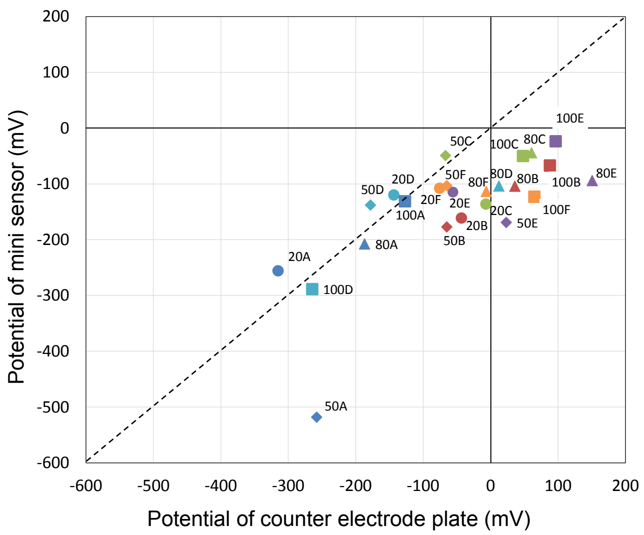

Fig.10 Comparison between mini sensor and counter electrode plate potential

4.2 Polarization resistance

Fig.11 and Fig.12 show the polarization resistances measured with the counter electrode plate and the sensor. To compare these values, the relationship of the value measured with the counter electrode plate and the sensor is shown in Fig.13. The values of both are almost equal even in cases where the penetrant materials are applied according to this figure. Therefore, it was confirmed that the electrical resistance in the surface part of the cover mortar did not influence the measurement of the polarization resistance.

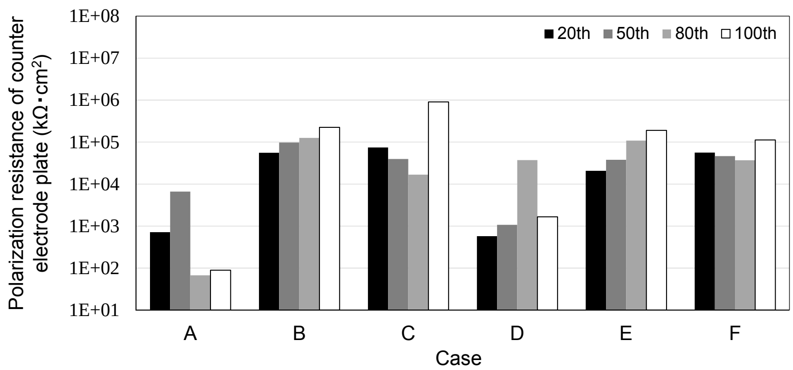

Fig.11 Polarization resistance of counter electrode plate

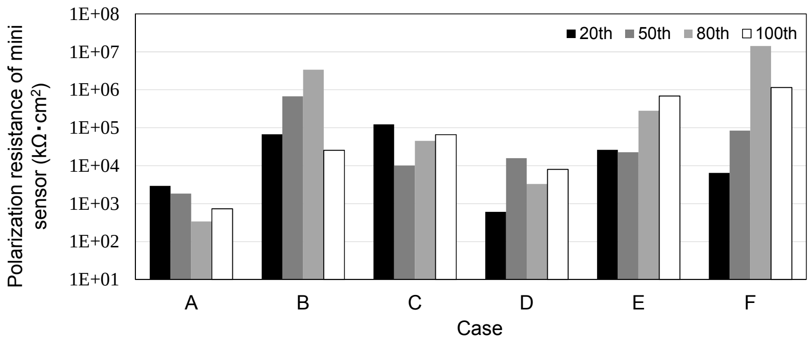

Fig.12 Polarization resistance of mini sensor

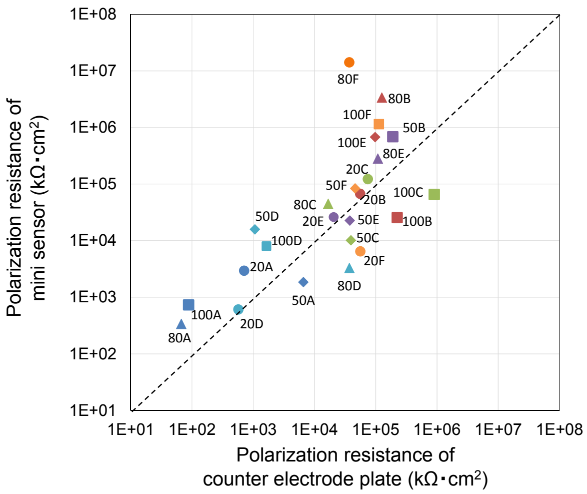

Fig.13 Comparison between mini sensor and counter electrode plate polarization resistance

5. SUMMARY

(1) The value of the potential measured by using the reference electrode and the counter electrode set on the mortar surface is different from the value of the potential measured with the sensor embedded near the steel bar when the penetrant material is applied. That is, the former becomes high compared with the latter.

(2) The value of the polarization resistance measured by using the reference electrode and the counter electrode set on the mortar surface equals to the value of the polarization resistance measured with the sensor embedded near the steel bar, even in the case of the penetrant material is applied.

(3) After the silane type surface penetrant material is applied, it is desirable to inspect the steel corrosion by not potential but polarization resistance. Because if the electrode is set on the mortar surface, the result of potential leads underestimated evaluation of the degree of the steel corrosion.

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