Study on Anti-corrosive Method with Sacrificial Anode for Embedded Steel Members in Concrete using Water Swelling Rubber

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1 Introduction The serious corrosion cases at embedded boundary of steel and concrete were reported lots in recent years, such as the vertical truss and steel pier of urban highway bridge. It has been recognized as the major cause of degradation of structures in many parts of the world [1]. The occurrence of these electrochemical corrosion damages should mainly due to the stagnant water at the corner, as shown in Fig.1. Recently, the anti-corrosive method with sacrificial anode has being applied to ships and offshore structures. In this study, aimed at the boundary corrosion at embedded steel members in concrete, the water swelling rubber was used in the system, and the swelling and drying tests of rubber were carried out to clarify its water retention. Furthermore, five specimens were conducted by the moist curing and immersion test, to demonstrate the efficiency of anti-corrosion current in different corrosion environment.

2 Corrosion test method The anti-corrosive system including the sacrificial anode and water swelling rubber, as shown in Fig.2. At the rainy days, the accumulation of water between Fe and Zn plate would act as electrolyte. At the same time, it would evaporate into the air and be absorbed by the rubber. At the sunny days, the absorbed water by rubber could act as electrolyte for a long-term, so that the anti-corrosive current continuous flowing. Therefore, the anti-corrosive tests including the immersion test (120-240hrs.) and moist curing test (0-120hrs. and 240-360hrs.) to simulate the alternate change of immersion and dry environments, respectively. The test specimens were composed by Fe plate(70×70×9mm; JIS G3106 SM490A), rubber(40×40×6mm), Zn plate(70×70×1mm), and fixed by PEEK (polyetheretherketone) bolt. The dimensions of specimen and the images of anti-corrosive tests as shown in Fig.3. Both of the immersion test and moist curing test were conducted in the thermo-hygrostat which could provide the curing temperature 18°C and relative humidity 75% in. The anti-corrosion current flowed between Fe and Zn plate would be recorded every 10 minutes by non-resistance galvanometer.

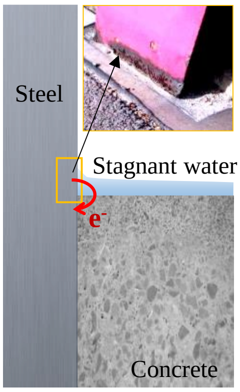


Fig.1 Corrosion damage

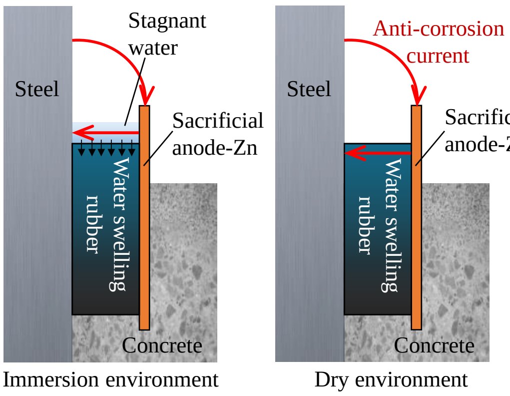


Fig.2 Anti-corrosive method with sacrificial anode using water swelling rubber

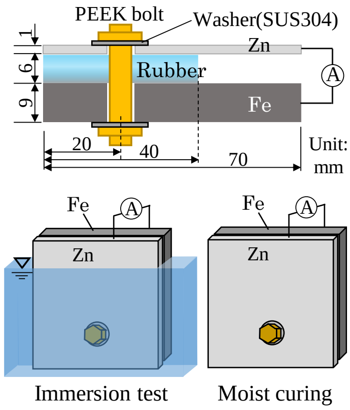


Fig.3 Dimensions of specimen and corrosion tests

Water swelling rubber is a kind of superabsorbent polymer material, which owns a better water-retention property and adhesion than the fiber sheet. It could be attached to the surface of embedded steel members in concrete in a stable condition. The material properties of water swelling rubber as shown in Table 1[2]. The time-variant weight of water swelling rubber in distilled water and 3.5wt%NaCl as shown in Fig.4. It shows the rubber tend to reach the maximum water absorption after dipping for 30 days, and the weight of rubber would back to initial value after it drying for 60 days. Moreover, the ability of water absorption is due to osmotic pressure, which could force the rubber swelling and store plenty of water. Therefore, the absorbent solution at low concentration would lead to a better absorption capacity of rubber.

The concentration of rubber absorbent solution were also discussed in anti-corrosive tests: 1wt% and 5wt% $NaNO_2$aq were used as the electrolyte of rubber absorbent solution. To study the effect of residual water of rubber on the time-dependent anti-corrosive current, the dry processing on rubber was also conducted at two specimens as contrast. Moreover, five tests were carried out with 3.5wt% or 0.1wt% NaClaq to simulate the seawater and rainwater of immersion environment. The test conditions as shown in Table 2.

