

Measurement of salt solution uptake by ceramic brick using γ -ray projection

D. Ogura^{1,*}, M. Abuku², S. Hokoi¹, C. Iba¹, S. Wakiya³, and T. Uno⁴

¹Graduate School of Engineering, Kyoto University, Kyoto, Japan

²Faculty of Architecture, Kinki University, Higashi-Osaka, Japan

³Nara National Research Institute for Cultural Properties, Nara, Japan

⁴Department of Architecture, Mukogawa Women's University, Nishinomiya, Japan

* ogurad@archi.kyoto-u.ac.jp

Abstract

Measurements of pure water/salt (NaCl) solution uptake by ceramic brick that use γ -ray attenuation have been conducted. A measurement set-up is described to determine the average pure water/salt solution content in the measured spot of a specimen. Two different types of specimens are prepared: a specimen of 3 x 5 x 10 cm with all surfaces made vapour tight, except the bottom and top sides which absorb pure water/salt solution or evacuate air and vapour; the other specimen that has the same dimensions and vapour barriers but being initially salt laden. Differences in pure water/salt solution uptake rate in the specimen are quantified. From the obtained data the liquid water permeability is determined, that is influenced by dissolved salts and salt crystals. The effect of salts on the sorption isotherm of the material is also implemented in the model.

Keywords: non-destructive measurement, liquid water uptake, sodium chloride, liquid water permeability, viscosity

Introduction

Prediction of water and salt transport and the resulting salt crystallisation that leads to salt damages of cultural heritage porous materials is feasible when the material properties such as the sorption isotherm and liquid water permeability, are well known. To date much advanced experimental and numerical research for such purpose has been made. In this work, pure water/aqueous NaCl solution uptake by ceramic brick is measured using γ -ray projection, in order to determine the influence of dissolved salts on the liquid water permeability.

Methodology

This study employs the model to analyse transport of a salt solution at a constant concentration in porous materials. The model is thus formulated in a simplified manner, based on an existing model and assuming a constant salt concentration, to assess the influence of salt on the sorption isotherm and liquid permeability of the material. The following three steps are taken:

- (1) The time evolution and spatial distribution of the content of pure water/salt solution in the material during uptake processes are experimentally determined using γ -ray attenuation.
- (2) The sorption isotherm and liquid water permeability of the material that contains pure water are determined by evaluating the experimental data for pure water uptake.
- (3) The experimental data are numerically treated, where the model implements the influences of salts on the sorption isotherm and permeability. Because the permeability is considered to depend on not only on the amount and type of salt but also on the porous material itself, the permeability of the material that absorbs a salt solution has to be determined to obtain a good agreement between measured and modelled data .

Experimental set-up and conditions

The volumetric pure water/salt solution content was measured in laboratory conditions of $\sim 23^{\circ}\text{C}$ and 50% RH using the set-up illustrated in Figure 1. The set-up consists of a stage, γ -ray source, collimators and detector as well as a sample holder placed on the stage. The (measured) circular spot has a diameter of approximately 10 mm. A single spot is measured every second during 40 seconds to determine the moisture content averaged over the last 7 seconds.

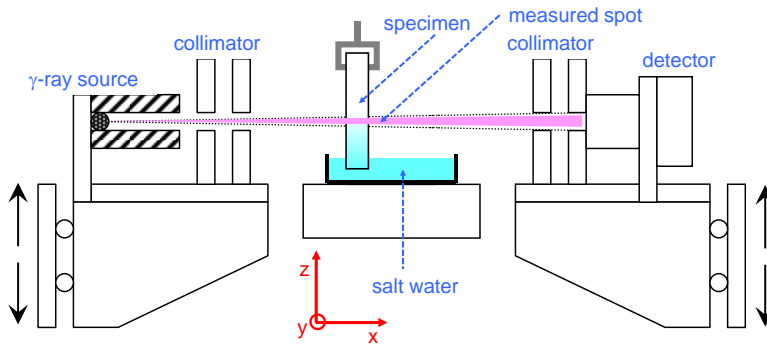


Figure 1: Schematic representation of the measurement set-up

Results and discussion

The time evolution of measured volumetric pure water/ salt solution contents at five different heights above the liquid surface in the container is shown in Figures 2 and 3. Each symbol in the figures depicts the content averaged over the measured spot. The time interval between two successive measurements corresponding to a difference in position of 1 cm is 80 seconds.

Significant differences in uptake rate between pure water and saturated salt solution are observed. Comparison of the two figures suggests that the uptake rate of pure water is almost three times that of a saturated salt solution.

At the end of the uptake, the pure water content is slightly higher than the salt solution content. This can be explained by a higher viscosity and higher surface tension of a saturated salt solution compared to pure water, resulting in a slower or limited absorption into pores of the material.

Acknowledgement

This work was supported by JSPS KAKENHI Grant Numbers 23560694 (Grant-in-Aid for Scientific Research (C)) and 26709043 (Grant-in-Aid for Young Scientists (A)). We also thank Mr. W. Kotera and Mr. K. Wada for their assistance in the experiments.

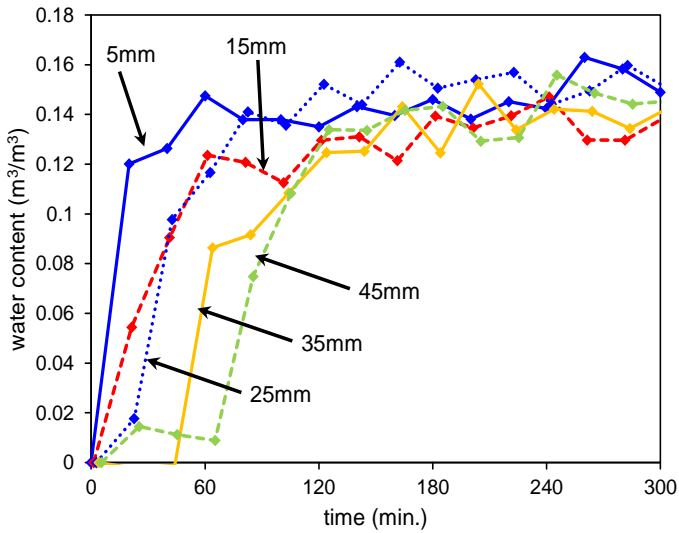


Figure 2: Evolution of water content during pure water uptake measurements

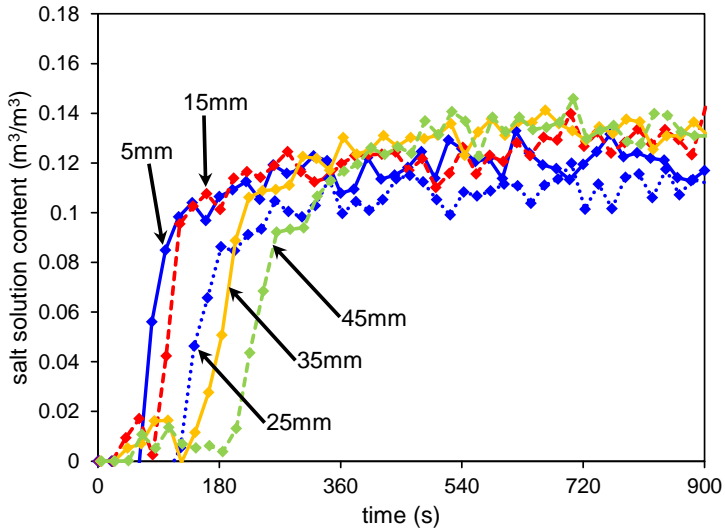


Figure 3: Evolution of salt solution content during saturated salt solution uptake measurements