

Electrochemical Study on Ground Corrosion Sensor used for Corrosion Prediction of Steel Members near the Air-liquid Interface

Kyushu University Regular member ○M. Yang
Kyushu University Fellow member S. Kainuma

1. Introduction In recent years, local corrosion damages occurred near the boundary of steel members between embedded and exposed portions were reported. Since the stagnant rainwater or anti-freezing admixture staying for a long time at the surface of steel structure near the ground, the coating deterioration there would be accelerated due to the hydrolysis effect¹⁾. Moreover, the difference at oxygen concentration always existed near the air-liquid interface, and it would lead to the macrocell corrosion and some secondary damages. Therefore, it is important to predict and evaluate the progressiveness of corrosion damages near the ground quantitatively. In this study, a ground corrosion sensor was developed to predict the macrocell corrosion near the air-liquid interface. Moreover, two kinds of electrochemical tests on sensor were conducted to estimate the corrosion rate of steel near the air-liquid interface of NaCl aqueous solution.

2. Sensor structure and electrochemical tests The developed sensor in this study was used to consider both of macrocell and microcell corrosion, using two corrosive modes simulated by working electrodes (WE: denoted as Ch.1~Ch.32) and counter electrode (CE: denoted as Ch.0), sensor structure as shown in Fig. 1 (a). 32 pieces of WE sensors arrange in vertical, each piece owns same dimensions of 20×1 mm. One piece of CE sensor with dimension of 20×63 mm, arrange side by side with WE. During the electrochemical tests, sensor was immersed in 3.5mass% NaCl aq with temperature 20°C. The Ch.1 of WE was fixed above the water-line and exposed to the air, while Ch.2~Ch.32 were immersed in the solution, as shown in Fig.2. A zero resistance ammeter (ZRA) was used for measuring the corrosion current (current range: 0.1nA ~ 100mA). Figure 3 shows the corrosion current between Ch.23 and other WE sensors when Ch.23 was used as counter electrode. Herein the 0.1mass% NaCl aq was considered as contract test for comparison with 3.5mass% NaCl aq environment. Obviously, the oxygen concentration difference in immersion depth direction would lead to the potential difference between different WE sensors, which would cause the electron migration and corrosion current occurred between electrodes. Besides, 3.5mass% NaCl aq would lead to a larger corrosion current.

In macrocell test, the macrocell current caused by potential difference could be measured between CE Ch.0 and each piece of WE, the electric circuit as shown in Fig.2. The currents were measured every 10 minutes. The comparison of macrocell corrosion currents in different test stages as shown in Fig.4. It shows the initial current is relatively large while the data tends to be stable after 48~72 hours. Herein the stable currents at 72 hours was used for the estimation of macrocell corrosion depth, the corrosion surface condition and calculated macrocell corrosion depth of 200 days as shown in Fig.5. Furthermore, a cathodic area with reduction reaction of H₂O and O₂ always occurred near the air-liquid interface, and an anodic area with oxidation reaction of Fe always occurred under about 10 mm below the water-line.

After the macrocell test of 72 hours, the tested sensor was also used for microcell measurement at the same immersion environment. The microcell corrosion at each piece of WE could be calculated according to EIS (Electrochemical Impedance Spectroscopy) test results and Stern-Geary Equation. From the polarization resistance R_c obtained from EIS test and the Stern-Geary constant K which considered as 0.0209 V², the estimated microcell corrosion depth after 200 days as shown in Fig.6. The corrosion depth of Ch.1~3 near the water-line is larger than others.

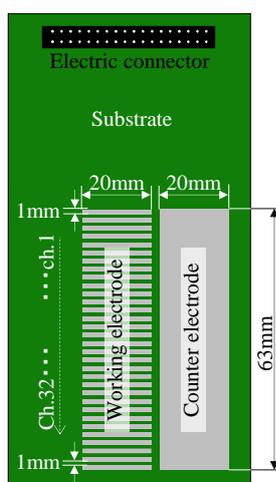


Fig.1 Ground corrosion sensor structure.

