MC BASED CORROSION PROGRESS EVALUATION METHOD INCLUDING VARIABILITY OF CONCRETE COVER

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1. INTRODUCTION

Corrosion degradation due to the ingress of the chloride ions and the formation of the corrosion products on the rebar steel surface is an important and critical degradation factor for reinforced concrete structures located along coastline. The corrosion products are inducing cracking of the protective concrete cover and consequently a further increase in the speed of the corrosion degradation. Ultimately, corroded reinforcement could lead to degradation of structural element strength. Various computational models have been proposed for the modeling of the corrosion progress for the steel rebars located inside the concrete elements, such as the model proposed by Kishi et. al. (2001), Morikawa et. al. (2007) considering the influence of certain physical characteristics of the protective layer of concrete and its dimensional characteristics and the size of the rebars inside concrete. Current paper is investigating the variability of the corrosion progress induced due to variability of factors modeling corrosion.

2. CORROSION EVALUATION METHOD

Kishi et.al. (2001) had proposed a model for the analysis of the relations between the corrosion induced crack opening and the corrosion speed and progress, considering concrete cover and the rebar diameter as per the formula (1) to (5). The relation between the concrete measurable surface crack width X, the corrosion amount Y, and the corrosion speed shown in the equations (1)(2)(3) are computed using the parameters a and alpha identified by fitting to existing corrosion experiments.

$$x = C\exp(\alpha * t_{cr} / a) \quad (1)$$
$$y = a\,x \quad (2)$$
$$dy/dt = \sigma \quad (3)$$
$$a = 0.141\exp(1.078\ d/\Theta) \quad (4)$$
$$alpha = 54.82\ d^{-1.17} \quad (5)$$

Value of a is identified based on fitting existing data for d/Θ in the range [2.0 to 3.5] as described in the Kishi et. al (2001) where d is the concrete cover expressed in mm while Θ is the reinforcement steel rebar diameter in mm. The relation between the corrosion loss and the time since corrosion initiated is represented on Fig. 1.a, while the relation between the crack width and corrosion loss is plotted in Fig. 1.b.

The impact of the variability of the material parameters on the determined corrosion rate values are being analyzed using the assumed variability of the parameters by Monte Carlo Simulation method. For instance, the concrete cover variability measured on old RC structures built over 50 years ago was determined to vary more than 10 percent. A concrete cover normal distribution with mean value 27.9mm and variability 9.7% is being used in the analysis as plotted in Fig.2.a. The variability of corrosion loss estimation induced by the concrete cover variability is being estimated by described analysis method and shown in Fig.2.b for the case of corrosion loss estimated for a measured crack opening of 0.4mm.

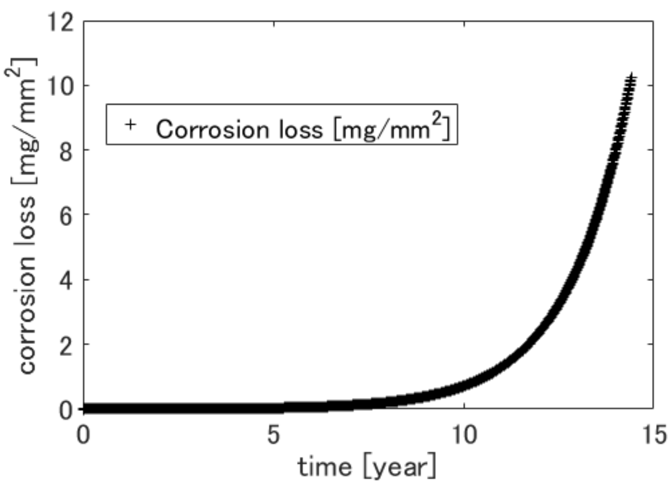

Fig.1.a Evaluation of the corrosion progress versus time for the concrete cover mean value 30mm and rebar diameter 13 mm.

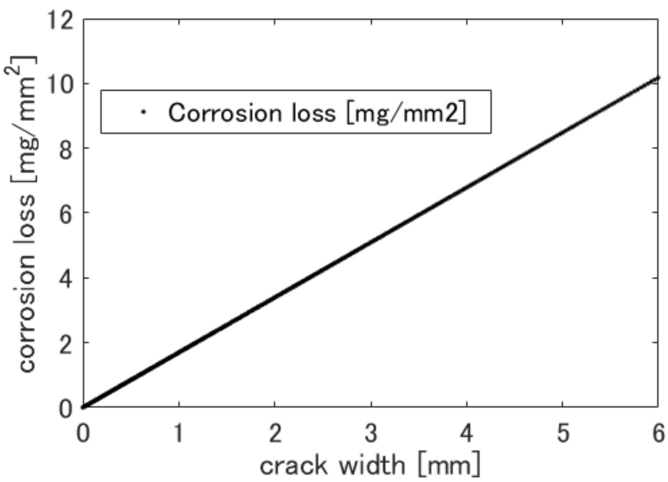

Fig.1.b Evaluation of the corrosion crack width versus corrosion loss for the concrete cover mean value 30mm and rebar diameter 13mm.

