Spatial Statistical Simulation for Time-dependent Corrosion Surfaces of Uncoated Steel Plates in Atmospheric Corrosion Environments

Kyushu University Student member ○Y. S. Jeong
Kyushu University Regular member _S. Kainuma

1. Introduction Steel structures have been deteriorated mainly due to corrosion damage. It is important evaluate the corrosion behavior to ensure the safety of such structures. The purpose of this research is to propose a numerical simulation method for time-dependent corrosion surfaces of uncoated steel plates. Atmospheric exposure tests were carried out on uncoated steel plates for 0.5, 1, 2, 3 and 4years in the Okinawa Island. In addition, corrosion surfaces of the tested specimens were analyzed using semi-variogram to quantify the spatial autocorrelation structures.

2. Atmospheric exposure tests Atmospheric exposure tests were conducted on uncoated steel plates for 0.5, 1, 2, 3 and 4 year in Okinawa Island(Latitude 26°15'N, Longitude 127°46'E). The specimens were mounted on a rack at angle of 0°, 45° and 90° to the horizontal. This range of angles was not used to investigate the influence of angle on the corrosion behavior, but simply obtain corrosion data for diverse corrosive environments. The mean corrosion depth of the specimen surfaces was calculated from both laser-measuring data and weight loss data.

Figure 1 shows the corrosion depth at the skyward-facing surfaces after 4 years of exposure at each mounting angle. The surface roughness was different for each mounting angle. In particular, localized corrosion was observed on the surface at the angle of 0°.

3. Numerical simulation of time-dependent corrosion surfaces

3.1 Spatial statics of corrosion surfaces Corrosion depth data of tested specimen was analyzed using a semi-variogram which is one of the spatial statistical technique[1)]. The range h and sill γ with parameter of corrosion surface in semi-variogram was calculated by using Eq. (1), and shown in Fig 2.

$$\gamma(h;\theta)=\begin{cases}\theta_1\left(1-\dfrac{3}{2}\dfrac{|h|}{\theta_2}+\dfrac{1}{2}\dfrac{|h|^3}{\theta_2{}^3}\right) & \left(0\le|h|\le\theta_2\right)\\ 0 & \left(|h|\ge\theta_2\right)\end{cases} \qquad \textbf{(1)}$$

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.

The mean corrosion depth d_{mean} of the specimens is shown in Fig. 3. Solid and dashed lines indicate regression curves for d_{mean} as function of exposed period t. The value of d_{mean} depends on the mounting angle and surface direction. Figure 4(a) shows the range of h for each corrosion surface plotted against d_{mean}. The mean corrosion depth increases with increasing range h. When the mean corrosion depth is less than 0.02mm on exposure period from 0.5 to 1 year, the value of range h for corrosion surface at the angle of 45° and 90° greater than that of 0°. This is because corrosion pits were not formed on all surfaces of the specimens. The curves varied widely for the different corrosive environments. These curves are given by the equation in Fig. 4(a).

The relationship between $\gamma^{1/2}$ and d_{mean} is shown in Fig. 4(b). This relationship holds for all the corrosive environments. Thus, they can be expressed as the equation in Fig. 4(b)

3.2 Numerical simulation of corrosion surface Corrosion surfaces were formed by the covariance function such as kriging formula. This formula is a multistep process; it includes exploratory statistical analysis of the data, semi-variogram analysis, creating the surface and exploring a variance surface. The size of simulated area and pitch were 40×40mm and 0.2mm, respectively. The simulated surfaces were compared to the corroded surfaces of tested specimens to verify the simulation method.

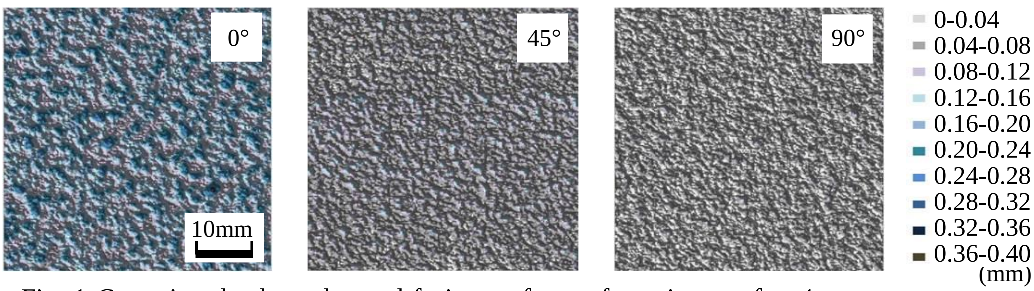


Fig. 1 Corrosion depth at skyward-facing surfaces of specimens after 4 years of exposure at each mounting angle.

Keywords: Corrosion, Steel structure, Atmospheric exposure test, Spatial statics, Semi-variogram
744, Motooka, Nishi-ku, Fukuoka 819-0395 Kyushu University

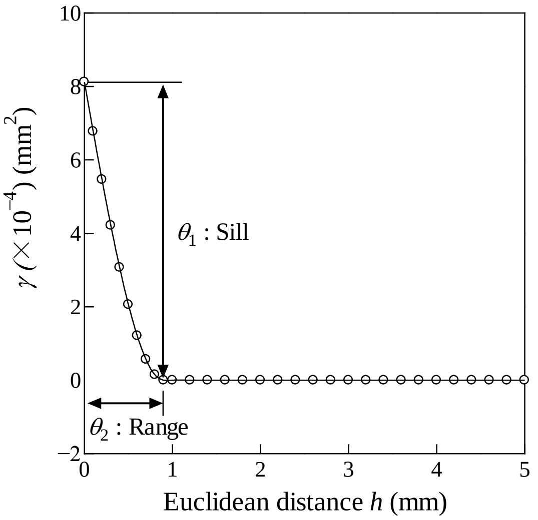


Fig. 2 Example of semi-variogram of corrosion surface of specimen.

