

Spatial Statistical Simulation for Time-dependence of Corrosion Surfaces of Uncoated Carbon Steel Plate in Atmospheric Corrosion Environments

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1. Introduction Severe corrosion damages have been observed in steel structures. However, there is currently no established method for predicting the corrosion behavior in various corrosion environments. In this study, atmospheric exposure tests were carried out on uncoated steel plates that exposed in the Okinawa Island. In addition, semi-variogram analyses were conducted on the exposed test specimens to clarify the characteristic of corroded surfaces. Moreover, numerical simulation method for time-dependent corrosion surfaces was proposed using spatial statistical techniques.

2. Atmospheric exposure test Atmospheric exposure tests were conducted on uncoated steel plates for 0.5, 1, 2 and 4 year on Okinawa Island. The material used of the test specimens is JIS G 3106 SM490A structural steel plates. The size of the specimens is $400 \times 60 \times 9$ mm. The specimens were installed on the rack at angle of 0° , 45° and 90° to the horizontal. The corrosion depth of specimens measured using a laser focus measuring instrument system and weight loss method following removal of the rust.

The corrosion depth at the skyward-facing for angle of 0° , 45° , 90° for exposed period of 4 years is shown in Fig. 1. Corrosion depth increases as time passed and the corrosion surface is different for each mounted angle. The mean corrosion depth of 0° -specimen after exposed period for 4 year is 1.8 times than that of 45° , and 3.4 times than that of 90° -specimen.

3. Numerical simulation New approaches to corroded surface are taken by Kainuma and Hoshomi, by using spatial statistical techniques such as semi-variogram analysis (Cressie 1985). The range h and sill γ with parameter of corrosion surface in semi-variogram was calculated by using Eq. (1), as shown in Fig 2.

$$\gamma(h; \theta) = \begin{cases} \theta_1 \left(1 - \frac{3}{2} \frac{|h|}{\theta_2} + \frac{1}{2} \frac{|h|^3}{\theta_2^3} \right) & (0 \leq |h| \leq \theta_2) \\ 0 & (|h| \geq \theta_2) \end{cases} \quad (1)$$

where Eq. -(1), $\gamma(h; \theta)$ is the covariance function of the spherical model, θ_1 and θ_2 are the sill and range, and h is the Euclidean distance.

Figure 3 shows the relationship between range h and mean corrosion depth d_{mean} . The mean corrosion depth increases with increasing range h , and mean regression curve was different for each mounted angle. When the mean corrosion depth is less than 0.02mm, the value of range h for corroded surface at 45° and 90° -specimen is greater than regression curve. This is because that the corrosion pits were not formed on all surfaces of the specimens. The relationship between sill $\gamma^{1/2}$ and mean corrosion depth d_{mean} is shown in Fig. 4. Also mean regression curve and confidence interval were designated by the curves. The value of $\gamma^{1/2}$ in various corrosion environments increases in proportion to d_{mean} . There is a marked contrast between range and sill. The range at uniform corrosion was influenced by corrosion environment, while sill affected the mean corrosion depth than corrosion environment.

The corroded surface makes a comparison between the simulation data and test specimen by the covariance function. The size of simulated area and pitch were 40×40 mm and 0.2mm, respectively. Fig. 5 shows the experimental and simulated result of skyward-facing of 45° -specimen after exposed for 4 years. Fig. 6 shows the histograms of frequency of corrosion depth in test specimen and simulated result. The simulated result is similar to the spatial distribution of corrosion depth and a frequency distribution curve with the actual corroded surface of the specimen. These results demonstrate that numerical simulations accurately describe the corroded surface.

Range, sill and corrosion depth of corroded surface assumed that numerical simulation of time-dependence of corrosion surface was executed for spatial statistical techniques.

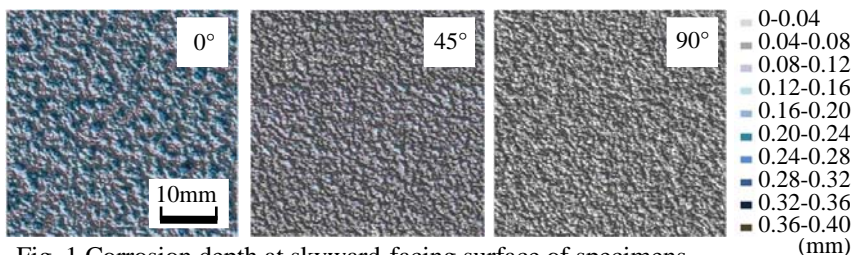


Fig. 1 Corrosion depth at skyward-facing surface of specimens after exposed for 4 years.

