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

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Introduction

Water transport in concrete is the key to most degradation processes. However, most of the methods used for testing water transport properties are empirical and have no scientific background. Those tests give no information on the state of water or the saturation regarding distance from surface. Better understanding of those tests are very important for future use especially for high performance materials with new binders to predict long-term performance. Nuclear magnetic resonance (NMR) is an established method for both pore structure analysis and water transport in porous media. Therefore it is an appropriate technique for comparison, but no standard procedure exists and results are not easily comparable.

Aims and objectives

- ❑ to validate the surface GARField NMR against known samples such as saturated sandstone that has similar NMR response to concrete
- ❑ to refine the NMR measurement so as to create a NMR standard test procedure for the characterisation of water in concrete in situ in an industrial setting
- ❑ to validate conventional capillary sorption and water permeability tests against the NMR on a variety of concrete microstructures
- ❑ to further investigate water transport mechanisms in concrete

Conventional tests

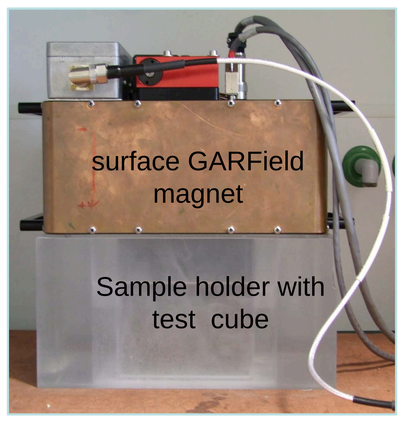
Both capillary sorption and permeability tests are widely used test methods. Very simple test procedure that rely on visual observation and weight increase.

Capillary sorption The dried specimen is placed in contact with water and the only force is capillary suction. Water uptake is measured by weight increase or penetration depth up to 24 hours at intervals. Simple test procedure, but no information on the state or distribution of water. Sample size affects the result.

Permeability The water penetration under pressure test is a standard test procedure (EN 12390-8). The saturated sample is under water pressure on one side for 72 hours, then split to measure maximum penetration depth. Simple test procedure, but gives no information on actual transport mechanism. Water line can be difficult to determine for high performance concrete.

Magnetic resonance

The NMR signal depends on the amount of water in the pores and the lifetime of the signal depends on the mobility of the molecules. Surface GARField (Gradient At Right angle with the Field) is a portable one-sided NMR, where the sample can be larger then the magnet itself and gives spatial resolution. The maximum depth is 30 mm and usual resolution is 1 mm.

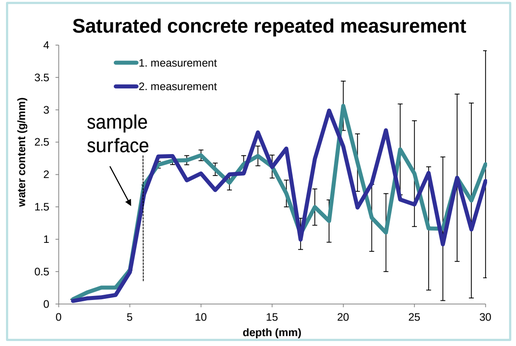


NMR Experiment

Due to the setup of the magnet the signal intensity exponentially decreases by depth as the sensor is further away from the sensitive slice, therefore the uncertainty of the measurement is higher. The first 5 mm is above the sample surface.

The standard test procedure was determined on saturated concrete and dry samples after capillary sorption. Calibration was done using saturated sandstone as the NMR parameters are similar to concrete and the pore structure does not change with drying/wetting.

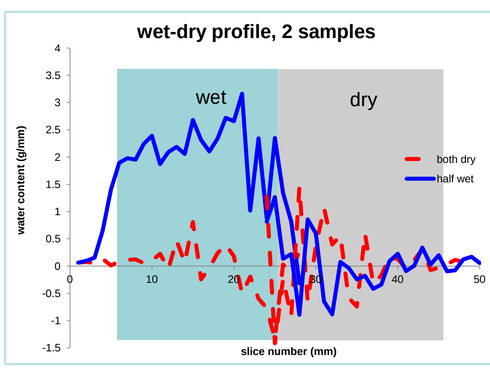
NMR profiling of the same sample show good reproducibility as well as different samples of the same mixture. At higher depth, results are highly affected by the low signal to noise ratio.



Calibration

The equipment is calibrated for 150x150 mm surface are and the water content is given for 1 mm thick slices.

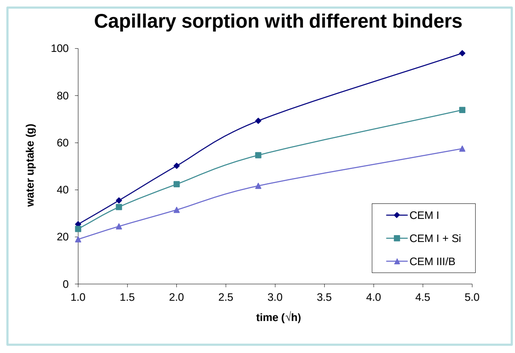
2 pieces of 20 mm thick concrete slabs. One was saturated (left), one remained dry (right). NMR profile shows the change in the water content. Water content of the wet specimen was 51.0 g by weight and 52.0 g calculated from the NMR water profile.



