# INFLUENCE OF REAL CRACKS ON CHLORIDE DIFFUSION

**C. Sosdean [1] , G. De Schutter [2] , L. Marsavina [3]**

**Summary:** *The novelty of this study consists in using drilled cores from a large scale OPC reinforced slab, exposed to a simulated accidental failure of the central support and subsequent vertical loading until collapse, in order to determine the influence of real cracks in concrete structures on the penetration of chlorides. The experimental results were obtained with the non-steady state migration test described in NT BUILD 492, using an electrical field and real cracks. In order to study both the influence of rebars and cracks, reference samples were used. The chloride penetration depth was measured with a colorimetric method on each specimen. From these penetration profiles the influence of cracks on the penetration depth and the diffusion coefficient is investigated considering the crack patterns.*

**Keywords:** *real cracks, chloride penetration, experimental results*

## 1 Introduction

Chloride induced corrosion remains one of the major challenge; many studies were performed in the last decade in order to predict durability of concrete structures. In reality, these structures are frequently cracked either by mechanical loading either they are a consequence of non-mechanical effects such as: temperature and moisture gradients, expansive chemical reactions or are induced by corrosion of reinforcement in the propagation stage of the chloride attack. Generally it is recognized that the existence of cracks accelerates the ingress of chloride ions. Thus, it is very important to have a better understanding of chloride diffusivity in cracked concrete.

Several experimental studies were carried out in order to have a better image on this complex interaction between physical and chemical processes which is chloride ingress. Based on the crack preparation method, the reported experimental studies can be divided into two groups: destructive methods and non-destructive methods. The former studies adopt different mechanical loading techniques to prepare cracks, such as wedge splitting test [1, 2], three or four-point bending test [3], Brazillian splitting test [4, 5] and expansive core method [6]. Other studies use in order to simulate a crack by means of the positioning and removal of thin copper sheets before final setting of concrete [7, 8] or produce a crack by saw cutting concrete cylinders longitudinally [9].

Yet, none of these studies were made using samples obtained from real cracked structures.

[1]Ing. Corina Sosdean, Politehnica University of Timisoara, Department Strength of Materials, Blvd. M. Viteazu, No. 1, Timisoara 300222, Romania, email: corina.sosdean@yahoo.com

[2]Dr.-Ing. Geert De Schutter, Ghent University, Magnel Laboratory for Concrete Research, Department of Structural Engineering, Technologiepark-Zwijnaarde 904, B-9052 Ghent, Belgium, email: Geert.DeSchutter@UGent.be

[3]Dr.-Ing. Liviu Marsavina, Politehnica University of Timisoara, Department Strength of Materials, Blvd. M. Viteazu, no. 1, Timisoara 300222, Romania, email: msvina@mec.upt.ro

## 2 Experimental program

### 2.1 Concrete samples and crack configuration

The samples used in this study were drilled from a cracked RC slab of $140\,\mathrm{mm}$ thickness and $1800\,\mathrm{mm}$ wide, having the total length of $14.30\,\mathrm{m}$. This slab was exposed to an artificial failure of the central support and subsequent vertical loading until collapse. A detailed description of the test set-up and the results for the experimental large-scale tests are described in [10, 11]. The $8$ drilled cores used in this research have $100\,\mathrm{mm}$ diameter and $50\,\mathrm{mm}$ thickness; the positioning of the rebars and of the cracks can be observed in Figure1; it can be seen that the cracks go all the way through the samples; the average crack width of each sample was measured before the non-steady state migration test using the optical microscope.

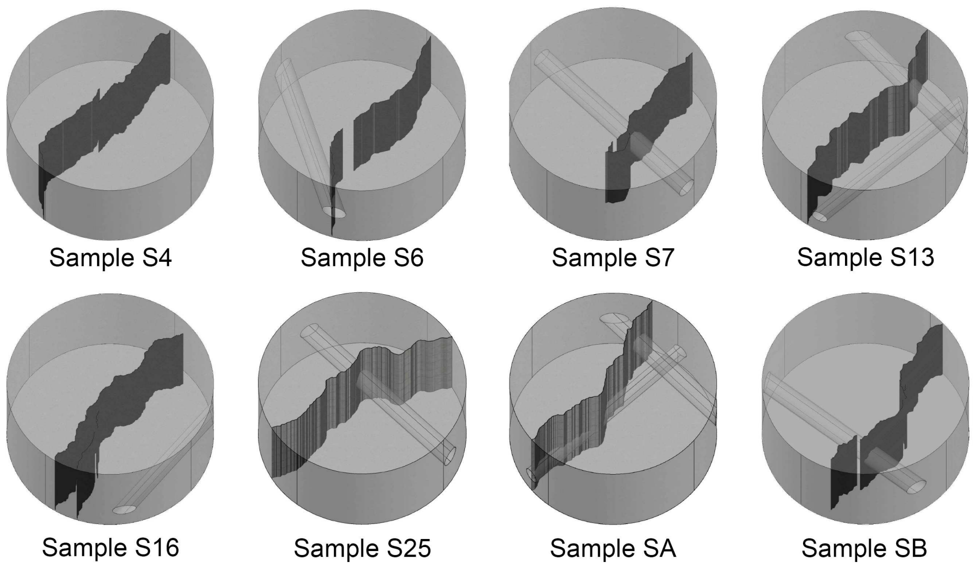


Figure 1: Drilled samples with the positioning of cracks and rebars

### 2.2 Testing method

On these drilled cores a non-steady state migration test was performed according to NT BUILD $492$ [12]. Before testing, the samples were vacuum saturated with a saturated $Ca(OH)_2$ solution. Afterwards an external electrical potential of $30$ Volts was applied on the samples for $24$ hours, forcing the chloride ions from the 10% NaCl solution to migrate into the specimens (the exposed surface was the outer surface). After the test, the samples were cut in $5$ parts each and sprayed with $0.01$N $AgNO_3$ solution and using the colorimetric method [13] the chloride penetration profile is determined.