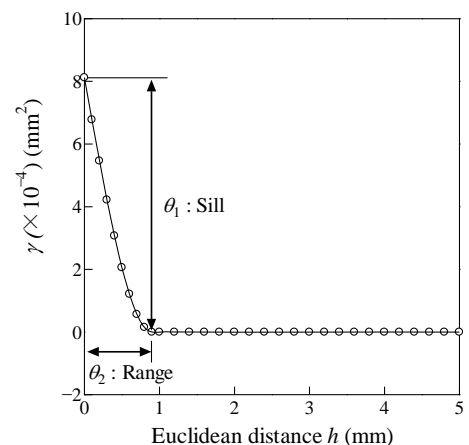
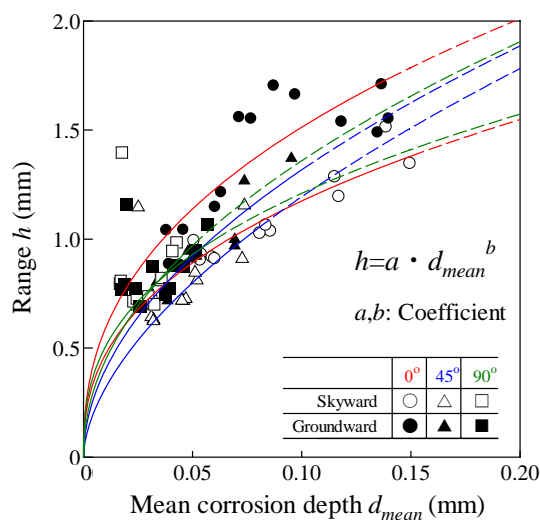
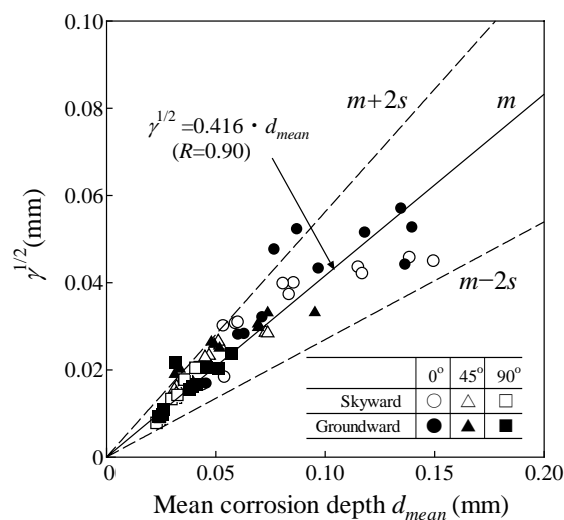
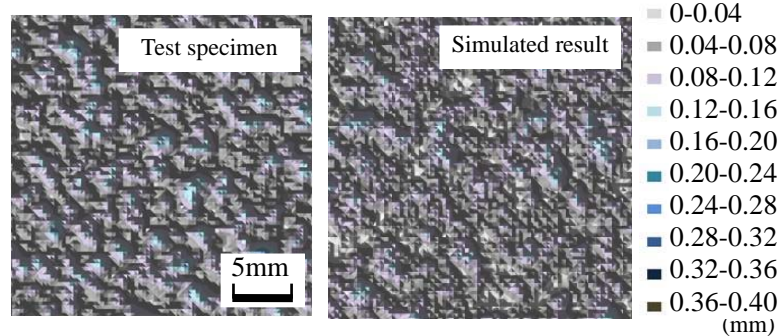
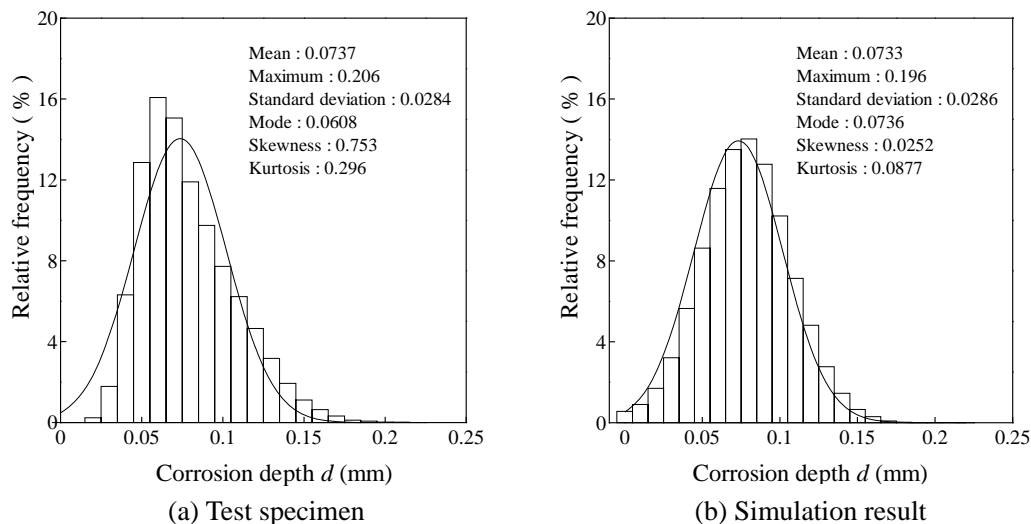


Fig. 2 Semi-variogram

Fig. 3 Relationship between range h and d_{mean} .Fig. 4 Relationship between $\gamma^{1/2}$ and d_{mean} .Fig. 5 Measured depth of corroded surface and simulated specimen on skyward-facing surface at an angle of 45° after exposed for 4 years.Fig. 6 Histogram of frequency of corroded surface in test and simulated data on skyward-facing surface at an angle of 45° after exposed for 4 years.

However, the range and sill were difference by corrosion environment. Accordingly, conducting experimental and numerical study for various environments intend the numerical simulation of time-dependent environments.

4. Summary

- 1) The relationships between the range and exposure period, and the sill and exposure period were formulated.
- 2) A numerical simulation method was proposed to estimate the time-dependent corroded surfaces of uncoated carbon steel plate in atmospheric corrosion environments.

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