Concrete Beam Life Model Based on Shear Strength Degradation Under Different States of Chloride Ion Ingress

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ABSTRACT

Concrete structures undergo a reduction in strength and ultimately premature deterioration during their life due to environmental factors. Corrosion of reinforcement is known as one of the most important factors in reducing the performance of concrete structures. Assessing the current condition as well as predicting the remaining useful life of structures is very important for providing maintenance plans. In this research, considering the limit-state function of the shear strength of reinforced concrete beams, the life model is calculated under different scenarios of chloride ion penetration. Reduction of the cross-section of longitudinal and transverse rebars, reduction of the cross-section of the concrete beam, and reduction of mechanical properties of concrete and rebar, which are known as side effects of rebar corrosion, have been considered in evaluating the life model. Stochastic properties of effective parameters in shear strength, as well as chloride ions, are also considered for the probabilistic evaluation of the life model. The Monte Carlo sampling method was used to generate the input values of the models. The results show that considering the effect of concrete scaling causes a large difference in the predicted values for shear strength of concrete beams so that in the critical case, considering the effects of concrete scaling reduces the shear strength by 20% and a more realistic estimate of the remaining life of the structure will be obtained.

KEYWORDS

Life model, Reinforcement corrosion, Shear failure, Concrete beam, Chloride ingress

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1. Introduction

Reinforcement corrosion in reinforced concrete (RC) structures causes propagation of cracks, reduction of bond strength between rebars and concrete, spalling of concrete cover and eventually degradation of structures due to reduction in strength of RC element. The products of corrosion usually have much volume than that material consumed during the corrosion process[1]. The increase in volume around the reinforcement causes the tensile stresses in the concrete and cracks the cover. With cracking the cover and increasing the crack width, the detrimental effect of the corrosion will be enhanced. Uniform and non-uniform corrosion (pitting) are two major type of steel reinforcement corrosion in RC structures. Chloride ingress usually causes non-uniform corrosion, although with passing the time and joining the pitting corrosion along the rebar length, the rebar will be corroded uniformly.

Lots of research has been done about the service life model of the RC structures which were affected by reinforcement corrosion due to chloride ingress. This research mainly focused on strength degradation and evaluation of ultimate limit-states of the RC structures[2]. The type of the degradation factors affect how the performance of the structure degraded. For the effects of rebar corrosion, many models have considered the performance reduction in proportion to the reduction in rebar cross-section[3].

In concrete beams, shear deterioration may occur due to the penetration of chloride ions. In bridge girders, where some construction joints are located on the sides, due to the infiltration of saltwater in winter from these joints, the hazards in the girder support will increase. Previous research has not done much on the conditions and directions of chloride ion penetration, and most researchers have evaluated the effect of corrosion effects on the strength of beams by creating accelerated corrosion. In this study, by considering different scenarios of chloride ion penetration in concrete beams, the corrosion effects of rebars on the residual shear strength have been evaluated. The effect of uncertainty of effective parameters on shear strength also has been considered.

2. Methodology

To investigate the effects of rebar corrosion on the shear strength of concrete beams, the steps of different effects of chloride ion penetration in the applied scenarios are considered. The diffusion of chloride ions into the cross-section is considered one-dimensional based on Equation (1):

$$C(x,t) = C_0 + \left(C_s - C_0 \left[1 - erf\left(\frac{x}{2\sqrt{D_{app,c}t}} \right) \right] \right) \tag{1}$$

where $C(x,t)$ is the chloride ion concentration at depth of x and time t; C_0 is the chloride ion concentration in the concrete; C_s is the chloride ion concentration at the surface of concrete; $D_{app,c}$ is the diffusion coefficient of chloride ions in concrete; *erf* is the error function. To evaluate the effects of different chloride ion diffusion scenarios, the beam shown in Figure 1 is considered. How chloride ions penetrate into the concrete beam is assumed in the four scenarios shown in Figure 2. The nominal shear strength of the beam, V_n at time t from the onset of corrosion is calculated as follows:

$$v_n(t) = v_s(t) + v_c(t) \tag{2}$$

where *Vs* and *Vc* are the steel and concrete shear strength respectively.

