



Effect of osmotic pressure on salt extraction by a poultice



V. Voronina, L. Pel^{*}, K. Kopinga

Transport in Permeable Media, Department of Applied Physics, Eindhoven University of Technology, P.O. Box 513, 5600 MB Eindhoven, The Netherlands

HIGHLIGHTS

- Investigation moisture and ion transport in poultice/substrate system by NMR.
- Effect of osmotic pressure on moisture flow in a poultice/substrate system was shown.
- The buildup osmotic pressure within the poultice will improve the salt extraction.

ARTICLE INFO

Article history:

Received 31 July 2011

Received in revised form 15 October 2013

Accepted 31 October 2013

Available online 29 December 2013

Keywords:

Porous media

Desalination

Salt

Osmotic pressure

Ion transport

ABSTRACT

Salts are widely recognized as a cause of deterioration of porous building materials. A general approach to slow down salt damage problems is reducing the salt content of the affected object. One of the most common treatments is the application of poultices. Desalination by poultices may result from two different salt transport processes: diffusion and advection. In this study we consider only the advection process. In the case of advection based desalination the efficiency of salt extraction strongly depends on the pore-size range of the substrate and the poultice. For advection to be effective, the poultice materials should be adapted to the pore-size distribution of the substrate. However, the poultice can shrink during drying, which affects the pore-size distribution of the poultice material. The salt transport from the poultice to the substrate by water advection results from a capillary pressure gradient, but upon drying a salt concentration gradient may appear in the poultice/substrate interface. Because of this concentration gradient an osmotic pressure arises, which may change the drying behavior of the poultice/substrate system. We have investigated the effect of the pore size distribution of the poultice and the osmotic pressure on the drying behavior of a poultice/substrate system. To this end, we have measured the time evolution of moisture and salt concentration profiles in a system consisting of kaolin/sand poultice on a fired-clay brick, using a specialized NMR setup. Comparison of the results with a model based on capillary pressure equilibrium at the poultice/substrate interface shows that the accumulation of salt from the substrate in the poultice may improve the salt extraction process, because the osmotic pressure decreases the effective pore size of the poultice.

© 2013 Elsevier Ltd. All rights reserved.

1. Introduction

It is well known that the decay of historic buildings and monuments made of porous materials is caused by the presence of soluble salts [1–3]. One of the common approaches to protect historic buildings and monuments from further decay is desalination by poulticing [4]. Desalination by poulticing means the transport of soluble salts from the affected object into the poultice material. The salts that are dissolved in water can move from the object into the poultice by two mechanisms: diffusion and advection. Because salt transport by diffusion is relatively slow (it can take several months) [5], in this study we only consider advection, which is a considerably faster mechanism.

Salt transport by advection requires a capillary pressure gradient as the driving force during the drying process. During drying the largest pores, where the capillary pressure is lowest, will empty first. In a porous system consisting of two layers water will flow from the material with larger pores to the material with smaller pores. Consequently, in a poultice/substrate system the poultice should have smaller pores than the substrate in order to provide water flow from the substrate into the poultice. Therefore, in order to improve the salt extraction efficiency, the pore sizes of the poultice should be adapted to the pore sizes of the substrate.

During drying of a poultice/substrate system salts migrate from the substrate to the poultice and a concentration gradient develops in the poultice/substrate interface. The presence of a concentration gradient in this interface creates an osmotic pressure, which can significantly influence the water flow. In [6] the influence of

^{*} Corresponding author.

E-mail address: l.pel@tue.nl (L. Pel).

osmotic pressure on the water flow in a layered system of two porous materials has been shown. It was demonstrated that the osmotic pressure generated by a saline solution in a porous material will reduce the effective pore size of that material. During drying salt will be transported from the substrate into the poultice, and hence the effective pore size of the poultice will decrease. Since for salt extraction by advection [5] the pores of the poultice have to be smaller than those of the substrate, the accumulation of salt in the poultice can effectively decrease the pore sizes and improve the salt extraction process. However, in that study the experiments were conducted using rigid porous materials in order to create a pure osmotic pressure effect. These materials were selected to avoid shrinkage effects which are commonly inherent to poultice materials.

The objective of the present research is to investigate both the effects of osmotic pressure and varying pore size distribution of the poultice on the water flow in a poultice/substrate system during drying. To this end a series of drying experiments on a kaolin/sand/water poultice (1:5:0.2 by weight) and a fired-clay brick substrate have been done. First, the theoretical aspects related to the moisture and ion transport in a poultice/substrate system will be discussed. Second, the experimental methods and the main characteristics of the poultice and substrate material will be given. Next, the moisture transport measurements during drying will be presented. The paper ends with a discussion and some conclusions.

2. Experimental

2.1. Sample materials

In order to study the effect of osmotic pressure on salt and moisture transport between substrate and poultice during drying, experiments were conducted using a rigid porous material as substrate and various poultice materials. The substrate used in this study is a fired clay brick with pore sizes in the diameter range 3–10 μm (Fig. 1). Cylindrical substrates were drilled with a diameter of 19 mm and a total length of 31 mm. The poultice mixture selected for the test is kaolin/sand/water (1:5:0.2) by weight. The sand was siliceous sand (standard sand CEN-NORMSAND DIN-EN 196-1). This mixture was selected on the basis of a characterization survey, including pore-size distribution measurements, of a large range of different poultice mixtures, the results of which are presented in [9]. The selection of the ratio of the components was primarily based on criteria such as workability, easy application and good adhesion to vertical surfaces such as a wall.

