確率論に基づくコンクリート構造物の塩化物浸透及び補修最適化システムの構築

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Structural reliability analysis　Chloride diffusion　Concrete crack
Corrosion progression　Surface treatment　Repair mortar

1. Purpose of research

Maintaining reinforced concrete (RC) structures is very expensive, and chloride-induced corrosion is one of the most serious threats to their integrity. Accordingly, this study develops a Monte Carlo simulation-based system for assessing the corrosion-related degradation of RC structures. A rapid numerical approach for measuring the chloride diffusion in cracked concrete is used to incorporate the coupled degradation effect of crack development and corrosion progression into a system for estimating the probable corrosion failure of RC beams over time.

2. Research contents

2.1 Field investigation

A filed investigation of RC bridge was conducted to collect statistics data for the reliability analysis. Several parameters were measured, including concrete cover depth, crack width and compression strength. These parameters follow normal distribution (Fig.1 ~ Fig. 3). It shows that these statistics data can be used for Monte-Carlo simulation.

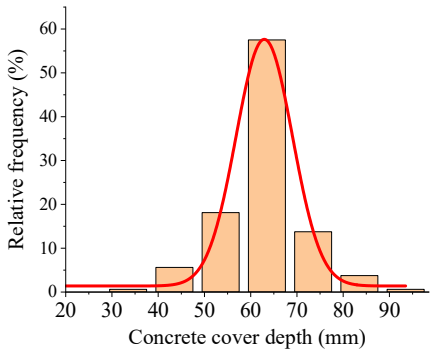

Fig. 1 Statistics data of concrete cover depth

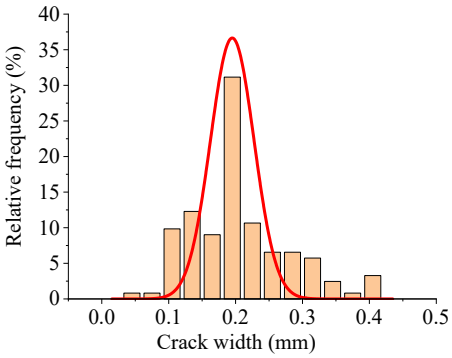

Fig. 2 Statistics data of crack width

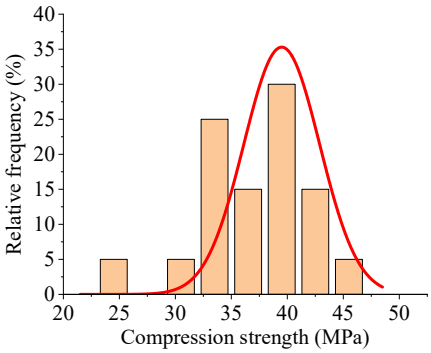

Fig. 3 Statistics data of compression strength

2.2 Analysis system

RC structures undergo continuous deterioration due to a combination of chloride ingress and loading actions. A reliability assessment system was developed to estimate the failure time of RC structures under the coupled degradation effects of crack development and corrosion progression (Fig. 4). The required inputs are the water-binder ratio, temperature, the rebar properties, concrete strength, pH of a pore solution, geometry of an RC beam and the boundary conditions to which the concrete beam will be exposed during its life cycle. These parameters are assigned probabilistic distributions in Monte Carlo simulations (Fig. 4a), in each of which the chloride diffusion profile of cracked concrete is first represented as a rapid two-layer diffusion model (Fig. 4b). Then, based on the chloride content of rebar, the corrosion rate and pitting corrosion area are determined using corrosion rate and pitting corrosion propagation models (Fig. 4c). Next, the widths and thicknesses of the cracks are determined through mechanical equilibrium analyses of the corroded rebar (Fig. 4d), and these crack geometry data are used as the input for the estimation of chloride ingress next step. The above steps are repeated until the

stress on the rebar is higher than its yield strength (Fig. 4e), i.e., until it fails, and the time to failure for the simulation is recorded. Finally, all of the Monte Carlo simulation enables the CFP of the RC to be determined (Fig. 4f). As flexural cracks are the most common cracks in RC structures, we simplify the reliability analysis system by considering an RC beam subjected to flexural moment.

2.3 Analysis results

Parmeter analyses were conducted to study various effect on corrosion failure probability (CFP) of RC beam. The results show that (1) the CFP of RC structures is significantly underestimated if the coupled degradation effect of crack development and corrosion progression is not considered (Fig. 5); (2) surface treatments efficiently improve the durability of RC structures subjected to heavy loads (Fig. 6).