Keywords: Corrosion degradation progress estimation, Concrete cover variability, Fragility evaluation
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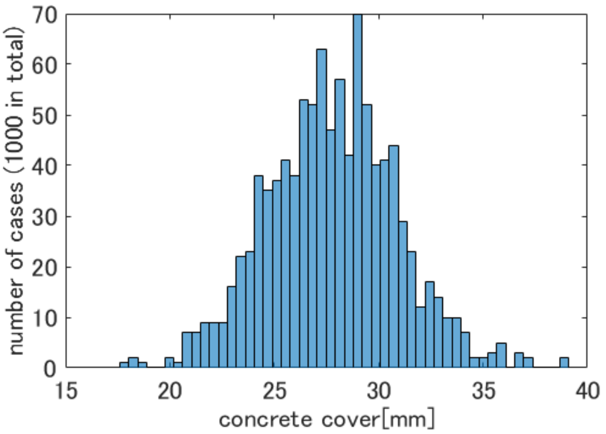

Fig.2.a Histogram of concrete cover variability.

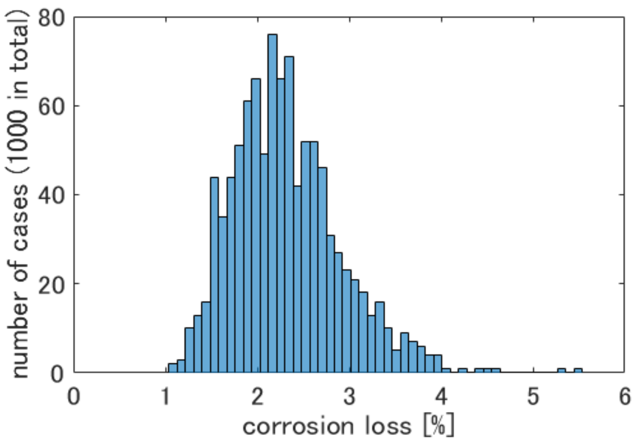

Fig.2.b Variability induced in corrosion loss estimation due to concrete cover variability for a measured crack width 0.4mm.

3. FRAGILITY CORROSION EVALUATION METHOD FOR RC ELEMENTS

The above described corrosion estimation method is being applied for the corrosion dataset described by Koji et al (1984) with the rebar size 13 mm and the concrete cover with actual mean value 30mm. The analysis results by the equation (1)~(5) computed for incremental values of crack opening are being plotted versus the experimental data in Fig. 3.

MC method is suitable for evaluation of corrosion progress modeling significant parameters uncertainty including the dimensional variability of concrete cover. The fragility curves are summarizing the exceedance of the corrosion threshold limit. The mean fragility curves are being drawn for the concrete cover 27.9mm (while variability of the concrete cover is being considered 9.7% of the cover depth) with a 1000 MC parameters generated at each crack opening from 0.1 to 5mm. The degradation limit state criteria is set when the rebar corrosion section loss is exceeding the 5% and 20% threshold respectively, the results being summarized in Fig.4.

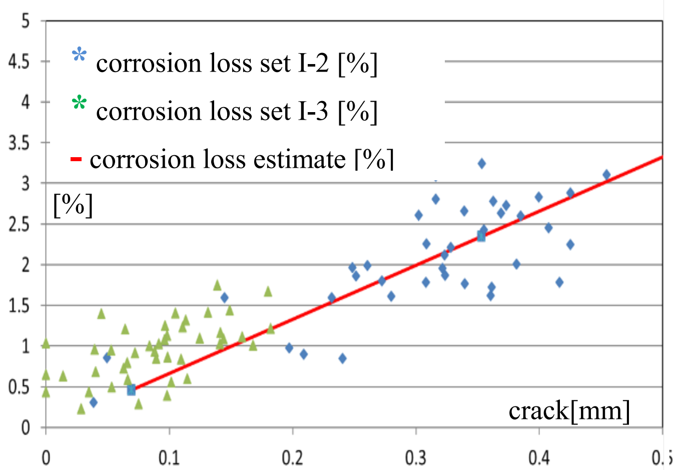

Fig.3 Comparison of the corrosion loss estimate versus experimentally measured corrosion loss by Ozaki(2005).

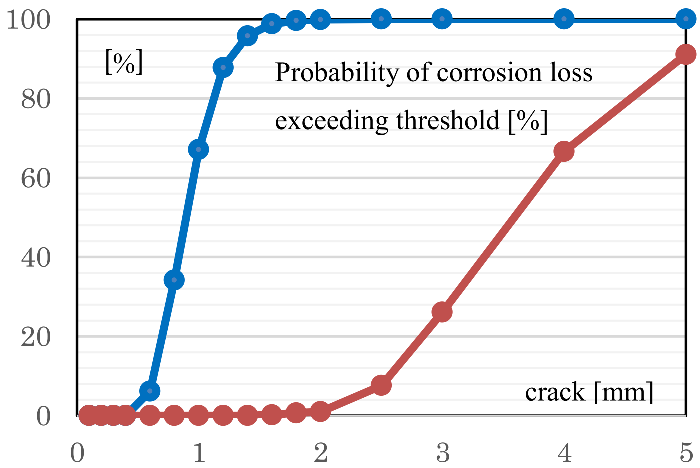

Fig. 4 Fragility curves for corrosion of 13mm rebars due to the exceedance of 5% (orange) and 20% (blue) corrosion section loss threshold.

4. CONCLUSIONS

The evaluation of the rebar corrosion progress in concrete is a very complex phenomenon influenced by the environmental conditions and variability of concrete protective layer. The modeling of dimensional variability is applied for the modeling the probabilistic distribution of the corrosion progress based on observable crack opening. MC method was applied for estimating fragility curves determining probability of exceedance of certain corrosion degradation limit.

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