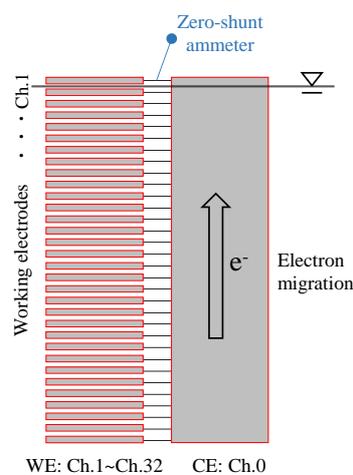


Fig.2 Electric circuit of macrocell test.

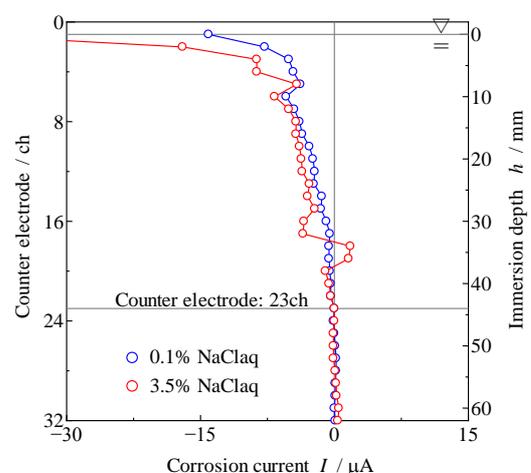


Fig.3 Corrosion current between WE and Ch.23 when Ch.23 be used as CE.

Keywords: Corrosion sensor; Electrochemical test; Impedance; Corrosivity evaluation; Steel member
744, Motooka, Nishi-ku, Fukuoka 819-0395 Kyushu University

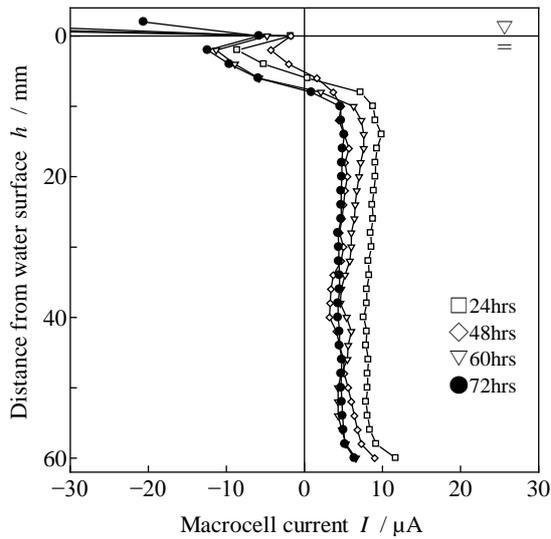


Fig.4 Comparison of macrocell current distribution in different test stages.

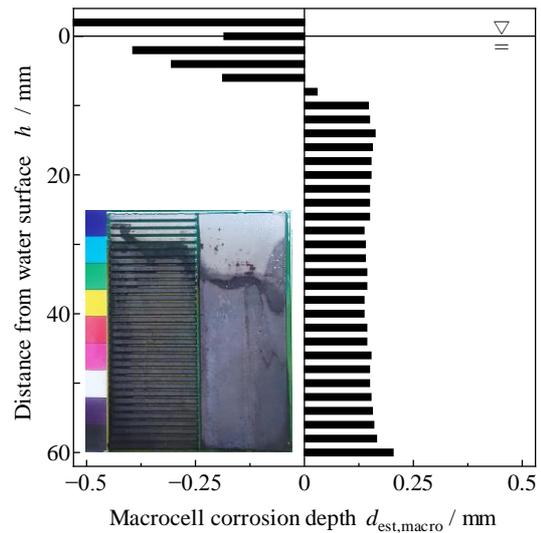


Fig.5 Surface corrosion condition of sensor and calculated macrocell corrosion depth of 200 days.

