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THE INFLUENCE OF TEMPERATURE AND HUMIDITY ON RUST GROWTH ON WEATHERING STEEL

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In this study, to develop a growth prediction method of rust on weathering steel, the rust progress characteristics under constant temperature and humidity have been conducted. In order to achieve a long life of weathering steel bridges, determination of several problems are required. Especially, rust evaluation technology, rust prediction method and repair technology of corroded weathering steel are significant. Different concentration (0.3%, 1.0%, 3.0%) of salt water sprayed on steel test pieces and,- were placed in a constant temperature and humidity test vessel, to observe the progress of rust in in-plane direction. Four patterns of exposure environment were tested. Exposure environment were combination of temperature (40°C, 20°C) and relative humidity (50%, 95%). To calculate the increase of rust area, specimen surface was confirmed. Higher salt water concentration (3%) brought rapid rust development. Furthermore, the increase of rust area was highly dependent on temperature than humidity. From time observations, it becomes clear that increase of rust area can be approximated to a logarithmic curve.

Keywords: Weathering steel, Rust, Salinity, Temperature, Humidity.

1 INTRODUCTION

In recent years, cost in construction has been based on life-cycle-cost. Life-cycle-cost consists of not only initial construction cost but also maintenance cost (Kihira 2007). Generally, a large part of maintenance cost of steel structures is paint. Paint has been used for corrosion control of steel structures.

Weathering steel is a steel which can reduce the corrosion rate by generating a dense protective rust on the steel surface and exert anti-corrosion performance. Thereby, weathering steel could be provided corrosion protection performance without painted layer. Due to these advantages in maintenance cost, number of weathering steel bridges has been increased in Japan (Kage *et al.* 2007). However, in some cases, very severe surface corrosion which be able to reduce load bearing capacity has been observed (JSSC 2006, JSSC 2009).

In order to achieve a long life of weathering steel bridges, rust rating technique, method of rust predictive simulation and repair technique of corroded weathering steel member must be established.

To establish a growth prediction method of rust, relationship between rust growth speed and the corrosive environment has to be clarified. In this study, exposure tests of weathering steel were performed under constant temperature and humidity environment. During exposure test, area of rust was observed by image analysis to estimate spread speed of rust on specimen surface. From the results of test, horizontal spread of rust could be approximate as logarithmic curve.

2 MATERIALS AND METHODS

2.1 Exposure Test

Exposure tests were started from October 20, 2015. A growth of rust is horizontal spread on steel surface and three dimensional progress by occurrence of steel wear and corrosion product. In exposure test, weathering steel of 70×70×6(mm) was used as specimen. Salt water of 0.02 ml was dropped on the specimen. Salt water was made from sodium chloride and deionized water. One specimen was supplied only one kind of salt water. Then moisture on the specimen surface was dried. The specimen was installed in a small environment tester. The concentration of salt water was set to 0.3%, 1% and 3%. In this study, the specimen which is dropped salt water was exposed. Furthermore, to clarify the effect of salt to steel corrosion in this tests, non-supply specimens ware also set. Table 1 gives conditions of the test. Temperature and humidity were decided due to the performance of small-environmental-tester and observations of bridge sites. Formed rust on each specimen were photographed every day. The image was trimmed to 280 × 280 pixels around center of a salt water drop part. The area of this image was 1238.278mm^2. Shot images are divided into three components, red, green and blue(RGB). Then using analysis software, the image was taken out only green component from the RGB components. The area ratio of rust part was calculated by extracted image. The area of rust part was the ratio of rust and trimmed image area.

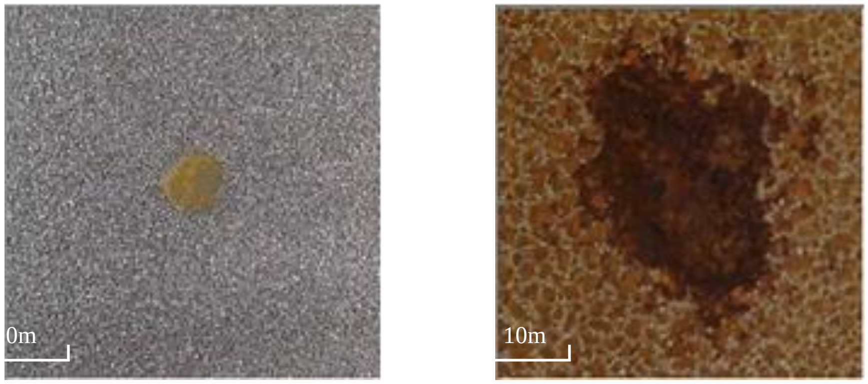
Table 1. Test conditions.

