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Effect of Cement Type and Micro-cracks on Chloride Penetration in Concrete

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1 Introduction

Corrosion of reinforcing steel is one of the major durability issues affecting reinforced concrete (RC) structures in chloride-bearing environments. The durability models are based on several design parameters – among which concrete chloride penetration resistance is of particular relevance – but refer to uncracked concrete, a rare-occurring condition in RC structures. Studies carried out on the topic have detected that also micro-cracks (crack opening <100μm) lead to an increase in chloride penetration in concrete (Yoon and Schlangen, 2014). In this study, chloride penetration resistance of different types of concretes was evaluated, in uncracked and micro-cracked configurations, exposed to 3.0% NaCl solution for 32 and 90 days.

2 Experimental Procedure

Different concrete types were obtained with Ordinary Portland (OPC), Portland-Limestone (OLC) and Pozzolanic cement (PC), with 422 kg/m^3 of cement and w/c ratio of 0.45. Prismatic specimens of dimensions 120×90×50 mm were manufactured, some of them subjected to a three-point bending test to induce a micro-crack. After 28 days of moist curing, cracked and uncracked concrete specimens were immersed in a 3% sodium-chloride solution for 32 and 90 days. The chloride penetration front was detected with a colorimetric technique on split surfaces, where also crack parameters (width and depth) were also measured.

3 Results and Discussion

Crack resulted to be 10-50 μm wide, and 8-30 mm deep. Figure 1 shows the local increase in chloride penetration depth with respect to average values in sound conditions (x_{cr}/x_s) as a function of crack parameters. After 32 days of exposure, micro-cracks led to a significant increase in chloride penetration, with x_{cr}/x_s always at least about 2 for crack width smaller than 30 μm and 10-20 mm deep, independently from concrete type. After 90 days of exposure, for PC concrete x_{cr}/x_s still showed a similar trend, while for OPC and PLC lower values of x_{cr}/x_s were detected (1.2-1.5) independently from crack parameters. From measurements of penetration depths and time an attempt was made in order to evaluate chloride diffusion coefficient (*D*). *D* was calculated according to the model proposed by Collepardi et al., 1970. In uncracked conditions *D* resulted to be equal to 1.79×10^{-12} m^2/s for OPC, 3.06×10^{-12} m^2/s for PLC and 0.34×10^{-12} m^2/s for PC concrete. In cracked conditions, the application of the same model was limited by the fact that the effects of crack geometrical parameters were not included in the evaluation of *D*.

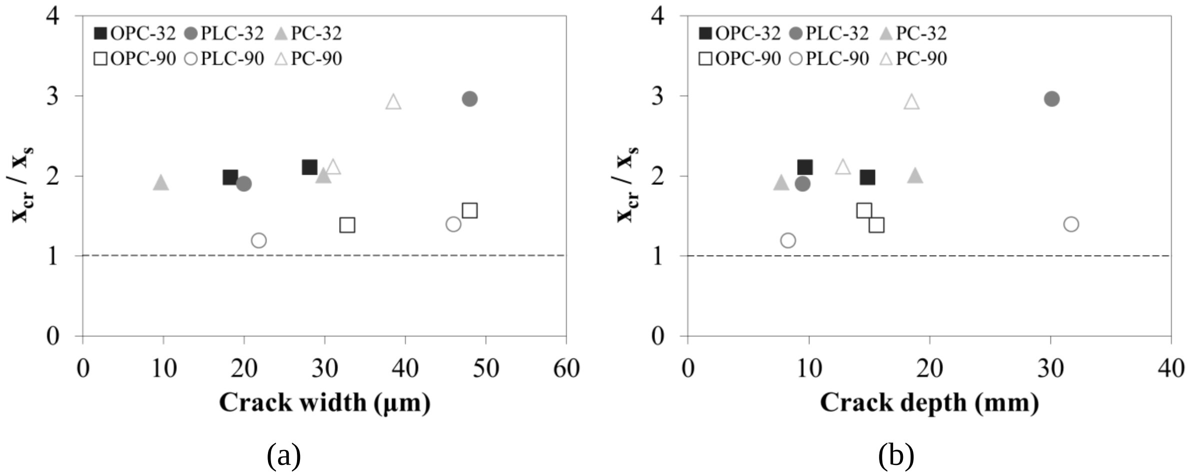

Figure 1. Local increase of chloride penetration depth in correspondence of the crack with respect to sound conditions, as a function of (a) crack width and (b) crack depth.

4 Conclusions

Chloride penetration in different types of concrete was investigated, in uncracked and micro-cracked conditions. Although micro-crack were characterized by narrow openings (10-50 µm) and shallow depth (8-30 mm) chloride penetration locally increased, from 1.2 to 3 times with respect to sound conditions. A mathematical model was applied to chloride penetration depth measurements in order to evaluate chloride diffusion coefficients (*D*). In sound conditions the lowest *D* was found for PC concrete, while for OPC it was more than five times higher and nine times higher for PLC. The application of the same mathematical model to cracked concrete resulted limited by the fact that crack geometrical parameters were not considered.

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