Mesoscale modelling of crack-induced permeability of reinforced concrete

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Motivation

Cracking due to tension in concrete is characteristic for reinforced concrete construction. In the case of macro cracks even small crack widths are able to impair the durability of structures, because of increased mass transfer through the cracks. In particular, the prediction of water transport is of great interest in practice. The influence of crack widths on flow rates has been investigated by several researchers. But despite of this, other values like the roughness of the crack surface and the crack path have a great influence on the flow rate. The degree of reinforcement and the concrete mixture are import factors in this context as well.

Question

So far only the crack width at the concrete surface and the crack roughness are taken into account for fluid transport calculation. The research project focuses on the question whether it is possible to include additional values like concrete strength or components thickness. The cubic law will serve a basis.

$$\Rightarrow q = \xi \cdot \frac{g \cdot I \cdot b \cdot w^3}{12 \cdot \nu} \qquad (1)$$

I = pressure gradient

b = crack length perpendicular to flow direction

w = surface crack width

v = kinematic viscosity

ξ = coefficient to take the surface roughness into account (0÷1)

Approach

- Stochastic description of crack path and roughness of the crack surface.
- Stochastic description of the crack pattern in the concrete element.
- Description of the concrete permeability by taking the influence of macro cracks into account. Computational modelling is planned in addition to the test program.
- Transfer of the results into a in practice useable fluid transport model for cracked porous structures.

Reference

(1) Imhof-Zeitler, C.: Deutscher Ausschuss für Stahlbeton. Bd. 460:Flow behavior of various liquids in through-cracked concrete structures. Berlin – Wien – Zürich: Beuth 1996

Experiments

Permeability

A permeation test of reinforced concrete samples with a specific crack width at the sample surface will be performed. The crack is induced due to wedges pushed into the sample. Crack width between 0.1 and 0.3 mm are investigated. In a first step water will be the admission flow. Later also concrete-aggressive fluids will be investigated. Furthermore several factors, e.g. aggregates and w/c-values and cement type will be varied.

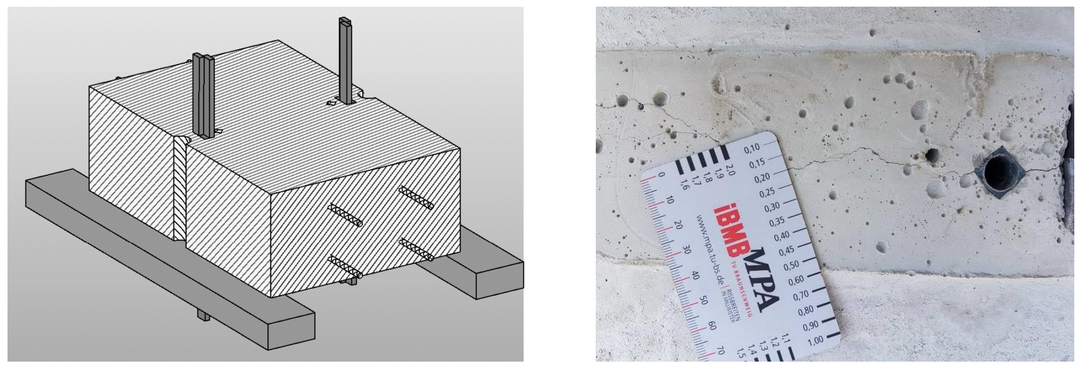

Figure 1: Diagram of a reinforced sample and crack induced due to wedges

To determine the effect of self-healing of cracks the permeation test, will be carried out as a short term and as a long term experiment. To define the relevant pressure gradient value, to investigate the concrete before loading and to see the crack before and after permeability test experiments on small cylindrical samples are conducted. An advantage of this test setup is that it is possible to see self-healing products in the micro-CT scans.

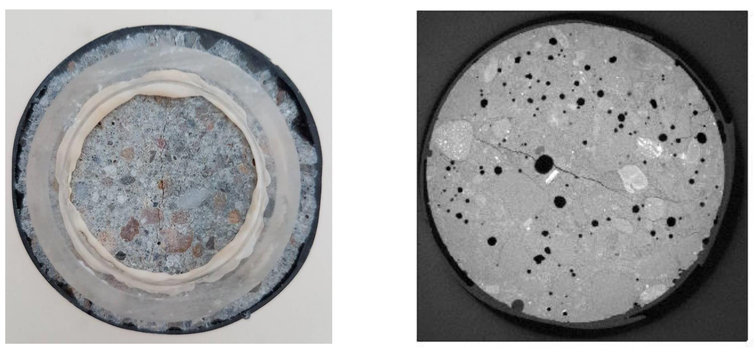

Figure 2: Cracked, cylindrical sample and corresponding µCT-Scan

Crack geometry

Micro-CT investigations will be carried out on drill core samples of the permeation-test-samples. To fixate the crack opening, epoxy resin is injected to obtain defined information on the crack pattern without losing any information.

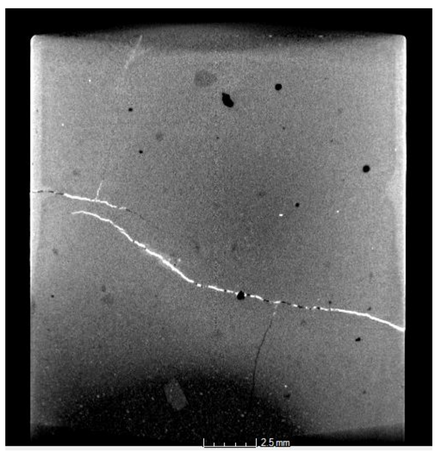

Figure 3: µCT-Scan with contrast agent

Surface roughness

The roughness of the fractured surface of samples will be determined by using a digital microscope. The parameters taken into account are arithmetic means and the fractal dimension of the surface.

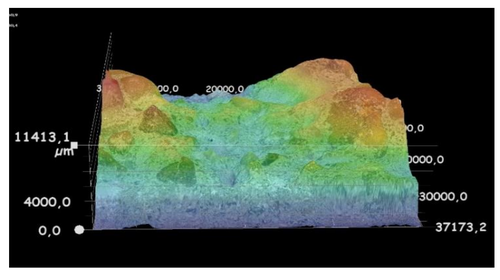

Figure 4: Fractured surface taken with a digital microscop