Neutron imaging of hydraulic flow within structural concrete

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Summary: The visualization of fluid flow and characterization of porous media in concrete, by means of neutron scans, will be tested at the NeXT imaging instrument (ILL, Grenoble). The preparation of the setup is ongoing and preliminary tests were performed.

1. INTRODUCTION

The durability of reinforced concrete structures is mainly governed by the transfer properties of the material. The permeability is one of the most important indicators of the durability. In concrete structures, fluids may migrate through different paths: in the bulk of the material due to porosity and microcracking, along macrocracks [2] if any, or along geometrical discontinuities (e.g. rebar interface [3], construction joints). Therefore, the analysis of relative influence of the different propagation modes is a key issue for the characterization and the modeling of the concrete structure durability.

Neutron radiography has shown in previous studies that the hydrogen (in water for example) highly attenuates neutrons [4, 5], thus its presence in the sample strongly reduce the intensity of the neutron beam allowing the hydraulic front to be detected easily. This technique is considered as a very powerful tool in determination of hydraulic behavior in geomaterials and concrete compared to x-ray radiography (which itself is better suited to following the solid Skeleton [1]). With this technique, it's possible to distinguish different isotopes of the same element. A good contrast between normal (H_2O, density 1.00 g/cm3) and heavy (D_2O, density 1.11 g/cm3) water can be obtained, since D_2O attenuates neutrons 7 times less than H_2O [4]. As these two liquids are miscible and a diffusion takes place when they are in contact, a study is carried out to see the effect of this diffusion in terms of imagery.

Quantitative estimates of water front velocity and connected porosity of the concrete can be made by analyzing the neutron-attenuation images when applying a pressure-driven flow into the saturated concrete sample. An inverse analysis will be required to estimate the local permeability.

2. EXPERIMENTAL METHOD

Cylindrical concrete samples (7cm x 14cm) saturated with normal water were prepared and they will be tested under a high pressure gradient of heavy water. Neutron radiographies will be performed in order to get images showing the raise of the D2O front in the sample. A Titanium hassler cell was designed in order to handle the high pressure and to be transparent to neutrons. De Beer and Middleton were the first to use two-phase fluid flow through oil bearing rock inside a Hassler high-pressurized apparatus in order to reproduce deep reservoir pressure conditions [6]. During the water percolation process, continuous neutron radiographies are performed and at some stages a tomography of about twenty minutes is envisaged to have the shape of the front in 3D.

3. RESULTS

The experimental campaign presented in this abstract is still ongoing. In order to answer some questions about the diffusion between heavy and normal water, a simple test was performed by putting in contact these two

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liquids in a tube of 12 mm diameter during 7hrs 30min. The diffusion during the time is presented in fig.1, it takes place in a length of 4 cm around the contact surface. The rate of diffusion begins rapidly at first and decreases with time as the surface of contact between these two liquids decreases progressively. On the other hand, preliminary tests were performed to characterize the beamline and the attenuation of some materials that will be use in the set-up.

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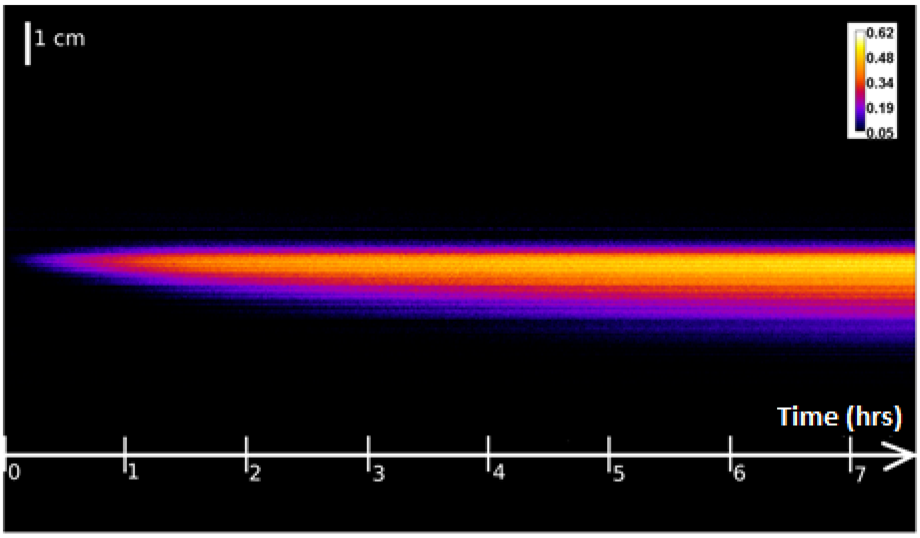

Figure 1: Diffusion of heavy and normal water in the tube during 7hrs 30min.