The 2017 World Congress on
Advances in Structural Engineering and Mechanics (ASEM17)
28 August - 1 September, 2017, Ilsan(Seoul), Korea

Prediction for corrosion depth of weathering steel using corrosion product layer

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ABSTRACT

The corrosion environments on steel structure are significantly different depending on structural member. The time-dependent thicknesses of the corrosion product layer were examined to quantifiably investigate and determine the corrosion depth of the corroded surface according to the exposure periods and corrosion environments. The corrosion depths were analyzed using a typical evaluation method and the thickness of corrosion product layer.

1. INTRODUCTION

The weathering steel has been adopted for steel bridges because of the reduction in repainting cost. The design of weathering steel bridges excludes the application of a protective coating such that the steel is permitted to rust at an uncontrolled rate. However, when in contact with airborne salt, anti-freezing agents, moisture and fugitive dust, the surfaces of the members did not form a protective rust layer in steel structural members. The corrosivity of the structural member and the time-dependent corrosion behavior are important factors in ensuring that weathering steel bridges can be used safely and are economical.

Previous studies regarding corrosion damage of weathering steel have usually been conducted to verify its corrosion durability and the corrosion environment by measuring the corrosion loss for anti-corrosion techniques such as atmospheric

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exposure tests based on the assumption by conventional power-law function (Kamimura 2006, Chen 2005). In predication model in the long term corrosion loss response of weathering steel, the durable state concept and series of sequential phases model have been applied (Kihira 2005). However, these tests cannot evaluate the thickness of corrosion product layer and corrosion environments, which emphasizes the importance of maintenance of steel structures in order to increase of their service life.

In this study, the time-dependent thicknesses of the corrosion product layer were examined to quantifiably investigate and determine the corrosion depth of the corroded surface according to the exposure periods and corrosion environments. Thus, their atmospheric exposure tests were carried out for 4 years, where, four test fields were chosen because their corrosion characteristics are different. The effect of the atmospheric on the thickness of the corrosion product layers was examined.

2. ATMOSPHERIC EXPOSURE TESTS

To examine the corrosivity of steel members under atmospheric environments, atmospheric exposure tests on weathering steel plates were conducted for 0.5, 1, 2, 3 and 4years. In case of corrosion problem, amount of airborne salt, moisture and sand puddle and their interaction and time-dependent effects are significant factors. Thus, 4 test fields were selected to determine the time-dependent corrosion factors in atmospheric corrosion environments. The test conditions of each test field are summarized in Table 1.

Table 1 Conditions of test field with 4 years

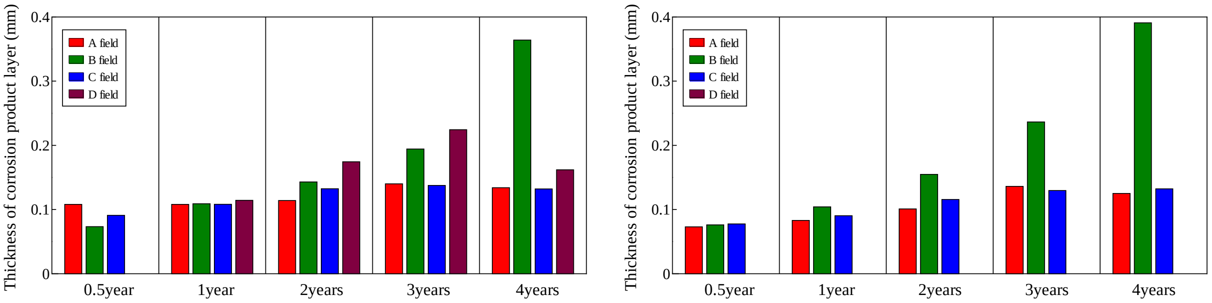
Field	Location	Length from coastline (km)	Temperature (K)	Relative humidity (%)	Airborne salt (mg·dm^{-2}/day)
A	lat. 33°35′ N, long. 130°12′ E	2.9	289	75	0.41
B	lat. 33°35′ N, long. 130°21′ E	0.05	291	66	0.57
C	lat. 26°15′ N, long. 127°46′ E	2.3	296	74	0.29
D	lat. 26°32′ N, long. 127°57′ E	0.05	296	74	0.68

The atmospheric exposure test specimens are uncoated weathering steel plates (JIS G 3114 SM490AW) with lengths, widths, and thicknesses of 400, 60, and 9 mm, respectively. In order to consider the various corrosion conditions based on the detail and installation of the steel structural members, they are installed at angles of 0°, 45°, and 90° to the horizontal. For the test specimens at an angle of 90°, the north-facing surface was defined as skyward in the A and C test fields. The seaside surface was defined as skyward in test specimens in the B and D test field. In addition, in order to examine the effect of rainfall in corrosion environments, B and D field were installed under Highway.

