THE FEASIBILITY STUDY OF EMBEDDED WIRE SENSOR FOR CORROSION MONITORING OF CONCRETE

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Abstract: This study was carried out as the theoretical study to proposed the titanium wire sensor as the new model of embeddable reference electrode to used in corrosion monitoring in the concrete. To this end, this paper present about the performance of titanium wire sensor exposed to aqueous solutions and variant temperature which compared to SSE reference electrode. The result indicates that wire sensor exhibits the less potential shift in the chloride environment, stability in ambient temperature and reliable to monitor the change of rebar potential in concrete as same as like the SSE reference electrode.

Key words: Titanium wire sensor, embedded, reference electrode, corrosion monitoring.

1. INTRODUCTION

Reinforced concrete may undergo physical deterioration (frost, cracking, fire, etc.), chemical degradation (acid attack, sea water attack, alkali-aggregate reaction, etc.) and steel corrosion. Reinforcement steel corrosion viewed as a major problem in the maintenance of the structural integrity of structures.

Since the corrosion of reinforcing bars in concrete is electrochemical in nature, therefore, various electrochemical techniques are being adopted to monitor reinforcement steel corrosion, such as half-cell potential, linear polarization, and electrochemical impedance spectroscopy.

In the half-cell potential method, the rebar potential is measured only in the vicinity where the reference electrode applied on the surface of the concrete. As a way of using the reference electrode, it classified into a movable electrode which measures the potential of the rebar from the concrete surface and an embeddable type electrode which is embedded in concrete beforehand [1]. Nowadays, some disadvantage of the movable electrode is facing during corrosion monitoring process such as it takes longer time in preparation because scaffolding installation needed when measuring at the site, the workability is unfavorable, and it is susceptible to the moisture content of the concrete. On the other hand, if the wire sensor applied in advance, the scaffold is unnecessary, and it difficult to be influenced by the moisture content because it embedded in the concrete. However, to measure the large area of the concrete structure, a significant amount of the reference electrode must be installed, which raises the problem of high cost. A perfect embeddable electrode must meet the following conditions: it must be stable, invariant to chemical and thermal changes in concrete, tolerant to climatic conditions and have the ability to pass small currents with a minimum of polarization and hysteresis effects, display long-term performance, cost effective and result from an environmentally safe manufacturing process [2].

This study focused on the titanium wire sensor as the new type of reference electrode with a diameter of 3 mm. Stability of wire sensor in the presence and absence of chloride ions, the effect of temperature and linear polarization as the performances characteristics of the titanium wire sensor are reported.

2. EXPERIMENTAL OUTLINE

2.1 Titanium Wire Sensor

The wire sensor consists of titanium probe activated with iridium-enriched mixed metal oxide and 3 mm in diameter is used as sensor electrodes in this study. Fig. 1 shows the schematic of the embeddable titanium wire sensor (WS) for concrete structures. Electrical contact is through the body length of wire sensor. There are fifteen of wire sensors were used to observed during this study.

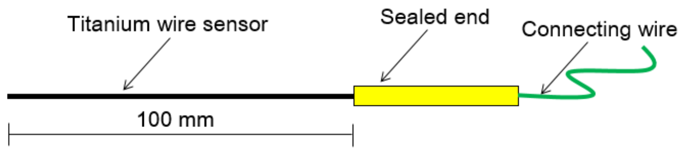


Fig. 1 Schematic of the embeddable titanium wire sensor for concrete

2.2 Specimen Geometry and Exposure Condition

The fifteen wire sensors with 100 mm length exposed to aqueous solutions namely cement water (CW), cement water with 5% presence of chloride (CW5%) and cement water with 10% of chloride content (CW10%). Furthermore, the specimens used to exposed under the variant of temperatures i.e. 0ºC, 31ºC, 48ºC, and 66ºC.

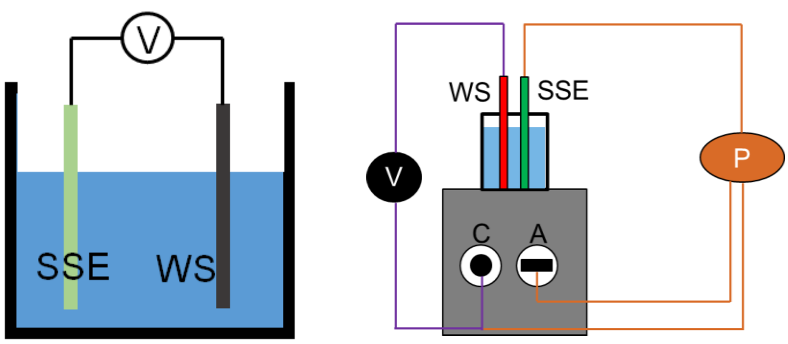
2.3 Response Test of Wire Sensor Electrode

All the electrochemical tests were performed using voltmeter and potentiostat devices.

