P14: Validation of concrete water transport tests by 1H magnetic resonance profiling

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A native of Hungary, Noemi Fischer got her MS in Civil Engineering at the Budapest University of Technology and Economics in Hungary 2009. She started to work at HeidelbergCement on 1st October 2010.

Project description

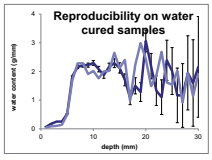
Conventional tests of water transport in concrete are empirically derived and usually based on weight increase or visual observation. These tests give no information on the state of water or the saturation within the nano, meso and micro pore structure of concrete and are not linked to transport theories. A recently developed one-sided NMR setup allows the investigation of samples larger than the equipment itself and gives spatial resolution of water profiles up to 25 mm depth. Both the test protocol and the instrument, which were developed under laboratory conditions, required commissioning and refinement in an industrial setting.

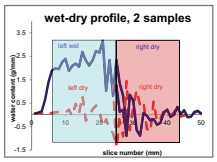
For capillary sorption, a dried specimen is placed in contact with water and the only force is capullary suction. Water uptake is measured by weight increase or penetration depth usually up to 24 hours at intervals. The water penetration under pressure test is a standard test procedure (EN 12390-8). The water cured sample is under water pressure on one side for 72 hours, split to measure maximum penetration depth. Water line can be difficult to determine for high performance concrete. Surface GARField is a portable one-sided NMR where the sample can be larger the the magnet itself and gives spatial resolution.

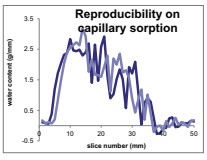
Three base mixtures were investigated, with CEM I (OPC), CEM I + 10% silica and CEM III/B (OPC with 70% slag), all had the same paste volume for comparison of the effect of different microstructures. Different w/b ratio was used for capillary sorption and permeability measurements.

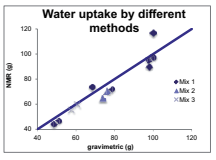
Project results

Surface GARField measurement protocol was optimised, both the data acquisition and the data analysis. Profiles show good reproducibility across different samples (top and bottom left). Error bars are based on the exponential signal decrease that is due to the setup of the magnet.
2 pieces of 20 mm thick concrete slabs (top right) show the validity of profiles. One was saturated (left), one remained dry (right) The wet slab was then sealed to avoid moisture transfer.. NMR profile shows the change in the water content.
The measurement was calibrated. Total water uptake by weight increase and NMR (bottom right) are within 10% difference on several concrete mixes.
The resolution of the profiles is 1 mm.



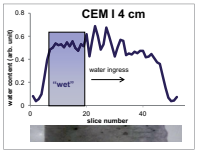


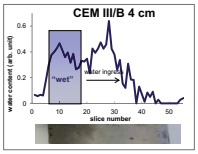




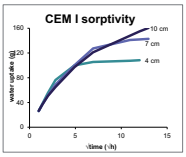
Results with arbitrary units were measured by the new probe that has not been calibrated yet.

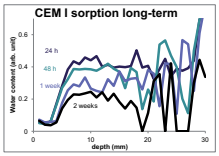
Capillary sorption was carried out on 4, 7 and 10 cm thick samples that were cut from 15 cm sealed cured cubes, that were dried after cutting. Water uptake was measured by weight at intervals up to 24 hours or longer, then water profiles by NMR was acquired.
Sample becomes darker, but there is significant amount of water beyond the visible water line (top left and right). The darker region of the cross section that is shown under the graph is highlighted blue.

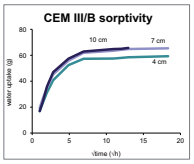


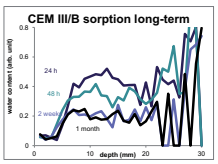


Long term capillary sorption experiment on CEM I and CEM III/B show loss of water on the NMR profiles(top and bottom right), but no decrease in weight of sample (top and bottom left).







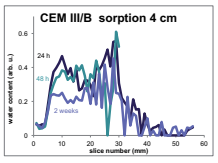


Half of the water disappears from the profiles in 2 weeks on both CEM I and CEM III/B. CEM III/B was measured up to a month and there was no change in weight or water profile after 2 weeks. The samples were minimum 6 month old.

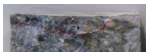
Relaxation time is shorter after 1 week of capillary sorption than measured after 1 day on CEM III/B.

CEM III/B	T_2			
	Short		Long	
1 day	286 µs	84%	4833 µs	16%
1 week	242 µs	90%	4505 µs	10%

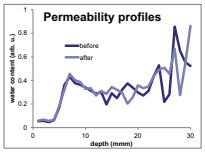
Capillary sorption on a 4 cm thick sample was measured from both sides by NMR. After 48 hours only the side in contact with water (left) was measured. The weight was the same as after 24 h. The waterline stopped and the right side remained dry.



Permeability testing was carried out with 0.5, 0.55 and 0.6 w/b on OPC samples. Water profiles were acquired before and after test, but no visible change in water content. 0.5 and 0.6 w/b tested, water penetration depth was double with higher w/b, no difference in profiles.


Water line after test on split sample


Test setup



What I am planning to do for the remaining time

- Capillary sorption
  - measure CEM I with silica on different samples sizes and testing times
  - T_2 relaxation times at different length of sorption on CEM I samples
  - investigate the relationship between colour change and water filled porosity on dry, water cured, capillary filled and pressure saturated samples
  - T_2 relaxation time on both sides of sample, one in dark region, on outside of dark ergion
- Permeability
  - measure thin (4 cm) and thick (15 cm) samples for different times to investigate the depth of penetration
  - T_2 measurement on water cured and pressure saturated sample

Outstanding questions

- Does the CEM III/B hydrate after 1 week of capillary sorption?
- Is the darker area on capillary sorption is related to a certain pore size filling?
- What causes the waterline in permeability?
- Why the penetration depth changes by diametre?
- How much water goes in the sample during the permeability measurement?

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