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Short communication

Probabilistic evaluation of initiation time in RC bridge beams with load-induced cracks exposed to de-icing salts

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ABSTRACT

In this study, a reliability-based method for predicting the initiation time of reinforced concrete bridge beams with load-induced cracks exposed to de-icing salts is presented. A practical model for predicting the diffusion coefficient of chloride ingress into load-induced cracked concrete is proposed. Probabilistic information about uncertainties related to the surface chloride content and the threshold chloride concentration has been estimated from a wide review of previous experimental or statistical studies. Probabilistic analysis to estimate the time to corrosion initiation with/without considering the effect of the load-induced cracks on the chloride ingress into concrete has been carried out. Results of the analysis demonstrate the importance of considering the effect of the load-induced cracks for correct prediction of corrosion initiation in RC bridge beams exposed to chlorides.

1. Introduction

Chloride-induced corrosion of reinforcing steel in concrete is known to be one of the major causes of deterioration of reinforced concrete (RC) structures. Normally concrete protects embedded reinforcing steel against corrosion due to a thin iron oxide (Fe_2O_3) layer that forms on the steel surface and remains stable in the high alkaline environment provided by the concrete porous solution. However, if a RC structure is exposed to chlorides as exampled by highway bridges exposed to de-icing salts, chloride ions can penetrate the concrete cover and arrive at the surface of reinforcing bar. When the concentration of chloride ions in concrete at the surface of reinforcing bars reaches a critical level, known as threshold, the passive layer that protects the reinforcing bars from corrosion is broken down and hence the corrosion initiates. After initiation, corrosion may propagate relatively fast, which will result in the longitudinal cracking and delamination or spalling of the concrete cover and finally leading to structural failure. Usually, the time taken for the surface chloride to penetrate through the concrete cover and build up the threshold concentration at the reinforcing bars level to cause corrosion is termed the time to corrosion initiation (initiation time). Therefore, the initiation time represents an important parameter in controlling deterioration of RC structures and the estimation of this time period is important for the prediction of the service life of RC structures exposed to chlorides.

The initiation time depends on various factors including the surface chloride content, the rate of penetration of chloride ions in concrete, the depth of the concrete cover, as well as the threshold chloride concentration. Numerous models for ‘perfect’ and uncracked concrete developed from Fick's second law of diffusion [1] have been used to predict the initiation of chloride-induced reinforcement corrosion in concrete in the past decades [e.g., 2–10]. The influence of the rate of penetration of chloride ions in concrete due to the presence of cracks and its effect on the time to corrosion initiation have been also investigated in some recent researches [11–13]. However, all the previous models are developed within a deterministic framework. Because there is significant uncertainty associated with the factors related to the chloride ingress into concrete, it might be more appropriate to use a probabilistic approach to predict the initiation time.

In order to account for various sources of uncertainty and considering the problem of chloride ingress and corrosion initiation in RC structures in probabilistic terms, many probabilistic approaches and techniques are recently proposed for the evaluation of initiation time [14–19]. However, these applications using probabilistic approaches have been generally limited to the sound concrete without considering crack effect. Since the occurrence of visible macro-cracks is inevitable for RC structures under service loads, the influence of cracks on the time to corrosion initiation should be taken into account.

The main objective of this study is to present a reliability-based method for predicting the initiation time of RC bridge beams with load-induced cracks exposed to de-icing salts. A practical model for predicting the diffusion coefficient of chloride ingress into load-induced cracked concrete is proposed. Probabilistic information about

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