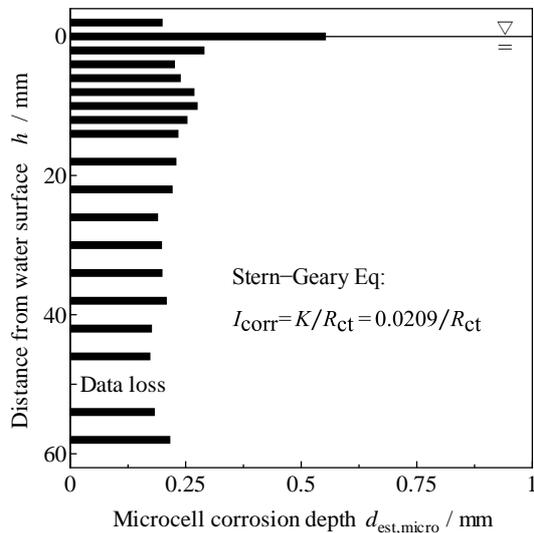


Fig.6 Calculated corrosion depth of 200 days according to microcell test and Stern-Geary Equation.

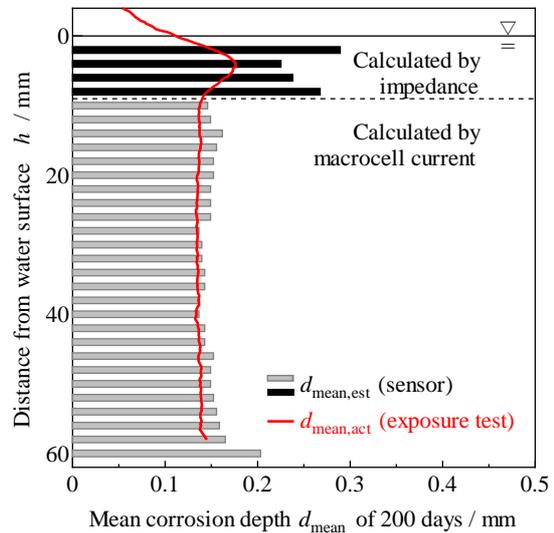


Fig.7 Corrosion depths comparison by exposure test and sensor estimation.

3. Electrochemical test results

Both microcell and macrocell mechanisms contribute to metal loss at a steel member, the Evans diagram representation indicates that an increase in the macrocell current density results in a decreasing contribution from the local microcell at the macrocell anode³⁾. Therefore, the corrosion depth $d_{mean,est}$ of sensor prediction was determined from microcell and macrocell at different regions, as shown in Fig.7. The macrocell corrosion was considered as it only occurred at the macrocell anodic region; while the microcell was considered as it mainly occurred at the macrocell cathodic region. The corrosion depth $d_{mean,act}$ of previous exposure test was used for comparison. For the corrosion depth near the air-liquid interface, sensor prediction is much larger than exposure test results. Since the corrosion depth of sensor is only using linear extrapolation according to the corrosion period t , it can be said that there is a difference in the time-dependent corrosion depths between the sensor estimation and actual. The time-dependent modification on corrosion depth is necessary in future works.

4. Summary

The main results of this study as following: In the vicinity of the gas-liquid interface, it is easy to be fixed as cathode due to the higher concentration of dissolved oxygen. Besides, the corrosion depth of the cathode and anode regions can be predicted by evaluate the microcell and macrocell corrosion rates, respectively.

Reference

- 1) S. Kainuma and N. Hosomi: Fatigue life evaluation of corroded structural steel members in boundary with concrete, International Journal of Fracture, Vol.158, No.1, pp.149-158, 2009.
- 2) T. Tsuru, R. Maeda, S. Haruyama: Application of A-C corrosion monitor to localized corrosion, Corrosion Engineering, Vol.28, No.12, pp.638-644, 1979. (in Japanese)
- 3) K. V. Subramaniam and M. Bi: Investigation of steel corrosion in cracked concrete: Evaluation of macrocell and microcell rates using Tafel polarization response, Corrosion Science, Vol 52, Issue 8, pp.2725-2735, 2010.