	Temperature-Humidity	Number of specimen	Salt water concentration	Period of exposure
Case1	40°C-95%	4	Not dropped	30
Case2	40°C -50%	4	0.3%	29
Case3	20°C -50%	4	1%	18
Case4	20°C -95%	4	3%	20

3 TEST RESULTS

3.1 Appearance Evaluation

Figure 1 shows the appearance of the specimen which is exposed of day1 and day 30 in temperature 40°C and relative humidity 95% (3% salt water). The color of the salt water drop part changed to black during 30 days. Therefore, it was possible to confirm clearly that the rust grew. Except for the salt water drop part, the occurrence of uniform corrosion was recognized. However, this uniform corrosion was not verification target. Figure 2 indicates the banalization of green component of Figure 1(b). This process is effective to enhance the rust region in images. Figure 3 shows the image of particle analysis. The area ratio of all images was calculated from this step.



(a) Day1 (b) Day30

Figure 1. Variation of area ratio at day1 and day30 (3% salt water)

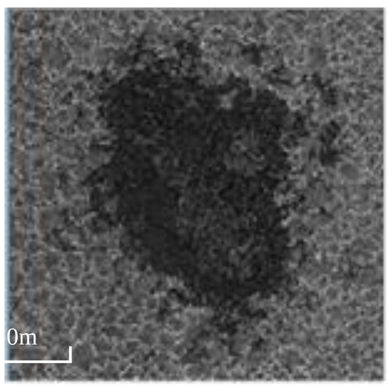


Figure 2. Image of green component

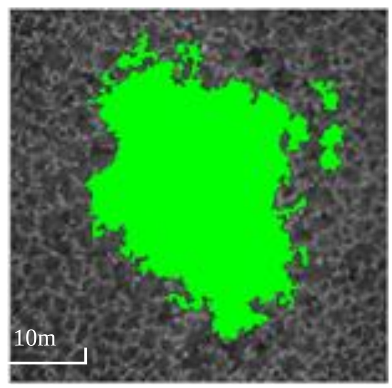
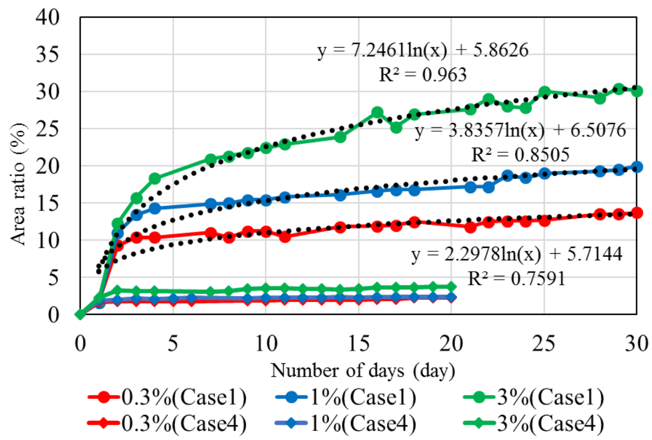


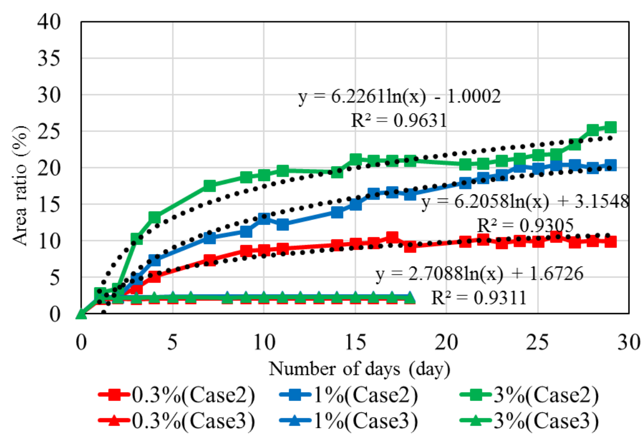
Figure 3. Particle analysis image

3.2 Evaluation of Area Ratio of Rust Part

Influence of corrosion environment is evaluated from the ratio of rust-region. Figure 4 (a) and Figure 4 (b) illustrates the variation of the area ratio with duration in Case1 and Case4, Case2 and Case3, respectively. In Case1 and Case 4, relative humidity is set for 95% in both case but temperature is different (40°C in Case1, 20°C in Case4). In Case2 and Case 3, relative humidity is 50%. In all cases, the area ratio of the specimen which was dropped 3% salt water was big. Therefore, the influence of salt on the rust growth could be confirmed. However, increasing tendency of the area ratio was different in Case1 and Case4. The area ratio which is dropped 3% salt water in Case1 was 25% in day 20. In contrast, the area ratio in Case4 was 3%. It was found that tendency did not depend on the salinity. Furthermore, it was observed that the influence of temperature to growth of rust is big from Fig.4 (a) and Fig.4 (b). This tendency could be confirmed in Case2 and Case3 that are low relative humidity. From the comparison with Case1 and Case 2, in the same temperature and same salt water concentration, high relative humidity provides large area ratio. However, this tendency could not have observed in low temperature (Case3 and Case4). The logarithmic approximation formula is shown to Fig.4 (a) and Fig.4 (b) dashed line. But the approximation was impossible from data of Case3 and Case4. The calculated approximate value from these approximate formula was close to the actual measured value. In all cases, the coefficient of determination was more than 0.75.



(a) Case1 and Case4



(b) Case2 and Case3

Figure 4. Variation per day of area ratio with duration.

