Observation of water absorption in sand using fast neutron radiography

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Abstract. Water concentration in porous media is an important aspect when inferring the structural integrity of the building framework. A need has arisen to determine this water content. Experiments were conducted at the PTB cyclotron making use of a 6.6 MeV fast neutron beam and fast neutron radiography system to follow the uptake of water through porous media. The observed benefit of fast neutrons as compared to the thermal neutron complement, is the ability to interrogate thicker samples. From the resulting radiographs, the volume of water absorbed as well as the rate of absorption is shown.

1. Introduction

The water content available in high strength concrete and soils is important in buildings where nowledge of the structural integrity is essential. Slowing the cracking process in concrete can be better understood when the water content within dense mixtures is known[1]. Water content within the pores of a concrete structure has a direct relation to its strength and effective safe lifetime. Testing the sample for porosity, sorbtivity and water retention capability is a traditionally destructive processes and does not allow for quick testing on site.

Thermal neutron radiography has been used to examine the porosity and presence of water in a sample of prepared concrete and sand [2]. Due to the attenuation of thermal neutrons by hydrogen, the thermal neutron radiograph was used to determined the amount of water absorbed [3].

Sample thickness limits this technique, due to the penetration depth of the thermal neutrons and compromises the achievable contrast as the sample thickness grows. Fast neutrons have a higher penetration and attenuation for lighter elements (hydrogen and oxygen). Fast neutron radiogrphy has been used in this investiagtion to examine the water absorption in thick samples of a porous sand medium in order to infer the volume of water absorbed.

2. Experiment

The investigation was carried out at Physikalisch-Technishe Bundesanstalt (PTB) in Brausnschwieg, Germany, making use of the PTB cyclotron which produces a 6.6 MeV fast neutron beam via the D(^{9}Be,n) reaction. The beam flux was approximately 10^8 neutrons $s^{-1}cm^{-2}$ with the sample and detector placed 1.2 m away from the source of neutrons. The

TRION fast neutron radiography system [5] was used to conduct the radiography.
Figure. 1 shows the experimental setup for the sample, with regular dehydratded soil placed in a water tray. The soil was dehydrated in a microwave oven and placed in the setup shown. Water was allowed to drip into the tray folowing the path indicated in Figure. 1 subsequently being absorbed by the sand, this process was imaged via fast neutron radiography.

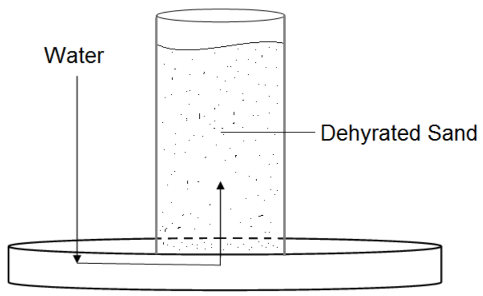

Figure 1. Experimental setup of water absorption experiment

The sample has a cross sectional thickness of 8.7 cm. To qualify the amount of water absorbed, the mass of the sand is recorded before and after being placed in water. The images where acquired in intervals of 12s during absorption.

3. Results

The radiographs in Figure.2 shows the absorption of water and areas of stratification forming. The fast neutrons can examine thicker samples, yielding different inforamtion about the bulk with a higher resolution over this thickness. Using the measured radiographs, Figure. 2, a method of comparing the attenuation coefficient of the dry and wet areas is applied to infer the volume of water absorbed. Three regions of interest (RoI) are defined on the radiographs, highlighted in Fig.2, with the attenuation coefficient being calculated at these regions.

Using the attentuation coefficent calcuated from the radiographs, the inferred volume of water absorbed (relative to the original dehyrated volume of sand) is obtained using Equation.1,

$$\frac{V_w}{V_s} \propto \left(\frac{\mu_{ws}}{\mu_s} - 1 \right) \tag{1}$$

where V_w and V_s are the volume of water and sand respectively, with μ_{ws} and μ_s the attenuation coefficient of the water sand mixture and sand respectively. For the 3 RoI's the results are shown in Fig.3 where the volume of water is inferred from the attenuation coefficient of water.

The data in Fig.3 shows that RoI 1 has the highest rate of absorption (during the initial 240 s and then slowing down from 240 s) when compared to the other regions of interest. The diminshing absorption rate after 240 s is indicative of the region of ineterest tending toward water saturation.