Stability test — The potentials of WS versus SSE monitored under exposed to aqueous solutions in the presence and absence of chloride ions namely CW, CW5%, and CW10%.

Effect of temperature — The potential of WS electrode measured under different temperatures (0ºC, 31ºC, 48ºC, and 66ºC) to investigate the influence of environmental temperature on the electrode potential. Furthermore, the temperature coefficients of these WS be measured and compared with available commercial reference electrodes such as CSE, Pb and Mn/MnO2. Stability test and effect of temperature test for WS as illustrated in Fig. 2(a).

Linear polarization measurement — The linear polarization condition corresponded to a potential sweep rate of 1 mV/s and potential ranges of +200 to -1500 mV from the open circuit potential. Linear polarization measurement of WS compared to SSE. The overview of this test as depicted in Fig. 2(b). Here, “A” means Anode and “C” mean cathode.



(a) Type 1　　(b) Type 2

Fig. 2 Potential measurement method for wire sensor

3. RESULTS AND DISCUSSION

3.1 Stability Test

Most often, permanent electrodes operated in a place where there is no light and usually in the very narrow temperature range. If they have properly designed and installed, permanent electrodes are less likely to be influenced by changes in contaminants.

Fig.3 shows about the wire sensor potential evolution exposed to aqueous solutions without chloride content (CW) and with chloride content (CW5% and CW10%). The averages of WS potential exposed to aqueous solutions are -15mV, -20mV and -30mV vs. SSE for CW, CW5%, and CW10%, respectively.

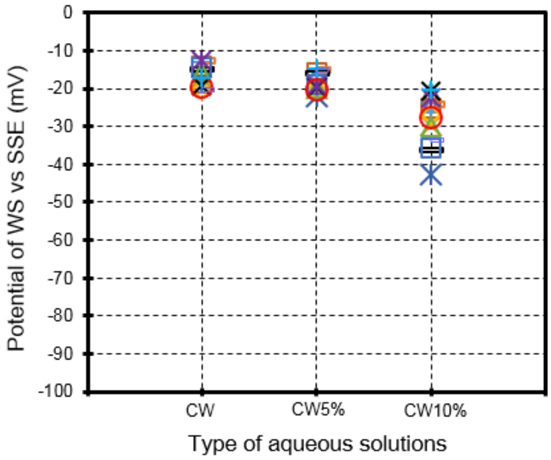


Fig. 3 Variations of potential of wire sensor exposed to aqueous solutions

The potential difference of WS between exposed to cement water with 0% chloride content compared to exposed to cement water with 5% and 10% chloride content are -5mV and -15mV vs. SSE, successively. It means the potential of WS electrode is less likely to be influenced even though by the presence of 10% chloride ions in the solution.

3.2 Effect of Temperature

Temperature is one of the external factors which affect the potential of a reference electrode (RE). Potential of RE changes with temperature for the reason that both electrochemical reactions and chemical solubilities. In electrical resistance, a temperature coefficient describes the relative change of a physical property that associated with a given change in temperature. It is necessary to know the temperature coefficient (TC) to minimize errors in potential reading and to know the electrical resistance of RE. Equation (1) estimates the TC as following [3)]:

$$E = E^0_{25} + (t - 25)dE/dt \qquad (1)$$

Here, E is potential of RE at t (mV), E^0_{25} is potential of RE at t = 25ºC (mV), t is temperature (ºC) and dE/dt is temperature coefficient (mV/°C).

Fig. 4(a) shows the effect of temperatures (i.e. 10ºC, 31ºC, 48ºC, and 66ºC) on the potential of WS and SSE electrode. Average potential of WS under temperature 10ºC, 31ºC, 48ºC and 66ºC are -26 mV, -39 mV, -55 mV and -73 mV, respectively. Meanwhile, the potential of SSE under temperature 10ºC, 31ºC, 48ºC and 66ºC is -41 mV, -48 mV, -53 mV and -60 mV, successively. It informed that increasing of temperature influence the potential of WS and SSE electrode decreased to the negative direction. The temperature increment ±10ºC effected on the ±15mV shift in the potential of WS electrode and ±10mV shift for the potential of SSE electrode.