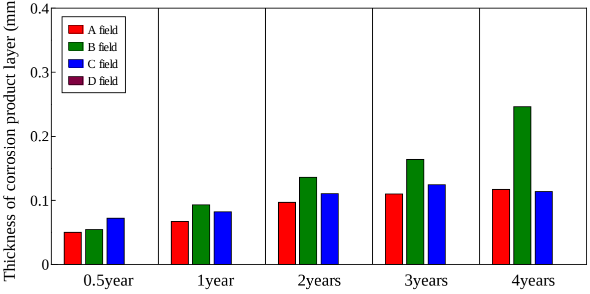
3. ATMOSPHERIC EXPOSURE TEST RESULTS

Fig. 1 shows the thicknesses of the corrosion product layers of the test specimens. The variation in the thicknesses of the corrosion product layers on the B and D field specimens are larger than that of the A and C field specimens, it was shown to not be directly influenced by the rain-wash effect. The variation shows the same tendency regardless of the exposure field and installation angle. The mean thicknesses of the corrosion product layers of the B field specimens are shown to increase according to the exposure period (year) in corrosive atmospheric environments. The corrosion environment of D field is similar to that of B field, however, it shows a tendency to decrease, as a result of porous surfaces due to the lack of rain-wash effect, depending on exposure period. The mean thicknesses of the A and C field specimens at an exposure period of three years is either constant, or decreases as a result of the rain-wash effect.

To examine the relationship of mean corrosion depth-thickness of the corrosion product layer and corrosion environment, the environments were classified as stagnant water, and with and without rain-wash effect. Fig. 2 show the relationship between the mean corrosion depth and the thickness of corrosion product layer, and the related coefficient values. In the case of test fields A and C, the thickness of corrosion product increased slightly with increased mean corrosion depth. The values of the B and D field specimens gradually increased with mean corrosion depth. In the cases of the corrosion environment under stagnant water conditions and with rain-wash effect, the thickness of corrosion product layer was less than 0.15mm, but those of without the rain-wash effect was increased at the increased mean corrosion depth.



(a) 0˚ (b) 45˚



(c) 90˚

Fig. 1 Measurement of corrosion product layer thickness

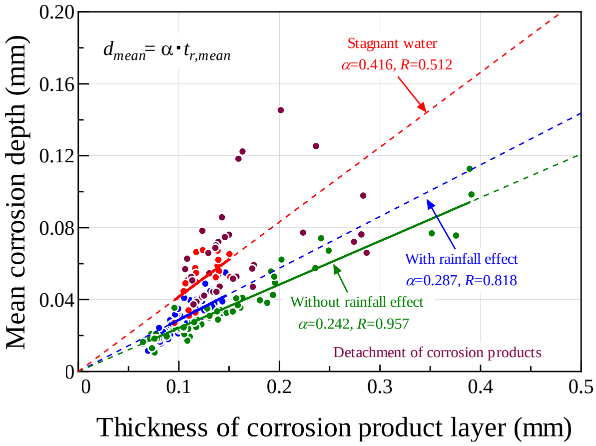


Fig. 2 Mean corrosion depths

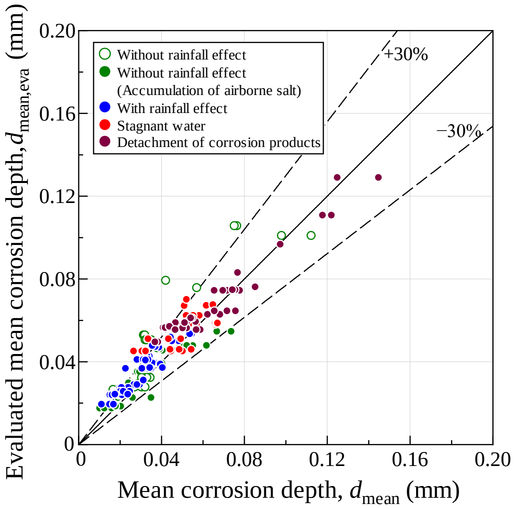


Fig. 3 Validation of mean corrosion depth

To verify the evaluated mean corrosion depth using the thickness of the corrosion product layer in an atmospheric corrosion environment, the evaluated mean corrosion depths were compared with measured mean corrosion depths for each corrosion environment, as shown in Fig. 3. It is shown to be similar to the mean corrosion depth of real corroded steel, and the evaluated mean corrosion depth is within 30%.

4. CONCLUSIONS

The corrosion depths were analyzed using a typical evaluation method and the thickness of corrosion product layer. From the results, the relationships of the mean corrosion depth and exposure time varied appreciably depending on whether the exposed surfaces are skyward or groundward, as well as on the installation angle of the exposure field. The mean corrosion depth and thickness of the corrosion product layer of each tested specimen were compared according to the corrosion periods. In addition, the mean corrosion depth was calculated based on the measured thickness of the corrosion product layer.

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