Table 1 Material properties of water swelling rubber [2]

Density kg/dm^3 (MPa)	Young's modulus E (MPa)	Hardness H	Tensile strength (MPa)	Elongation (%)	Bulk modulus V (%)
1.2	0.65	A40±5	4.0+	500+	200+

Table 2 Test conditions

Specimens	Electrolyte of rubber		Rubber processing (days)		Tests environment	
	Electrolyte	Concentration (wt%)	Swelling	Drying	Immersion	Moist curing
Dew1-S	$NaNO_2aq$	1.0	30	—	3.5wt%NaClaq (Seawater)	Temperature:18°C Humidity: 75%RH
Dew5-S		5.0				
Dry1-S		1.0	60	40		
Dry5-S		5.0				
Dew1-R		1.0	30	—	0.1wt%NaClaq (Rainwater)	

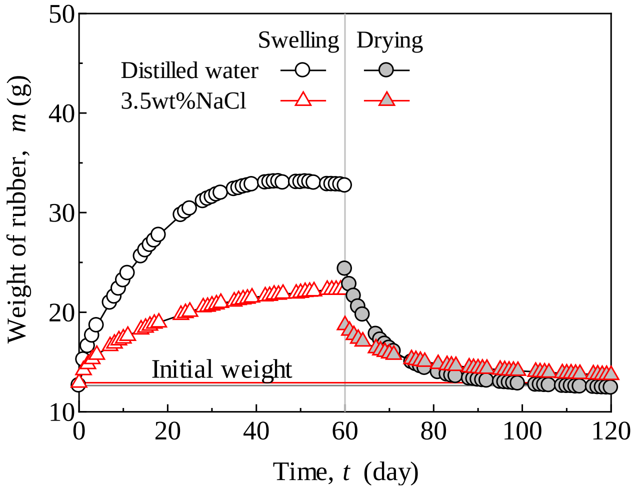


Fig.4 The time-variant weight of water swelling rubber in different electrolytes

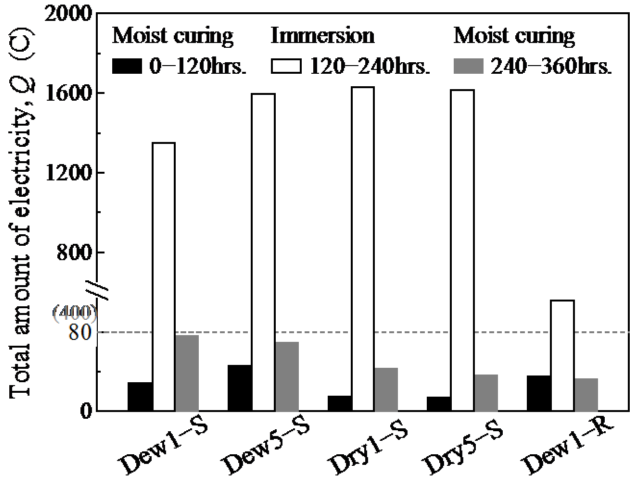
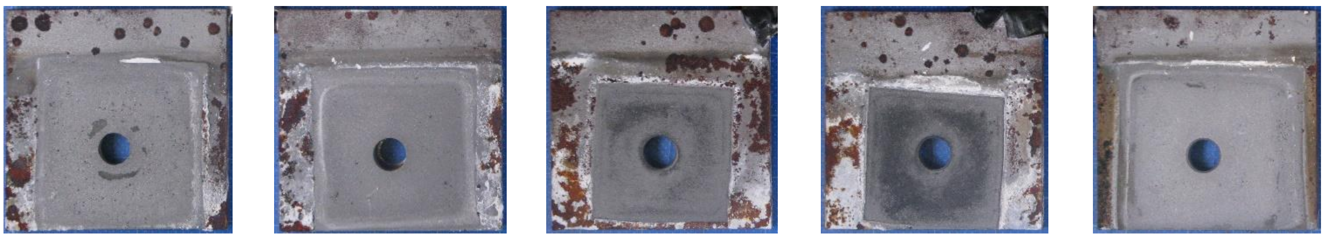


Fig.5 Total amount of electricity during the moist curing stage and immersion test



(a) Dew1-S (b) Dew5-S (c) Dry1-S (d) Dry5-S (e) Dew1-R

Fig.6 Steel surfaces after the anti-corrosive tests

3 Corrosion test results Based on the measurement of anti-corrosive current during three stages of testing, Fig.5 shows the total amount of electricity Q in the moist curing and immersion test. Obviously, the anti-corrosive current of immersion test is much larger than that of moist curing test, because the stagnant water owns a larger conductivity than rubber as an electrolyte. Compare the total electricity Q of twice moist curing tests, it shows the Q of 1st moist curing is usually smaller than that of 2nd, besides specimen Dew1-R which using rainwater as electrolyte during immersion test. For Dew1-R, the low concentration of ions inside of rubber is the main reason for its low Q value. It was considered the anti-corrosive current would change depending on the immersion environment. Besides, the cases of Dry1-S and Dry5-S show the total Q would always reduce when the water content in rubber decreased. However, trace water in rubber could still act as electrolyte, and provide anti-corrosion effect at interface between Fe plate and rubber, as shown in Fig.6. However, the Fe corrosion products of Dry1/5-S specimens are much more than other specimens at the non-contacted surface, it might due to the low current and low anti-corrosive efficiency during moist curing tests. Furthermore, the contrast case Dew1 and Dew5 shows not only the water content inside of rubber, but also the high conductivity of rubber swelling solution are the significant factors to improve the effect of anti-corrosion.

4 Summary 1) The low concentration of rubber absorbent solution owns has the better absorption capacity. 2) The anti-corrosive current would change depending on the immersion environment such as the solution concentration. 3) Both of the large water content and solution conductivity inside of rubber are the significant factors to improve the effect of anti-corrosion of system.

Reference [1] A. Poursaee (Ed.), Corrosion of steel in concrete structures. Woodhead Publishing, 1st Ed, 2016. [2] JIS K 6253. Rubber, Vulcanized or Thermoplastic–Determination of Hardness. Japanese Standards Association, Tokyo, Japan, 2006.