Capillary sorption

Three base mixtures were investigated, with CEM I (OPC), CEM I + 10% silica and CEM III/B (OPC with 70% slag) with 0.5 water-binder ratio. The mixtures only differed in binder. Samples were sealed cured for minimum 90 days. Then cut from the middle of 150 mm cubes and dried till constant weight. Samples were 40-45 mm thick.

Weight was measured after at 0, 1, 2, 4, 8 and 24 hours. The difference of water uptake of samples from the same mixture was 5-10%. Water profiles were acquired by NMR after 24 hours of capillary sorption. The samples were measured before and after the sorption experiment from both sides. Water contact was on the left (at slice 5).



Sample	Weight increase (g)	Water by NMR (g)
OPC	98.0	105.7
OPC + Si	73.9	70.8
CEM III/B	57.5	55.6

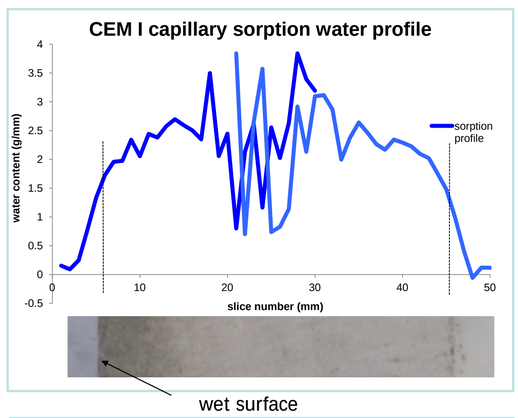
Conventional test method showed significant difference in sorptivity for the three concrete mixtures.

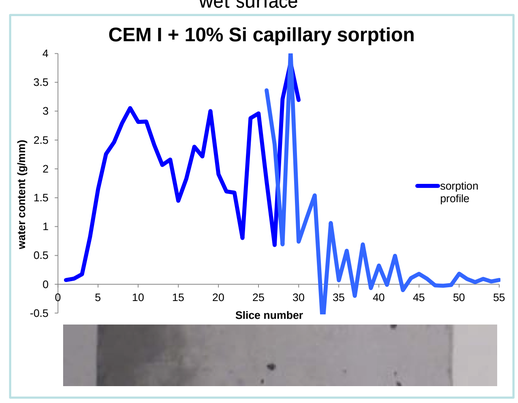
NMR results are in good agreement with water uptake by weight increase.

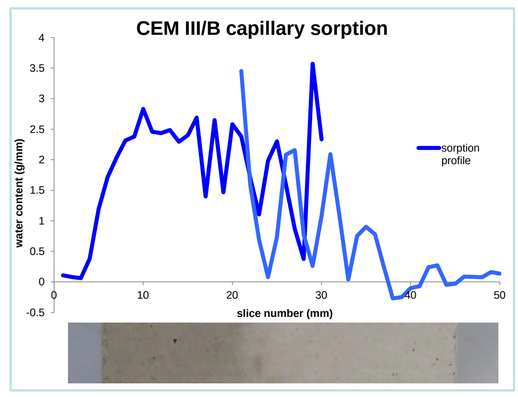
The three concretes have very different profiles. The CEM I is wet all the way across, the CEM+Si and CEM III/B about 25 mm from the wet surface. CEM III/B sample has a gradual change of water content, the CEM I+Si has a more sharp front. The cross section of the sample surface show the change in colour after the test. The dark region, which seems moist when the sample is split is not the same as the wet region according to the NMR profile.

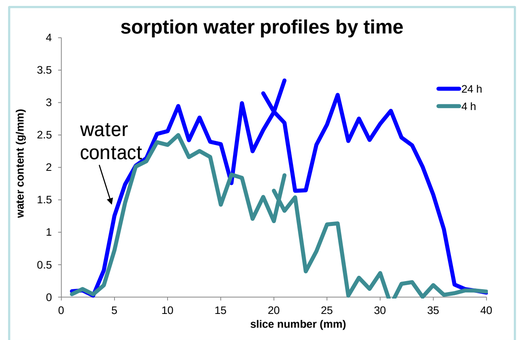
Water profile of the same sample after a 4 hour and a 24 hour capillary sorption experiment. The specimen was dried between the experiments. The water profiles were acquired from two sides.

Sorption time	Weight increase (g)	Water by NMR (g)
4 h	39.1	42.3
24 h	78.5	79.8









Conclusion

NMR parametres are set for concrete measurements and standard data analysis in under development. The system is calibrated for real water content on 150x150 mm samples. Capillary sorption results show very similar results by conventional method and NMR profiling. The relationship between the colour of concrete and water content will be investigated as it seem not to relate to water saturation.

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