The water/sand system has a mix of attenutaing material, each one effecting the complexity in the calculation of the attenution coefficient. Using the technique by Anderson *et a*l [6], the increase in the water thickness (designated by α) is caluclated using Equation.2,

$$\alpha = \frac{\log \frac{I_{ws}}{I_s}}{\log \frac{I_w}{I_s}} \tag{2}$$

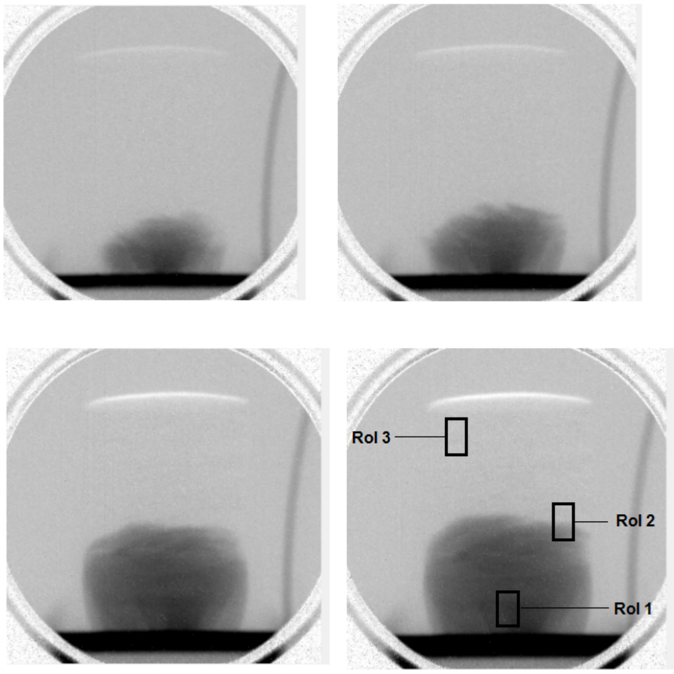

Figure 2. Fast neutron radiographs of the absorption of water in a column of sand.

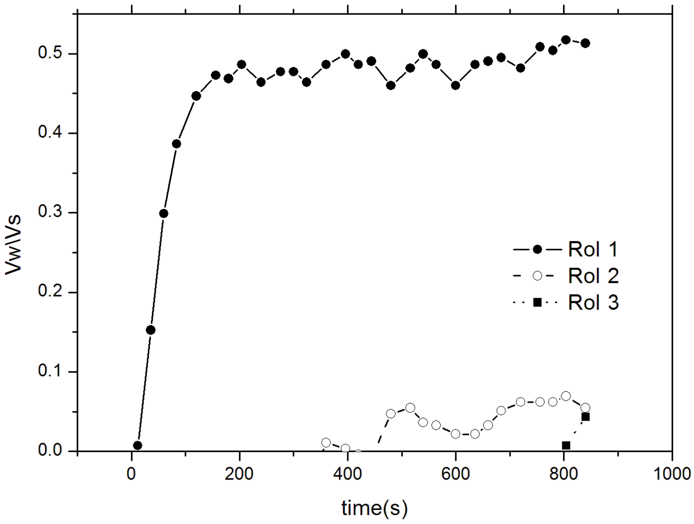

Figure 3. Volume of absorbed water, V_w, relative to original sand volume, V_s, as a function of time for the 3 RoI's.

where I_{ws} is the intensity from the composite water/sand radiograph with I_w and I_s being the intensitites from the water alone and sand alone, respectively. The results for the 3 RoI's are plotted in Fig.4.

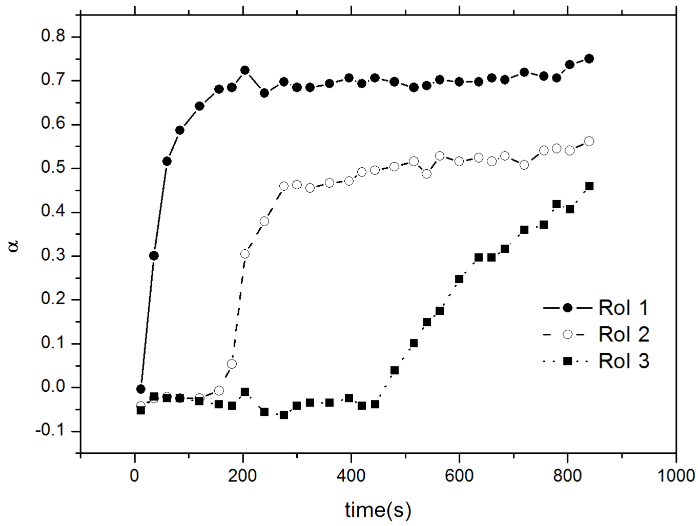

Figure 4. Water thickness as a factor of soil thickness over time.

Similarly to the results achieved and respresented in Fig.3, the trend of the volume contribution (α) increases faster in RoI 1 than the other contributing regions. There is a clear relation in the data represented in Fig. 3 and Fig.4 with a fast initial growth, indicative of a fast absorption rate that plateaus after around 240s as the RoI's begin to saturate.

4. Conclusions

The results respresented in Fig.3 and Fig.4, assist in inferring the amount of water absorbed and the amount of water present in a structure, at a given time, when compared to the dry sample. The benefit of using fast neutron radiography can be seen as the penetration depth of fast neutrons allows for the examination of thicker samples. The water being absorbed through thrugh the sand and the different thicknesses of water due to the increase in α is calculated from the resulting fast neutron radiographs. When compared to water absorption examined using thermal neutrons [4], the fast neutron radiography investigation can alanyse thicker samples.

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