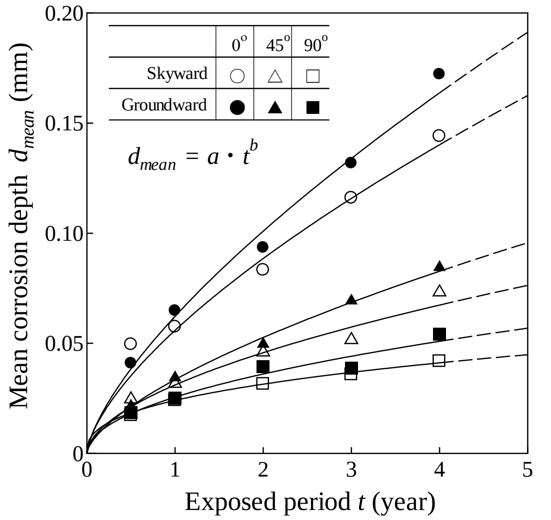
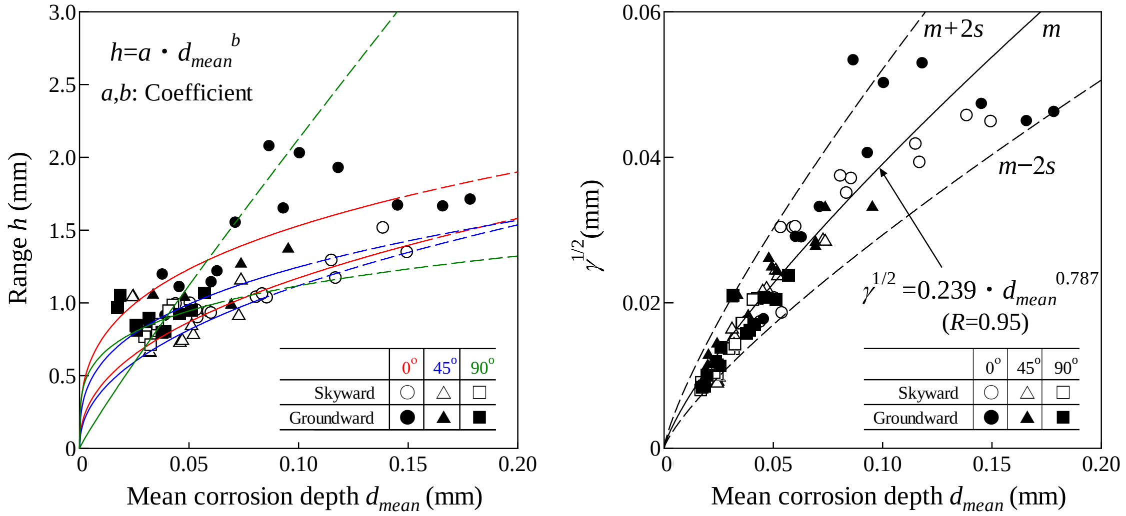
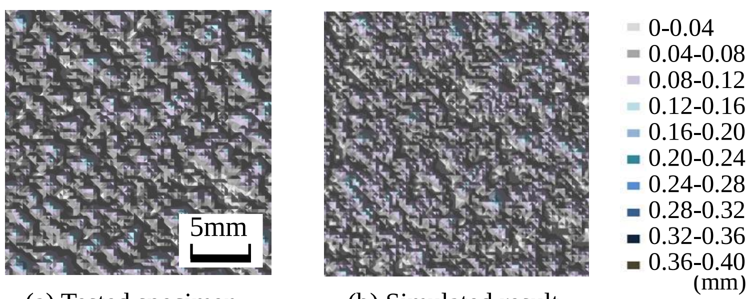


Fig. 3 Mean corrosion depth d_{mean} as a function of exposed period t.



(a) Relationship between range h and d_{mean}. (b) Relationship between $\gamma^{1/2}$ and d_{mean}.

Fig. 4 Relationship between the spatial statistics and the mean corrosion depth d_{mean}.



(a) Tested specimen (b) Simulated result

Fig. 5 Corrosion depth at skyward-facing surfaces of specimens corresponding to 4 years of exposure at mounting angle of 45°.

Figure 5 shows the experimental and simulated result at skyward-facing corrosion surfaces after 4 years of exposure at the angle of 45°. The spatial distribution of simulated corrosion surface is similar to actual corrosion surface of the specimen. The mean corrosion depth and maximum corrosion depth of the simulated result were also similar to the test specimen. These results demonstrate that numerical simulations accurately describe the corrosion surface.

4. Summary of findings The experimental and analytical results led to a method for evaluation the time-dependence of corrosion surfaces of uncoated steel plates in atmospheric environments.

References 1) Cressie. N : Fitting variogram models by weighted least squares, Mathematical geology, Vol.17, No.5, pp.563-586, 1985.
2) Matheron. G et al : The theory of resionalized variables and its applications, Cahiers du centre de morphologie mathematique, No.5, 1971.
3) Wackernagel. H : Multivariate geostatistics, Springer, 1998.