Simulation of Chloride Migration in Cracked Concrete

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Abstract

One of the key parameters influencing durability of reinforced concrete structures is an increased concrete permeability caused by cracking of concrete. In a largely cracked concrete the diffusion of chlorides approaches the diffusion in free water that can be further increased by the convection current due to the effect of temperature and/or small hydraulic pressure [1].

This contribution is devoted to the numerical solution of a two-dimensional diffusion-convection problem applied to chloride migration in cracked concrete. In the numerical solution chlorides are transported via two main mechanisms, the diffusion (Fick's law) discribing natural conditions and an electrical migration (Nernst-Planck equation) modeling remediation of reinforced concrete by applying an external electric current [2].The solution of the diffusion-convection problem is based on FEM and is implemented into an in-house open-source software. The effect of cracking in the mechanical model is coupled with the diffusion-convection model through an effective diffusivity that is based on the level of concrete damage. The concept of isotropic damage model is used where the scalar damage parameter evolves based on the effective mechanical strain and concrete fracture energy. The damage parameter is converted to the equivalent crack width and equivalent crack volume is calculated for each finite element.Chloride diffusion is separately defined for cracked and sound concrete using material parameters such as the degree of saturation of cracks, cracks constrictivity and tortuosity, and porosity. Diffusivity in the cracked part is formulated as a function of two predominant factors, i.e., volume fraction of cracks and the parameter representing crack width. Using this approach, both single and multiple cracks can be modeled.

The analysis is presented on a practical example of a reinforced beam, analysed in three different stages. Firstly, in the beam a crack is created by external mechanical load and the distribution of concrete damage is calculated. Following is natural chloride ion diffusion into the damaged beam showing increased diffusion in damaged parts. Finally, an extraction of chloride ions using external electrical field (modeled by the Gauss law of electrostatics, [2]) is applied. The efficiency of the remediation technique is shown for both sound and cracked areas of the beam.

References

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2. J. Němeček and J. Kruis and T. Koudelka and T. Krejčí. Simulation of chloride migration in reinforced concrete. Applied Mathematics and Computation 319 (2018), 575–585.