



Influence of the properties of granite and sandstone in the desalination process by electrokinetic technique



J. Feijoo^{a,*}, L.M. Ottosen^b, J.S. Pozo-Antonio^c

^a *Departamento de Enxeñaría dos Recursos Naturais e Medioambiente, Escola Superior de Minas, Universidade de Vigo, Campus Lagoas-Marcosende, 36310 Vigo, Spain*

^b *Department of Civil Engineering Building 117, Technical University of Denmark, 2800 Kgs. Lyngby, Denmark*

^c *Laboratorio de Aplicacións Industriais do Láser, Centro de Investigacións Tecnolóxicas (CIT), Departamento de Enxeñaría Industrial II, Escola Politécnica Superior, Universidade de Coruña, Campus Ferrol, 15403 Ferrol, Spain*

ARTICLE INFO

Article history:

Received 10 January 2015

Received in revised form 30 May 2015

Accepted 1 June 2015

Available online 3 June 2015

Keywords:

desalination

granite

sandstone

electrokinetic technique

Cultural Heritage

ABSTRACT

Soluble salts are considered a main cause of damage of porous building materials such as rocks, bricks or granites, which were commonly used in the building constructions of the architectural and archaeological heritage. Soluble salts are also responsible for various forms of deterioration such as sand disaggregation and superficial detachments. These problems can be solved by conservation technologies, which are aimed to decrease the salt concentration in rocks (desalination).

The present study aimed to investigate the efficiency of electrokinetic techniques for desalination of two different kinds of rocks: granite and sandstone. These rocks were contaminated with NaCl solution, and samples with a thickness of 6 cm were used in the tests. This study compared the percentage of salt removal at different depths (efficacy) and the time needed to get the same percentage removal (effectiveness) achieved in both stones.

From the results obtained, it was possible to find those inherent factors to each stone which could have an influence on the efficacy of the treatment. With this technique it was possible to reduce the salt concentration in the granite almost to 100%. However, in the sandstone samples the decreases were not equally high, mainly at the intermediate levels where slight enrichments were observed. The results indicate that although the used technique is efficient for salt removal regardless of the porosimetric distribution of the rock, the better interconnection between the pores in the granite samples (favored a faster desalination process).

©2015 Elsevier Ltd. All rights reserved.

1. Introduction

A great part of the porous materials used in construction are exposed to multiple deteriorating agents that imply a high risk for their future stability. One of the main agents of deterioration that affects these materials is the pressure caused by soluble salts, which crystallize in the interior of the material and pushing against the walls of their porous system.

The deterioration caused by soluble salts is due to continuous hydration and drying cycles or changes in the relative humidity, leading to the appearance of dissolution and crystallization processes of the salts. The pressure exercised by the salts in the interior of the pores can cause their growing, leading to the

decohesion of the altered material. Taking into account the importance of this alteration agent, there are multiple bibliographical revisions are focused on this subject [1–3].

Currently several desalination treatments are being investigated, which intend to eliminate or at least reduce the salt content present in the interior of the porous material. The most widely used ones are the immersion baths in water and the use of poultices. But these treatments show a series of technical limitations, which imply a low rate of salt removal (low efficacy), as well as high operative costs, which are dependent on the operation time (low effectiveness). In order to overcome these limitations, several researches have appeared during the last years focused on the application of electrokinetic techniques, with the aim of to force the migration of the salts towards the exterior of the porous material. Numerous researches studied the effectiveness of these techniques in the desalination of porous materials like e.g. bricks [4–8], granite [9], sandstone [10–11], limestone [8], etc.,

* Corresponding author. Tel.: +34 986812219.

E-mail addresses: jfeijoo@uvigo.es (J. Feijoo), lo@byg.dtu.dk (L.M. Ottosen), santiago.pozo@udc.es (J.S. Pozo-Antonio).

both at laboratory scale as well as on-site treatment of monuments and infrastructures.

Most of these studies analyze the effectiveness of the treatment for one kind of stone and focus on searching the best mechanism in order to buffer the extreme pH changes produced in the vicinity of the electrodes. However, there are no studies that analyze the influence of the different properties of the porous materials on the efficacy and effectiveness of this technique, mainly those properties that are related with the movement of water within the porous material. That is, those properties in relation to the porosity of the materials, in special, the accessible porosity, the capillarity and the connectivity of the porous network.

As reflected in the Nerst-Planck equation (equation (1)), the salts mainly move due to the action of three components. First, a diffusive component (first term in equation (1)), which reflects the movement of the ions due to the establishment of concentration gradients between nearby areas. Second, an advective component (third term in equation (1)), which reflects the movement of the ions in the same direction in which the humidity is moving. Finally, a component that reflects the migration of the ions to the electrode of opposite polarity (second term in equation (1)), which is caused mainly by the establishment of an electric field through the porous material.

$$J_j(x) = -D_j(\partial C_j(x)/\partial x) - (|z_j| F/R T) D_j C_j (\partial \Phi(x)/\partial x) + C_j v(x) \quad (1)$$

Being $J_j(x)$ the flux of species j in the x direction in $\text{mol s}^{-1} \text{m}^{-2}$, D_j the diffusion coefficient of species j in $\text{m}^2 \text{s}^{-1}$, z_j the charge of species j in eq mol^{-1} , C_j the concentration of species j in mol m^{-3} , $v(x)$ the velocity of the fluid in m s^{-1} , and F , R and T the Faraday constant (C eq^{-1}), ideal gas constant ($\text{J mol}^{-1} \text{K}^{-1}$) and kelvin temperature (K) respectively.

