Analysing dynamic neutron tomography of self-healing concrete using piecewise constant functions

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Summary: This work presents the analysis of a dynamic neutron tomography experiment. The goal is to visualize the internal water flow in a variety of cement-based materials that contain superabsorbent polymers. During hardening of the cement paste, the polymers seem to release their entrained water for internal curing purposes. Per-pixel analysis of the time attenuation curve using piecewise-constant functions clearly visualizes this feature and may lead to interesting results and optimization of the material.

1. INTRODUCTION

Concrete is a very popular material in construction due to its high compressive strength. But due to structural tension or autogenous shrinkage during the drying phase, cracks may form. This will make the material more susceptible to gas or water ingress, weakening the structure by deterioration of the cementitious material or corrosion of the reinforcement. The use of superabsorbent polymers (SAPs) is widely investigated to improve self-healing behaviour in cement [1].

A previous study has been conducted using neutron radiography on a small thin mold [2]. It was found that the imaging technique can be used to study the influences of SAPs in cement given sufficient resolution and the use of tomography. In earlier research [3], the smaller polymers are found to be more ideal in terms of mitigating self-dessication and autogenous shrinkage. Now 3D tomography is performed to give more information on the water kinetics from the SAPs towards the cementitious matrix. Furthermore, nuclear magnetic resonance testing clearly showed a difference when differently sized SAPs are added [4]. Their kinetics differ and the mechanism should be visualized.

A local change in attenuation coefficient is related to the transport of water inside the volume element or voxel. A reduction from the time attenuation curve to piecewise constant functions in each single voxel gives more accessible information to derive the local kinematics.

2. EXPERIMENTAL METHOD

Materials In the neutron imaging set-up, five cups with different mixtures were positioned in a vertical stage. The compositions of the different mixtures are equal to those stated in a previous experiment [4]. The cups have a height of 10mm and an internal diameter of 5.5mm. Two cement pastes are used as reference (R), while two other preparatives contain different types of SAPs (A_e and B_e). One final cup is filled with solely water. The mixtures are labelled from top to bottom H_2O, $R_{0.30}$, A_e, B_e and $R_{0.354}$.

Neutron tomography A neutron tomography experiment has been performed in the course of 57 hours to image the structural behaviour of water in drying cement paste. The sample has made 57 rotations of one hour each, and 47 projections were taken each 360° rotation from regular angle intervals. The quasi-parallel beam projection of each cylindrical cup is about 300 pixels wide on the detector plate with pixel size of 21μm.

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Reduction to piecewise constant functions A method developed for reconstruction improvement of dynamic CT [5] was implemented in GPU code as a stand-alone tool, used to analyse the outcome of a dynamic experiment. The simplicity of this technique makes it a great tool for a fast check of internal processes. Each spatial element independently converts its time attenuation curve (TAC) to a piecewise constant (PWC) function of four parameters and a significance measure D. The jumps from low (g_l) to high (g_h) attenuation phase occur at time instances t_a, or vice versa at t_b.

3. RESULTS

In figure 1 one can see a small selection of the PWC analysis in symbolic renders for the two SAP filled samples A_e and B_e. Disappearing water (dropping attenuation coefficient) is indicated in blue, adding water in red after the first transition. Only the regions with most significant transitions are shown, such that no apparent change was left in the water reference. These correspond well to the SAP regions, which illustrates the convenience of the PWC technique to detect interesting processes. Surprisingly, in A_e the surroundings seem to collect water before the SAPs are in the low phase (blue). This happens when the water outflow occurs at a slow pace: the PWC algorithm indicates approximately the middle time t_b of the phase transition, not the start. In B_e this flow is more synchronized, which can hint to faster dynamics. Starting at $t_b = 13$ hours after the scan beginning, the SAPs start to shrink and send their water to the surrounding matrix over the course of the next 12 hours.

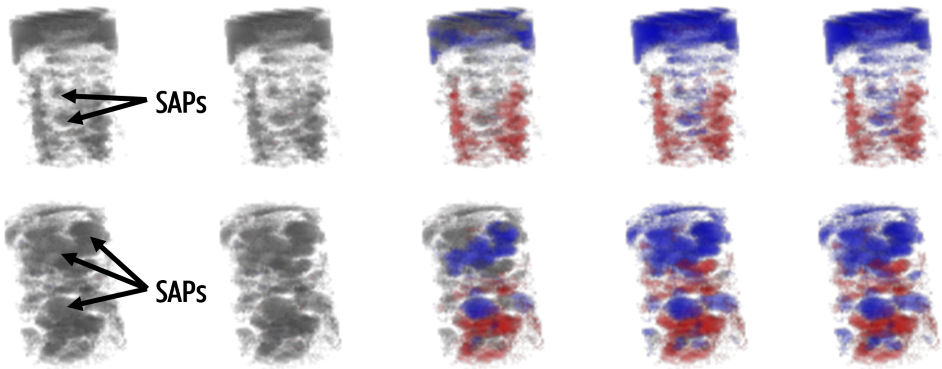

Figure 1: Result of the data processing on the two SAP filled cementitious materials for five time steps.

4. Conclusion

- The PWC analysis is a valuable and fast tool for processing of dynamic 3D processes.
- In slow processes the results should be interpreted carefully, further analysis is needed in A_e.
- The behaviour of SAPs in cementitious materials has been visualised with neutron tomography.
- SAP sizes change the internal dynamics, as seen in figure 1.

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