4 GROWTH PREDICTION METHOD OF RUST

This paper also aims to establish a growth prediction method of rust to quantitatively evaluate a corrosion process of weathering steel. From the results of exposure tests it became clear that rust growth is due to temperature, humidity, salinity. The relationships between horizontal growth of rust and exposure duration can be assumed by using logarithmic function. The rust growth prediction would be expressed by equation (1)

$$Y = A\ln(X) + B \tag{1}$$

Where, Y: rust thickness, X: exposure days, A and B: Constants.

In Case1 and Case2, rust growth could be confirmed clearly. The relationship between concentration of salt water and coefficient or intercept of the logarithmic formula was verified.

Figure 5 shows the relationship between coefficient of the logarithmic formula and concentration of salt water in Case1 and Case2. Also Figure 6 shows the relationship between the intercept of the logarithmic formula and concentration of salt water. In Case1, linear relationship was recognized between the coefficient and concentration of salt water. In addition, three values of intercept are almost the same in the case of concentration. And on the other hand, the tendency was not recognized in Case2. In Case2, the value of 1% salt water was protruded. The reason is that the rust growth of the specimen which was dropped 1% salt water was big in 10 days later in Case2. In Case1, the rust growth prediction equation was calculated. It became clear that *A* is 1.805*C* (*C*: concentration of salt water) and *B* is 6.027. The rust growth prediction equation was expressed by equation (2) in Case1.

$$Y=1.805C\ln(X)+6.027 \tag{2}$$

Where, *Y*: area ratio of rust, *X*: exposure days, *C*: concentration of salt water.

Figure 7 shows measured value and calculated value from equation (2). Equation (2) shows good agreement to measured value. Therefore, equation (2) is applicable as rust growth prediction equation in Case1. Accuracy of approximation could be improved by increasing the experimental results.

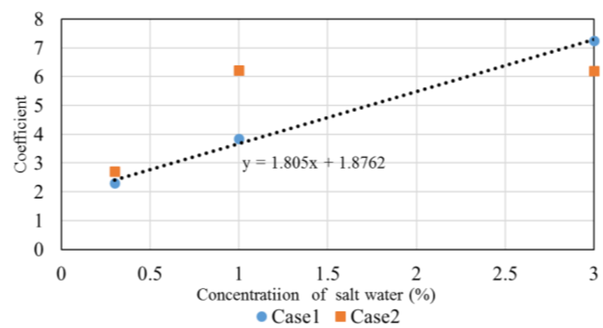


Figure 5. Coefficient and concentration of salt water.

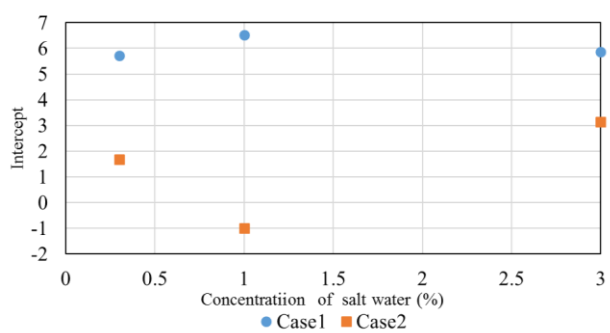


Figure 6. Intercept and concentration of salt water.

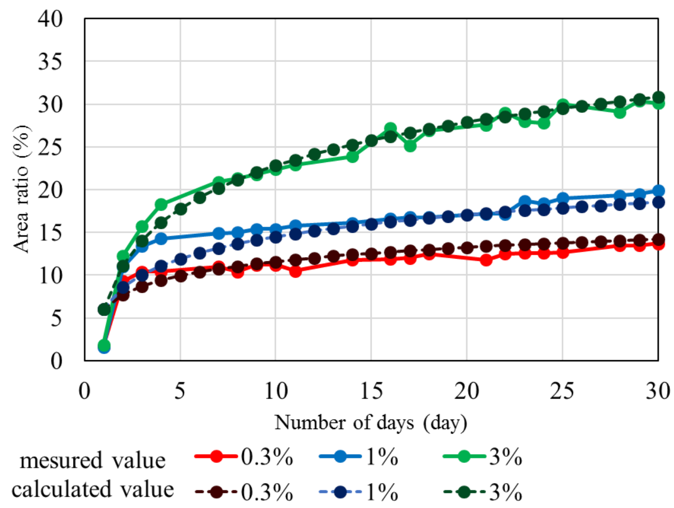


Figure 7. Measured value and calculated value.

5 CONCLUSION

Rust growth on weathering steel under several corrosion environment was evaluated by ratio of rust region. Results of this research could be pointed as below.

1. Rust growth is depending on temperature and salt condition strongly. An effect of relative humidity was small in this test.

2. Ratio of rust region could be approximated by logarithmic formula. Accuracy of approximation could be improved by increasing the experimental results.

3. Coefficient of approximated curves are related to concentration of salt water.

To apply the result of this research to actual bridges, corrosion environment (temperature, relative humidity and amount of airborne salt) of these bridges are required. A database of corrosion environment should be constructed for planning and design of weathering steel bridges.

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