When an electric field is established, the migration predominates over the other two ones.

In all of these components the properties of the porous network play a very important role, in a degree which depends on the mechanism that is predominant. In diffusion processes (mainly process on the desalination treatments based on immersion baths), the diffusion of the ions is not free; as they are within a porous medium, their movement is being restricted by the connectivity of the pores and the tortuosity of the porous network [12]. In the advection processes (which take place, together with diffusion, during desalination using poultices), the porosimetric structure of the material and the poultice defines the direction in which the humid front moves [12]. Finally, in the migration processes the term of diffusion exercises a direct influence on the movement of the ions. Therefore it may expect that the desalination treatment applied in two different materials, that takes place when an electric field is established, can be produced at different speeds.

Therefore, the present study wants to analyze the importance of the properties of porous materials in the ion migration in two different materials: sandstone and granite. If the ionic content present in the samples, which is responsible for the transportation of the electricity through them, and the voltage applied to the samples during the treatment, are similar, the differences in the results can only be attributed to the greater or lesser opposition exercised by the porous structure against the movement of the ions.

Furthermore, the present study analyses the possible effects of the electrokinetic treatment on the properties of both stones, paying attention on two aspects: the possible chemical alteration of both materials due to the extreme pH changes, which are caused by the water hydrolysis in the vicinity of the electrodes, and the possible generation of micro-fractures due to the circulation of electrical current through the porous network of the materials.

2. Experimental

2.1. Rocks used

For the completion of this study, two different stones, presenting different structural properties were selected in order to evaluate the influence exercised by their properties on the results: a granite stone composed of two fine-grained micas, quite often used in traditional constructions in the north-western of the Iberian Peninsula and a sandstone used in the construction of one of the most important buildings of Denmark's cultural heritage, Kronborg Castle.

In both cases, it was necessary to characterize their main physical and water conducting properties according to the following standards: RILEM 1980a [13] for the determination of the accessible porosity as well as the real and apparent density, ICR-CNT 1981 [14] and RILEM 1980b [15] in order to determinate the absorption and de-sorption coefficients respectively, and ICR-CNR 1885 [16] standard was followed for the determination of the capillarity absorption kinetics and its absorption capillarity coefficient. Furthermore, the total porosity of both stones and their porosimetric distribution were determined by a mercury intrusion porosimetry using an Autopore IV9500 porosimeter of Micromeritics working within high pressures ranging between 0.20 MPa–225 MPa and low pressures ranging between 14 kPa–0.20 MPa, thus allowing the characterization of the pores with diameter from 116 μm to 3.8 nm.

These physical values allow the determination of relevant parameters for the mobilization of the ions such as the accessible porosity, the interconnection between the pores and its tortuosity.

Tortuosity can be estimated in an indirect way (equation (2)), dividing the total mercury injected (by intrusion) by the content of mercury retained in the samples during the extrusion process that takes place during the determination of the porosimetric distribution, as previously done in [17].

$$V \text{ total intrusion Hg} / (V \text{ intrusion Hg} - V \text{ extrusion Hg}) \quad (2)$$

Therefore and following this equation the greater quantity of mercury retained within the sample after the extrusion process of mercury (see equation (2)) is used as an indicator of the greater difficulty in the flow of the mercury outwards due to pore network tortuosity.

A total of 3 samples for each kind of stone with dimensions of $8 \times 8 \times 6 \text{ cm}$ were used for this study. These dimensions, mainly the thickness of 6 cm, were selected for being high enough as to analyse the influence exercised by the properties of the porous material on the mobilization of the salts.

These samples were contaminated with 20% NaCl solution. To proceed the salt contamination process the samples were partially immersed in the solution during 4 h. After this period of capillarity absorption the samples were removed and let to dry during 20 h at room temperature. The faces in contact with the saline solution were changed alternatively, i.e. the face was changed after 24 h. For the purpose of a similar initial ionic content of both rocks, the samples of each kind of stone were submitted to a different number of contamination cycles using the methodology explained in [18–19], due to the differences existing between their dynamics of capillarity absorption as well as the also different porosimetric structure presented by each kind of stone.

This way it is possible to clear this variable of unknowns since the ionic content present in the samples of both stones which are responsible of the transport of the electric current is similar.

Download English Version:

<https://daneshyari.com/en/article/183497>

Download Persian Version:

<https://daneshyari.com/article/183497>

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