3. Results and Discussion

Figure 3 shows the results for all scenarios for comparison. In this figure, the effect of considering the reduction of the cross-section in different ways is quite obvious. Considering the most critical situation, which is scenario (d), the shear strength for concrete beams in which rebar corrosion begins in the 7th year reaches 0.65 of the initial shear strength after 60 years. If the life model is considered based on merely reducing the cross-sectional area of the rebar, the shear strength reaches 0.86 of the initial value, which is very different from the actual value.:

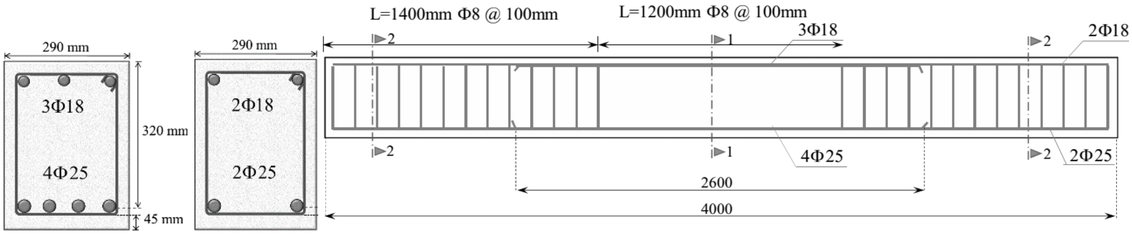

Figure 1. Simply supported RC beam

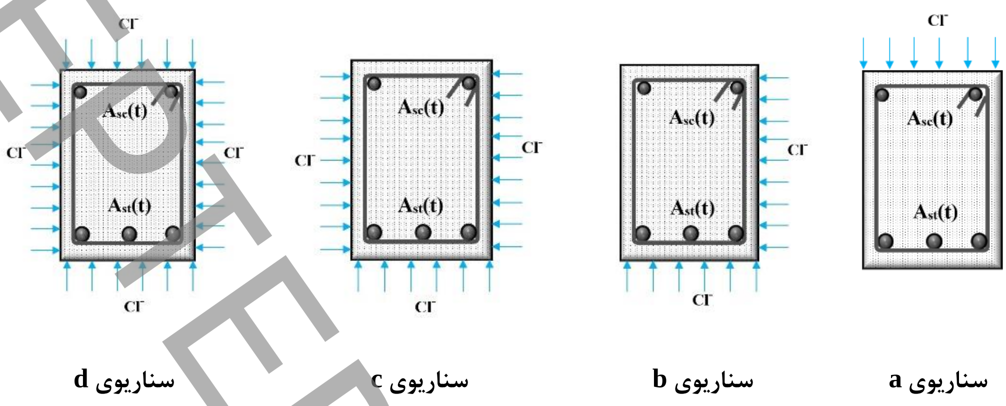

Figure 2. Different scenarios for how chloride ions penetrate

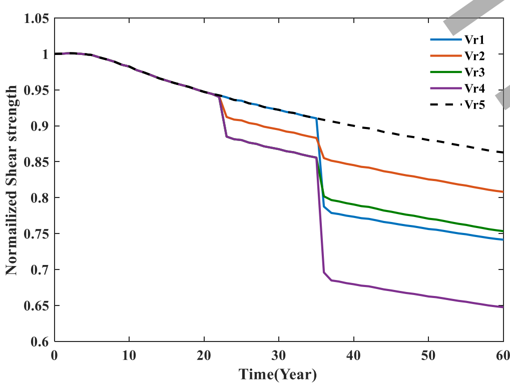

Figure 3. Shear strength at time t to initial strength for different chloride ion diffusion scenarios

4. Conclusions

Considering the effect of concrete scaling causes a large difference in the predicted values for the shear strength of concrete beams, so that in the critical state, considering the effects of concrete scaling, the shear strength decreases by 20% and a more realistic assessment of the remaining life of the structure is obtained.

5. References

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