The bar charts in Fig. 4(b) exhibit the temperature coefficient for several reference electrodes namely Titanium Wire Sensor (WS), Copper Sulphate Electrode (CSE), Plumbum Electrode (Pb) and Manganese Dioxide Electrode (Mn/MnO_2). Accordingly to this figure, the TC of CSE and Pb have the positive temperature coefficient which means the higher the coefficient, the greater increase in electrical resistance for a given temperature increase. Meanwhile, WS, SSE, and Mn/MnO_2 have the negative temperature coefficient which means the lower the coefficient, the greater a decrease in electrical resistance for a given temperature increase. It means even though WS reference electrode shows stability at ambient temperature, but it had a decrease in electrical resistance when the temperature raised.

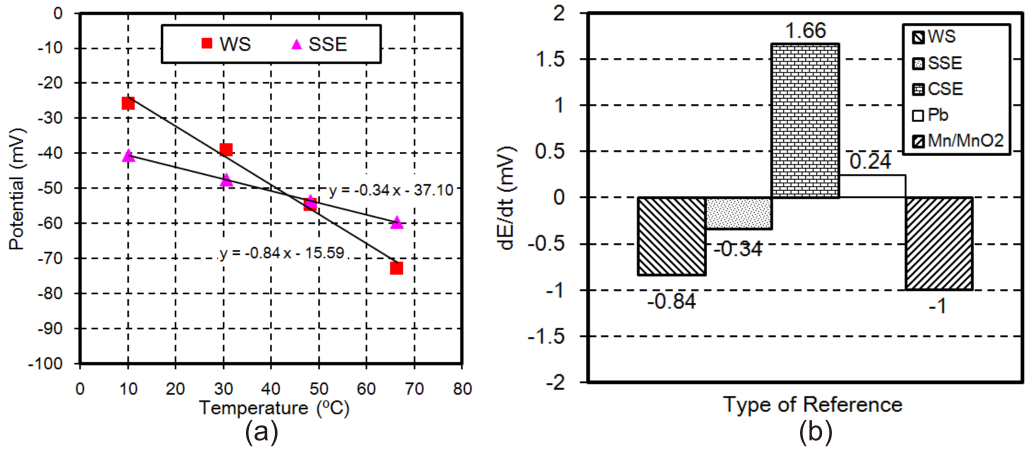


Fig. 4 Potential of wire sensor exposed to variant temperatures (a) and temperature coefficient (b)

3.3 Linear Polarization Measurement

The graph in Fig. 5 show the potential of rebar during linear polarization measurement measured by WS and SSE. The potential of the rebar was varied from + 200 mV to -1500 mV (vs. SSE). It had observed that potential difference of WS towards SSE electrode is 57 mV. The data measured by the WS electrode exhibit the same trend as the SSE electrode. It indicates that WS reliable to monitor the change of rebar potential in concrete as same as SSE electrode.

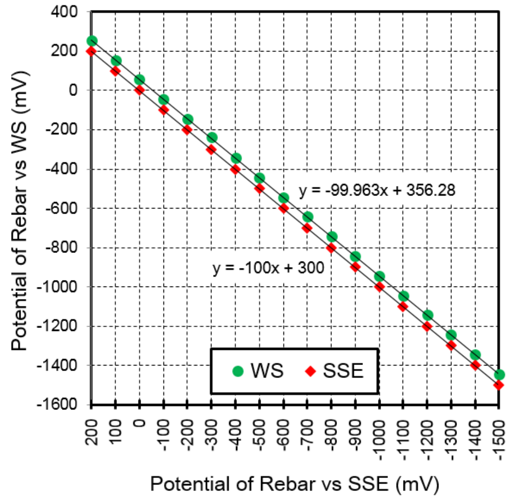


Fig. 5 Potential of rebar vs WS & SSE (mV)

4. CONCLUSIONS

Based on the experimental results, the following findings are derived:

1. The potential of WS electrode is less likely to be influenced even though by the presence of 10% chloride ions in the solution.
2. WS reference electrode shows stability performance at ambient temperature, but it had a decrease in electrical resistance when the temperature raised.
3. During linear polarization test to rebar, potential reading by WS electrode indicates the same trend as the SSE electrode. It means that WS reliable to monitor the change of rebar potential in concrete.

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