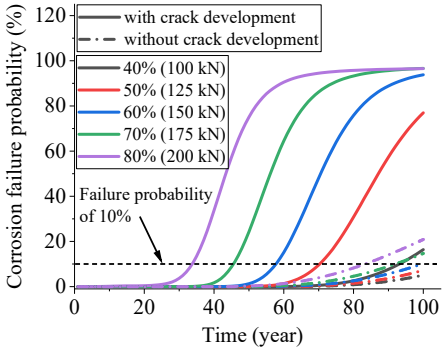

Fig. 5 Effect of loading on corrosion failure probability

Conclusions

This study develops a reliability analysis system that incorporates the coupled degradation effects of crack development and corrosion progression into the assessment of the CFP of RC structures.

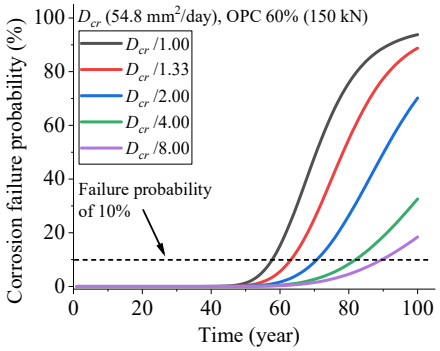

Fig. 6 Effect of surface treatment on corrosion failure probability

Future study

It should be noted that only flexural cracks are addressed in this study, which means that future research should examine other types of mechanical degradation cracks, such as shear cracks, fatigue cracks and corrosion expansion cracks.

Acknowledgment

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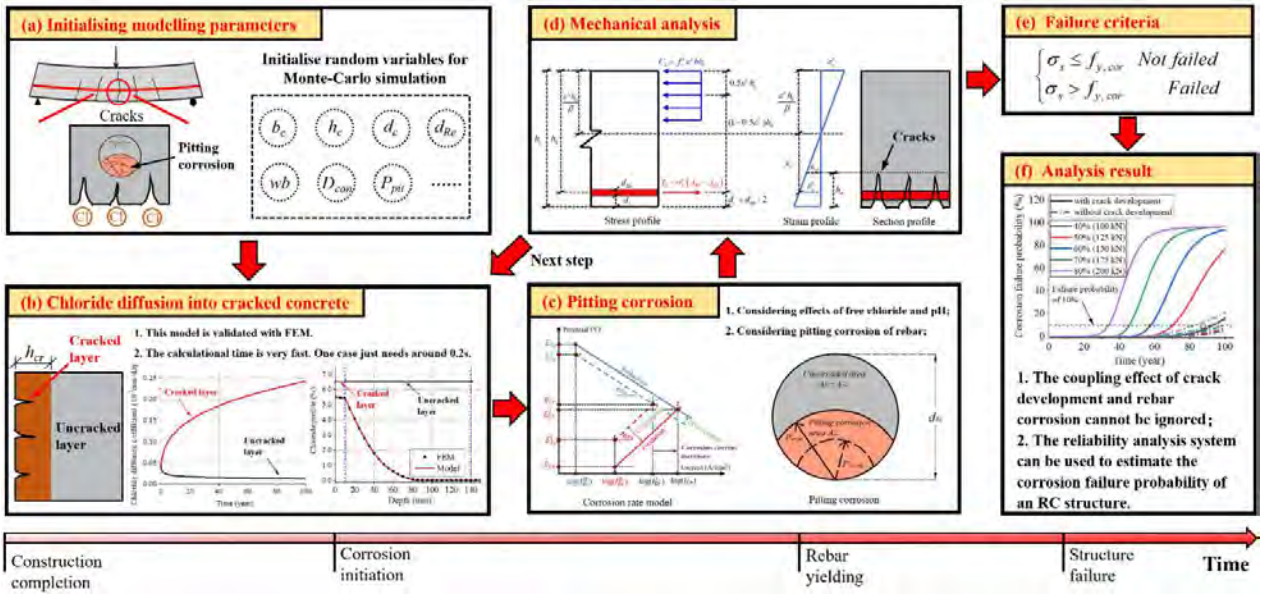

Fig. 4 Reliability assessment system for RC structures under chloride ingression

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