P5: Drying-wetting cycles: effects on transport within cementitious materials

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Project description

Durability of reinforced cement-based structures are controlled by diffusion of aggressive species through the concrete cover whose quality may be jeopardized by the cyclic drying-wetting climate condition. The main characteristics of moisture transport during drying-wetting conditions is the hysteresis behaviour, referring to the different moisture content at the same relative humidify. In the earlier research, modeling of moisture transport usually neglected the hysteretic effect. However, resent studies show that the this neglecting can lead to a significant error in determination of moisture content.

The main objective of this project is to study the hysteretic behaviour of water vapour sorption isotherms and develop a method to simulate the moisture transport occurring during weathering cycles (relative humidity changes). Since moisture transport properties is also affected by temperature, this will be considered to investigate hysteresis and to simulate moisture transport.

What I have done

Drying properties

(1). Gas pressure variation

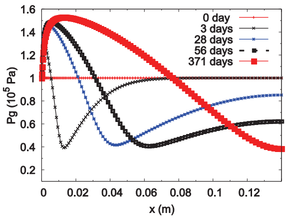
Simulation of gas pressure profiles during drying high initial saturation materials shows that a significant gas overpressure appears at the border layer. When the evaporated water vapor is forced to diffuse towards the surrounding air, the diffusion of dry air entries and takes the place of water vapor simultaneously . An obvious gas depression is also observed. Because liquid water movement is significant due to the high gradient of capillary pressure and the diffusion coefficient of vapor is lower because of the high water content, so that the diffusion of vapor is restricted.

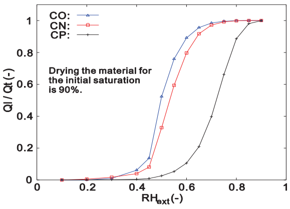
(2). Moisture transfer modes

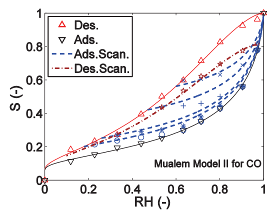
Drying process is mainly controlled by two modes: (a). liquid water in the material is transported to the boundary and then evaporates; and (b). liquid water evaporates within the material and then diffuses to the surrounding environment.

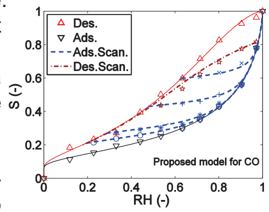
Hysteresis models

Both conceptual and empirical hysteresis models have been reviewed and evaluated by using experimental data collected from the literature. It shows that all models do not have significant different in prediction of the first scanning isotherms, either dying or wetting. Empirical models reveal a slightly better agreement with experimental data due to using one (or more) shape fitting parameters. However, this kind of models can yield aberrated phenomenon, called the "pumping effect" – non-closure scanning loops for secondary and up scanning isotherms.



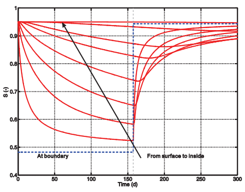


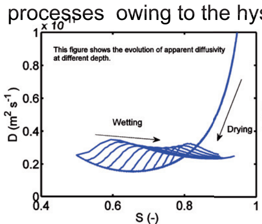


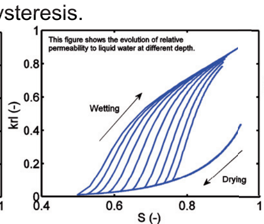


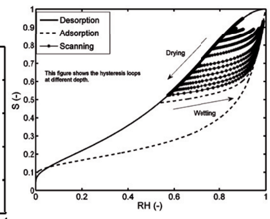
Modelling of drying-wetting cycles

Implementing the hysteresis model in moisture transport model is able to simulate and predict the moisture transport within cementitious materials. Different hysteresis models give different simulation results. Figures show the results from the proposed hysteresis model. The permeability and diffusion coefficient are different between drying and wetting processes owing to the hysteresis.









What I am planning to do for the remaining time

1. Refine modeling of drying-wetting cycles

(1). Boundary condition

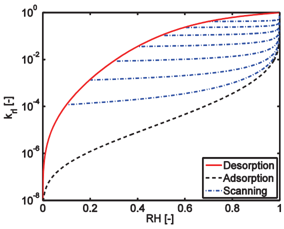
Evaporation boundary condition is more similar to natural environment, which can give better simulation and will be used to compare with experimental data.

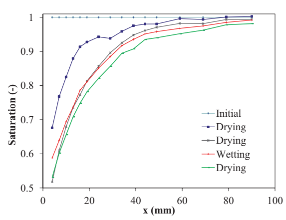
(2). Hysteresis models

The influence of "pumping effect" on modelling of moisture transport is not clear yet. More work needs to be done to analyse and compare the effect on moisture transport.

(3). Calculation of permeability to liquid water

Hysteresis of permeability to liquid water can affect the simulation results. Mualem model is able to simulate the hysteresis (see upper right figure) and compared with other non-hysteresis model.



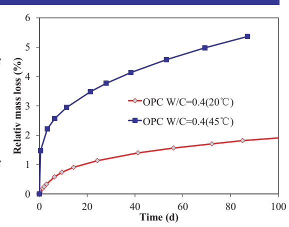


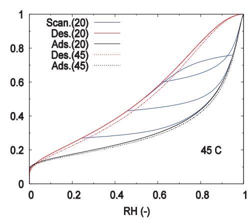
(4). Verified by experimental data

Most of my experiments, measurements of sorption isotherms (with the help of Project 6 in Lund) and drying-wetting experiments, have been finished. The measurement results, at 20°C and 45°C, will be used for verification of modelling.

2. Temperature effects of moisture transport

Studies have proved that at different temperature, moisture transport properties are not same. Drying materials at high temperature can increase moisture mass loss significantly (see right figure). This can be achieved through investigation of temperature affecting on sorption isotherm, diffusion coefficient, etc., in modelling of moisture transport under different temperature.





Outstanding questions of my project

1. Modelling method of drying-wetting cycles

Even though some hysteresis models show the better prediction of scanning curves and have been verified by experimental data, it is not easy to be applied to simulate drying-wetting cycles because of special function form.

It seems to be difficult to develop an universal method to simulate moisture transport in arbitrary drying-wetting conditions.

2. Experiments

Due to the relocation of IFSTTAR, I have reduced the duration of drying and wetting experiments. Some of measured water content profiles are not as good as we expected. Several unfinished gamma-ray attenuation tests will restart in next few month.

3. Secondment

It is not done yet. Planning to go to Lund for measurement of sorption isotherm at high relative humidity.

Other planning needs to be confirmed.

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