Evaluation for corrosion surface of carbon steel and weathering steel using spatial statistical technique

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1. Introduction Importance of maintenance in steel structures is emphasized according to increase of their service time. Fatigue and corrosion can be main deterioration depending on its structural behaviors, details and environmental conditions. In this study, atmospheric exposure tests were carried out on uncoated carbon steel and weathering steel 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, by using Kriging which is one of the spatial statistical techniques, long-term corroded surfaces were simulated in a micro-corrosive environment on the surface of specimen.

2. Atmospheric exposure test Atmospheric exposure tests were conducted on uncoated steel plates for 0.5, 1, 2 and 4 -year at Sembaru Campus, University of the Ryukyus (Lat.26˚15'N, Long.127˚46'E). The materials used of the test specimen are JIS G 3106 SM490A and JIS G 3114 SM490AW steel grade. The size of the specimens is 400 × 60 × 9mm. In order to consider the various corrosion conditions based on detail and installation of steel structural members, it is installed at angle of 0°, 45° and 90° to the horizontal. The laser focus measuring system was used to measure the corrosion depth on corroded surface after removal of the rust for each aged corrosion specimen.

Figure 1 shows the change in the mean corrosion depths and maximum corrosion depths of corrosion specimens depending on exposure periods. The carbon steel and weathering steel, mean corrosion depths of corrosion test specimens are shown to be increasing according to its exposure period under corrosion atmospheric environments. In case of test specimens with 0° installation angle, mean corrosion depths were gradually increased according to exposure periods. Mean corrosion depths of carbon steel were increased in the order of installation angle as 90°, 45° and 0°, it was shown that these of corrosion specimens with 0° installation angle were 1.9 times larger than those of 45° angle, 3.4 times for 90° angle. The maximum corrosion depths were from 2.4 to 4.5times larger than mean corrosion depth for each aged. Mean corrosion depths of weathering steel shows the same tendency for carbon steel, 0° installation angle were 1.4 times larger than those of 45° angle, 1.5 times for 90° angle. The maximum corrosion depths were from 3.0 to 6.4times larger than mean corrosion depth for each aged.

3. Numerical simulation New approaches to corroded surface are taken by S. Kainuma, 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).

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

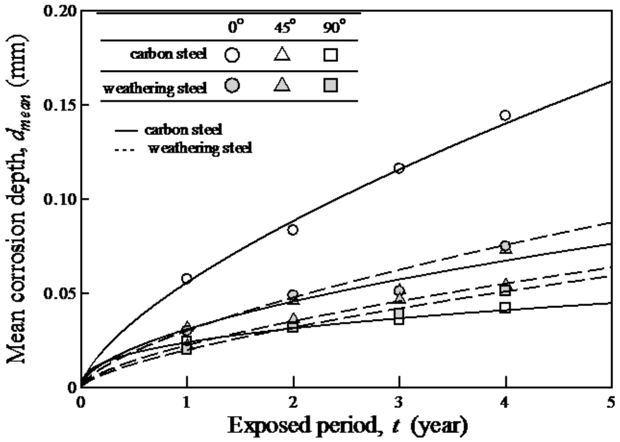
where Eq. (1), $\gamma(h;\ \theta)$ is the covariance function of the spherical model, θ_1 and θ_2 are the sill and range, and h is the Euclidean distance.

Relationships of mean corrosion depth-exposure period, range, sill-mean corrosion depth were evaluated in Fig. 2. In case of range values, it were increased in the order of installation angle as 45°, 0°and 90° at the exposure period 1-year, and it were increased in the order of installation angle as 90°, 45°and 0° at the exposure period 4-years. Especially, for corrosion specimens of carbon steel with 90° installation angle, range in respect to mean corrosion depth was sharply changed than other cases and it was shown to be very different for change in corrosion depth. In case of sill values, it were increased in the order of installation angle as 90°, 45°and 0° at the exposure period 1-year, and it was shown to be same tendency at the exposure period 4-years. It was different tendency because of the time of wetness according to the installation angle. In Fig. 2, comparison of the carbon steel and weathering steel when the exposure period 4-years, spatial statistical values with 0° installation angle of carbon steel were 1.2 times larger than those of weathering steel, spatial statistical values for 45° and 90° angle of carbon steel were similar to those of weathering steel.

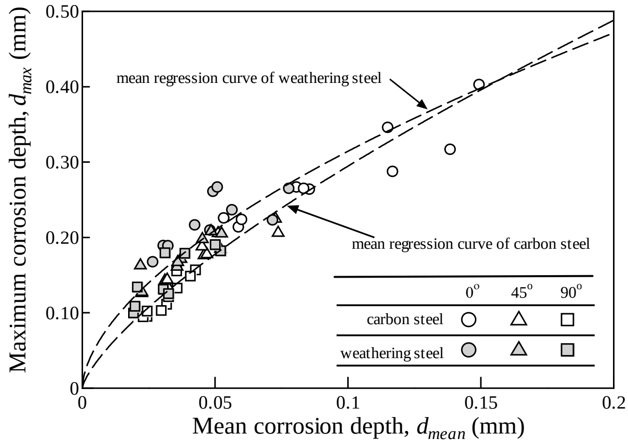
To verify the simulated corroded surface using Kriging under atmospheric corrosion environment, the simulated time-dependent corroded surfaces were compared with tested corrosion surface depending on exposed period and installation angles. The corroded surface and simulated corroded surface were compared with those of spatial statistical value in shown in Fig.3. They also were shown to be similar tendency with corroded surface under atmospheric corrosion environment. Fig.4 shows the simulation result of long-term corroded surfaces under the measured corrosion environment. If they will be undergone this corrosion environment during 40-years, it was evaluated that the mean corrosion depth of carbon steel with 0° installation angle will be decreased up to about 15% and those of weathering steel will be decreased about 7%.

