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Effect of pit distance on failure probability of a corroded RC beam

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Abstract

The present paper studies effect of the variation of pit distance on structural reliability of a reinforced concrete (RC) beam, with particular emphasis on the interference of localized corrosion on adjacent tensile rebars. The research question leading the inquiry of this article is how does average distance between corrosion pits in rebars affect the probability of failure in RC beams. In this paper, by using Monte Carlo Simulation (MCS), probabilities of failure in a corroded RC beam with different pit distances are quantified. Uncertainties in material properties, geometry, loads, corrosion modelling, pit distances and pit interference are taken into account. Statistical data reported in literature regarding the extent and location of corrosion is utilized to undertake a parametric study of corresponding probability distribution functions. According to results, variation of pit distance has significant influence on probabilities of failure. This influence increases if the effect of interference of localized corrosion is taking into account.

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Keywords: Concrete structure; localized corrosion; pitting; pit distance; probability of failure; interference of pits.

1. Introduction

Corrosion of steel rebars embedded in reinforced concrete (RC) members, causes deterioration of concrete structures, diminishing their capacity and serviceability. There are two types of corrosion: uniform and localized (pitting) corrosion. A typical deterioration of RC structures exposed to aggressive chloride environments is localized corrosion of rebar. Pitting corrosion can lead to high degrees of cross-section area loss along the rebar [1].

Assessing reliability of RC members with corroding rebars has received increasing attention in recent years [2-9]. Early studies accounted only for uniform corrosion in rebars. However, this approach requires additional measures to

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take into account spatial variability of cross-section along the bar and the reduction of mechanical properties of the bar due to local stress localizations [10-12].

Later studies have become more realistic by developing reliability assessments of RC beams by considering the effect of spatial variability of the localized corrosion on rebars. Kioumarsi et al. [13] studied the effect of interference of corrosion pits on adjacent rebars on the probability of bending failure of a corroded reinforced concrete beam. Spatial distribution of localized corrosion along a beam is considered in the analyses. These authors considered the appearance of corrosion pits as a Poison process, i.e. a process in which pits occur continuously and independently.

Different rebars, exposed to different environmental conditions would present different average values of pit distance, which in turn may affect the probability of failure of RC beams. In the present article, we follow up the work by Kioumarsi et al, drawing attention to the influence of average pit distance on reliability of corroded RC beams. The research objective leading the inquiry of this article is thus: Quantifying effect of average distance between corrosion pits in rebars on the probability of failure in RC beams. To answer the research question, we consider a case study and estimate failure probability using Monte Carlo Simulation (MCS). Uncertainties in material properties, geometry, loads, corrosion modelling, pit distances and pit interference are taken into account. Statistical data reported in literature regarding the extent and location of corrosion is utilized to undertake a parametric study of corresponding probability distribution functions.

2. Interference of localized corrosion on adjacent rebars

It is shown that the cross-section reduction varies along the tensile rebars and that the cross-section reduction differs between rebars [14]. The disparities of localized cross-section reduction between rebars may result in interference between the pits (see Fig. 1) [15].

Fig. 1. Plan view of potential pit locations and possible interference of localized corrosion between adjacent tensile rebars [15].

Kioumarsi et al. [15-17] selected an idealized case to quantify the possible interference of localized corrosion on adjacent rebars in an under-reinforced beam subjected to bending. In the idealized case two adjacent rebars were considered with one corrosion pit each. The two corrosion pits were equal in size. In a series of nonlinear finite element models the combined influence of two variables on the bending ultimate limit state (ULS) was quantified: the ratio of the distance between pits in two adjacent rebars to the distance between tensile rebars, l_p/l_r, and the ratio of the cross section reduction of the rebar due to localized corrosion to the initial cross section of rebar A_{pit}/A_0. From the numerical simulations it was found that pits interfere within a critical distance. Interference of localized corrosions reduces gradually for increasing distance between pits in two adjacent rebars (l_p). For the investigated beam with 80 mm distance between two adjacent rebars (l_r) the critical distance was 100 mm; i.e. for higher ratios of l_p/l_r > 100/80 = 1.25 no interference was observed [15-17].

Current analytical design rules cannot quantify the interference of localized corrosions for intermediate l_p/l_r ratios $\left(0 < l_p/l_r < 1.25\right)$ [17]. In order to take into account the possible interference of localized corrosions, Kioumarsi et al. [15] proposed using a modified total residual cross section of corroded tensile rebars in an analytical analysis of the strength of the cross section:

$$A_{res(mod)} = 2A_0 - (2A_{uni} + A_{pit} + \beta A_{pit}) \tag{1}$$