2.2. Experimental setup

The hydrogen and sodium profiles have been measured with a home-built NMR scanner especially designed for this purpose. An extensive description of this set up can be found in [10,11]. In our experiments the main magnetic field B_0 and the field gradient G were 0.7 T and 0.33 T/m, respectively. The RF circuit was specially designed in order to measure quantitatively both H and Na contents at different positions within the sample [12]. To determine the H and Na profiles over the whole sample, the sample holder was moved in the vertical (x) direction by means of a step motor. A standard Hahn spin-echo sequence was used. The time to measure both a H and Na profile within the sample and the poultice was about 1.5 h. The echo times for measuring hydrogen and sodium were 0.2 and 0.45 ms, respectively. Due to the short transverse relaxation time of Na in the solid phase, in our equipment only dissolved Na ions were measured. The Na signal was obtained from 256 successive spin-echo measurements of which the signals were averaged to obtain a sufficient signal to noise ratio. Using an external standard containing a NaCl solution ($c = 4 \text{ mol/l}$) the H and Na signal intensities can be related to the volume of water and the quantity of Na.

Experiments were performed in which initially either the substrate or the poultice was saturated with a saline solution, while the other contained only water. The substrate was first vacuum saturated with water or a 3 M salt solution. All sides of the substrate except the top were wrapped in Teflon tape to prevent water evaporation at these surfaces. The poultice composition prepared with water or with a 3 M NaCl solution was applied on top of the substrate and next the system was placed within the sample chamber of the NMR scanner. Dry air (at 5% RH) was blown over the exposed poultice top surface, thereby creating a one-dimensional drying experiment.

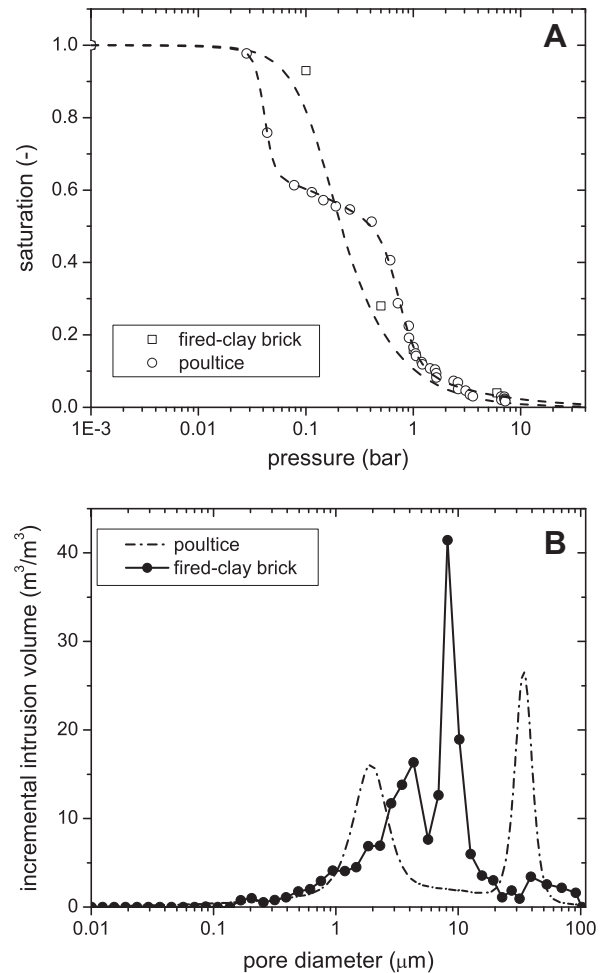


Fig. 1. (A) Capillary pressure curve of fired clay brick measured by a pressure plate and the capillary pressure curve of kaolin/sand poultice determined from drying experiments. The dashed curves are fits through the measured data points. As pressure plate measurements are very time consuming (one measurement point takes about several weeks), only a limited number of measurements have been performed. (B) Pore-size distribution of the fired-clay brick obtained by mercury intrusion porosimetry and that of kaolin/sand poultice obtained from drying experiments.

3. Theory

3.1. Capillary pressure

For a single pore the capillary pressure p_c is given by:

$$p_c = -\frac{2\gamma \cos \varphi}{r_m}, \quad (1)$$

where γ (N/m) is the surface tension of the liquid/vapor interface, φ (–) the contact angle between the liquid/air and liquid/solid interface and r_m (m) the pore size. In a porous material a distribution of pore sizes is present and hence the overall macroscopic capillary pressure of the material ψ , is a function of its pore size distribution. At any given moisture content, the distribution of water within the material depends on its pore size distribution. For any moisture content θ there will be a critical pore radius, r_m , which discriminates between the pores filled with water and the empty pores.

The capillary pressure curve and pore size distribution measured for a fired-clay brick are plotted in Fig. 1. As can be seen from this figure the fired-clay brick contains pores with diameters in the

Download English Version:

<https://daneshyari.com/en/article/257770>

Download Persian Version:

<https://daneshyari.com/article/257770>

[Daneshyari.com](https://daneshyari.com)