4. Summary

1) The relationships between the mean corrosion depth-exposure period, the maximum corrosion depth-mean corrosion depth and spatial statistics (range, sill)-mean corrosion depth were formulated.
2) The corrosion behavior of corroded surface on steel grade was examined in spatial statistical techniques.
3) The corroded steel surfaces of carbon steel and weathering steel plates were generated and it was verified by comparing

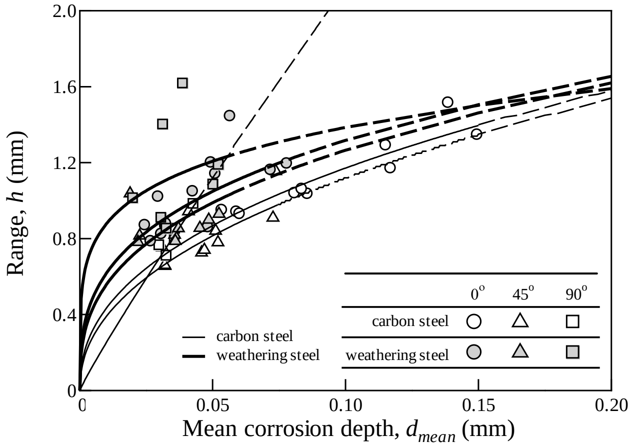


(a) Mean corrosion depths-exposure periods

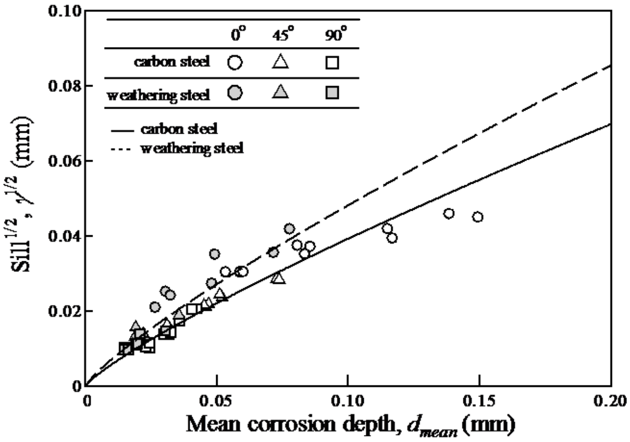


(b) Maximum corrosion depths-exposure periods

Fig.1 Comparison of corrosion depth in carbon steel and weathering steel

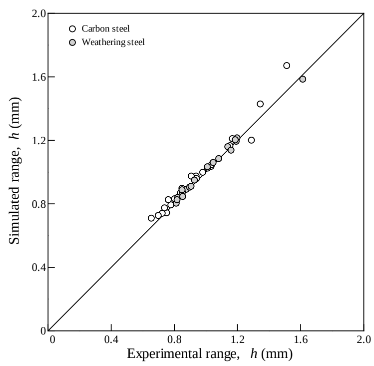


(a) Range-mean corrosion depths

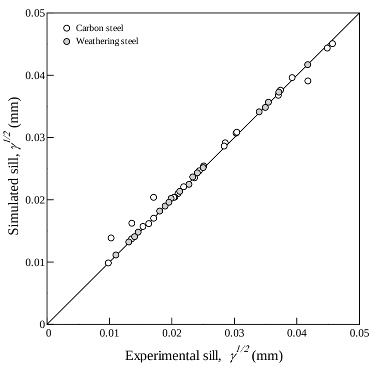


(b) Sill-mean corrosion depths

Fig.2 Comparison of range-sill in carbon steel and weathering steel



(a) Range



(b) Sill

Fig.3 Comparison of spatial statics for corroded and simulated surfaces

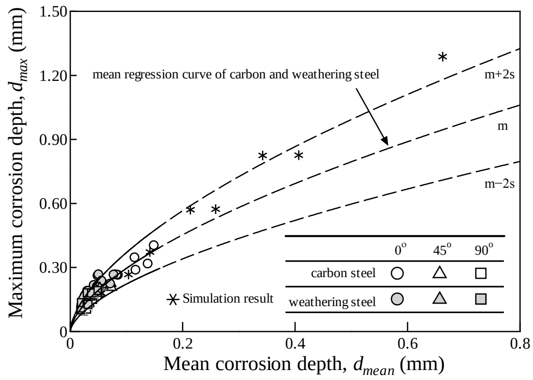


Fig.4 Comparison of corrosion depth for corroded and long-term simulated surfaces

measured corroded surfaces.

References 1) N. Cressie : Fitting variogram models by weighted least squares, Mathematical geology, Vol.17, No.5, pp.563-586, 1985., 2) S. Kainuma, Y. S. Jeong, K. Utsunomiya and J.H. Ahm : Numerical simulations for time-dependent corrosion surfaces of unpainted carbon steel plates in atmospheric corrosive environments using spatial statistical techniques, Zairyo-to-kankyo, Vol.61, No.7, pp.283-290, 2012., 3) S. Kainuma and H. Hosomi : fatigue life evaluation of corroded structural steel members in boundary with concrete, Interactional journal of fracture, Vol.157, No.1-2, pp.149-128, 2009.