## 3 Results and discussions

### 3.1 Penetration depth

In Figure 2 the mean penetration profile is presented for sample S4. On the vertical axis, the crack is represented, in five different points, corresponding to the faces where the penetration depths were determined: A, B, C, D, and E. The results show an almost uniform distribution of the chlorides, even though the crack is not situated in the middle of the sample. Also, it can be observed that the highest penetration depth is $27\,\mathrm{mm}$, even though the crack goes all the way through the sample.

### 3.2 Migration coefficient

Figure 3 shows the effect of crack width and rebar position on the diffusion coefficient. It can be easily seen that the migration coefficient increases with the existence of cracks; when increasing the crack width

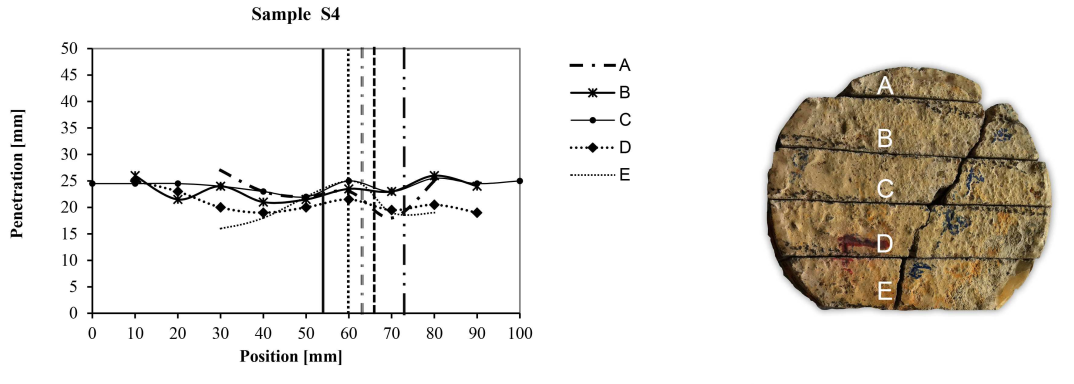


Figure 2: Chloride penetration depth for sample S4 with the localization of the crack

from $0$ (reference sample) to $173.2\,\mu\mathrm{m}$ (sample SA), the migration coefficient increases from $5.96\text{x}10^{-12}$ to $10.40\text{x}10^{-12}\,\mathrm{m}^2/\mathrm{s}$. As seen in Figure 1, samples S13 and SA have rebars on both directions and have the highest diffusion coefficient: $11.09\text{x}10^{-12}$, respectively $10.40\text{x}10^{-12}\,\mathrm{m}^2/\mathrm{s}$. Samples S25, SB and S7 have the rebar perpendicular on the crack orientation, and the migration coefficients values are pretty close. Even though the crack width for sample S6 is $153.87\,\mu\mathrm{m}$, the value of the diffusion coefficient is pretty low: $6.53\text{x}10^{-12}\,\mathrm{m}^2/\mathrm{s}$; a possible explanation could be the positioning of the rebar which intersects the crack only close to the edge. Further investigation needs to be carried on in order to have a better understanding of the influence of the rebar positioning on the diffusion process of cracked concrete.

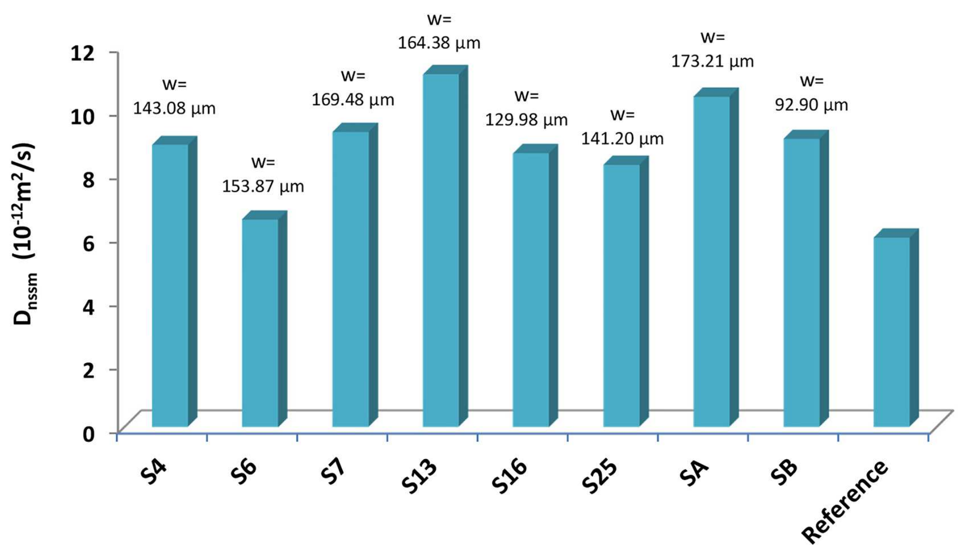


Figure 3: Comparison of diffusion coefficients according to crack width and rebar position

## 4 Conclusions

The following conclusions can be drawn from the present study:

1. Even though the crack goes all the way through the sample, the chloride profile has a uniform pattern.
2. It seems that the positioning of the rebars have an influence even bigger that the influence of crack

width, on chloride penetration, which requires further study in the future.

## 5 Acknowledgment

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