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Experimental study of water vapour condensation in cracked concrete with different specimen states visualised by fast neutron radiography

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Abstract:

This work provides new experimental evidence regarding two-phase fluid flow in damaged porous media. The results aim to provide novel cases towards leakage rate modelling dedicated to the well-prediction of reliability and durability of the pressurised concrete structures such as nuclear containment buildings.

Previous experimental works on the structural scale, e.g. reinforced concrete slabs tested at MPA Karlsruhe[1] and in MAEVA model[2] show that the air-vapour leakage rate is lower than the leakage rate of dry air. The accurate prediction of the complex interplay of multi-physics phenomena necessitates the use of sophisticated numerical models. The adaptation of such models demands the calibration and validation in simple yet realistic experiments whose thermo-hydric boundary conditions are well-defined.

With this regard, we present an experimental study, where, a pressurised autoclave is used to generate vapour and inject it into a cracked concrete cylindrical specimen of diameter and length 40mm. Brazilian test is conducted on the specimen, equipped with LVDTs on both circular faces, to create $\approx 150\mu m$ crack opening displacement (COD). The required COD is achieved by progressive crack opening with several loading/unloading cycles.

Dry and saturated cracked specimen states, representative of the in-situ limiting conditions, are examined for interaction with the injected vapour. Temporal evolution of temperature and pressure at both specimen boundaries are recorded, and the whole process is examined in-operando using fast neutron radiography diagnostics of $30Hz$ frequency and $85\mu m$ pixel size. The speed of vapour travel along the crack is reported higher for saturated specimen state in comparison to the dry state. The capillary suction around the crack is prominent for dry specimen and comparatively negligible for the saturated specimen. Also, the quantitative estimation of the sorption coefficient is presented. A direct physical link between the material microstructural content and material damage is established thanks to neutron micro-tomography carried out before and after the vapour injection test.

[1] Niklasch, C. and Herrmann, N. (2009). *Nonlinear fluid-structure interaction calculation of the leakage behaviour of cracked concrete walls*, Nuclear Engineering and Design, 239, 1628-1640.
[2] Granger, L., Rieg, C., Touret, J-P., et al. 2001. *Containment Evaluation under Severe Accidents (CESA) : synthesis of the predictive calculations and analysis of the first experimental results obtained on the Civaux mock-up*, Nuclear Engineering and Design, 209, 155-163.