Modeling of Chloride Transport in Cracked Concrete: A 3D Image-Based Microstructure Simulation

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Abstract

The prediction of concrete materials service life is not easy, because the complex heterogeneous microstructure and the random nature of concrete materials. Study the presence of cracks in concrete and their effect on coupled reaction and transport are of great interest in civil engineering. Cracks with different widths and depths will reduce the cover thickness and accelerate the migration of chloride ions. So, it's highly desirable to develop a model to predict the chloride diffusion depth in cracked concrete while considering the real microstructure including cement, voids and aggregate. While current models consider a variety of concrete at varying levels of complexity, predicting the initiation of chloride-induced corrosion, considering the influence of cracking is generally beyond their scope. Previous research has used COMSOL Multiphysics to investigate the microscale corrosion of reinforced concrete cracking due to non-uniform corrosion (Pan and Lu 2012). The cracked and porous media was analyzed by COMSOL (Perko et al.). Reaction and diffusion processes were also studied by (Richter et al.). Digital image analysis was used to represent rock structures (Zhang et al.). In this study, the 3D image-based microstructure was provided by the advanced mathematical representation of random microstructure (Lu and Garboczi). Next, a 3D mesh representing true multiphase microstructure was written in Nastran mesh and imported to COMSOL Multiphysics. Two COMSOL interfaces, Transport of Diluted Species and User Defined ODE Mathematics, were employed in this study to examine the influence of cracking on chloride penetration into concrete. Moreover, we use COMOL to assign boundary conditions directly on 3D mesh, rather than on the geometry. Eventually, predicting the chloride penetration in heterogeneous microstructure of concrete can be accurately simulated with COMSOL Multiphysics. The chloride concentration gradient existed in the crack obviously, and it changed the chloride concentration along the crack and irregular aggregate surfaces continually. Comparison to experimental data indicates that the contributions of binding of the chloride ions by the cement paste play a significant role in slowing the ingress of chlorides and should be accounted for in any modeling efforts.

Reference

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Figures used in the abstract

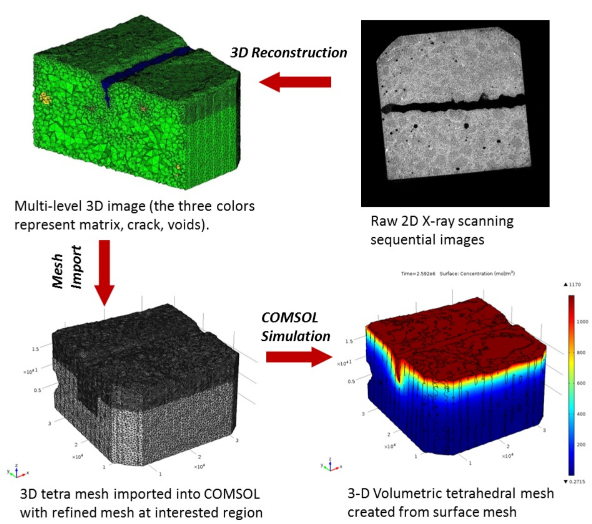

Figure 1: X-ray computed tomography (CT) images stacked into a 3D digital image, exemplified by the Virtual Cement and Concrete Testing Laboratory (VCCTL).Coupled transport and reaction processes are simulated by COMSOL Physics.

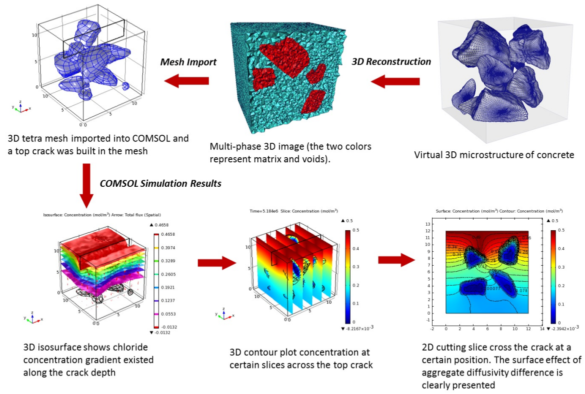

Figure 2: Real-shaped sand and gravel particles, represented by spherical harmonic series, are used to generate a virtual cement concrete structure. Coupled transport and reaction processes are simulated by COMSOL Physics.