Magnitude of the stage I drying rate of porous building materials with different porosity

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ABSTRACT

In building conservation, many problems are related to the presence of water in porous materials such as stone, mortars and ceramics. Indeed, moisture can be seen as the catalyst for many deterioration mechanisms. It gives rise to harmful chemical reactions, such as sulphate attack, enables biodeterioration and prompts salt decay, one of the most harmful deterioration mechanisms of porous building materials. A better understanding of drying processes can provide an important basis to find efficient ways of controlling the presence and, therefore, mitigating the damaging effects of moisture. This is particularly important in the case of salt decay because it typically occurs during drying when water and ions are transported towards the surface as the water evaporates. Therefore, a better knowledge of drying is also necessary for the understanding of the decay mechanism itself.

In this study we have looked at the evaporation from various porous materials with different porosity and surface roughness.

Generally, a two-stage model (Fig. 1) is considered appropriate to describe drying of porous materials. The two stages are the constant drying rate period (CDRP), which takes place at the higher moisture contents, and the falling drying rate period (FDRP), at the lower moisture contents. In the CDRP, the drying front is very close to the outer surface. Liquid moisture transport dominates and the evaporation rate is highest. In general, it is in this period that most of the moisture content in a material drying from saturation is eliminated. In this period, if salts are present, they will be transported to the surface where they crystallize as efflorescence.

It is often assumed that the CDRP drying rate is similar to that of a free water surface, due to the presence of a liquid film covering the whole surface of the material during this period. This idea has been contradicted by experimental results of different researchers [1-3], who reported that the CDRP evaporation rate of porous building materials was not necessarily equal, and may even be significantly higher than that from a free water surface subjected to similar environmental conditions.

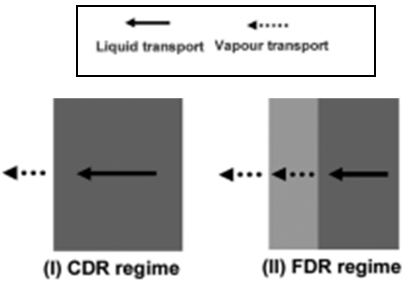

Figure1: *Drying of a porous building material*

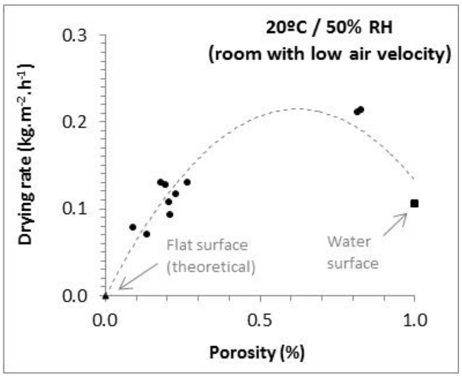

Figure2: *Variation of the CDRP evaporation rate with the capillary porosity of the materials*

In this study we analyze the CDRP drying rate for eight porous building materials. Both natural stones and artificial materials were tested: the Bentheimer sandstone, four limestone varieties (Ançã, Lecce, Malta's Globigerina, and a Portuguese low porosity limestone), red ceramic brick, slaked lime/sand mortar (1:3 in volume) and three kinds of calcium silicate material. The capillary porosity of the stones, mortar and bricks is in the interval 9-27%, whereas two of the calcium silicate materials (with 82% and 83% porosity, respectively) cover the higher range of values.

Several experiments were performed following RILEM procedure for measurement of the "evaporation curve" [4], at 20ºC and various RH.

The results of one of these experiments can be seen in Fig. 2, which shows the CDRP drying rate as a function of capillary porosity. Here, a free water surface is regarded as a material with 100% porosity (P=1). Point (0,0) is attributed to a theoretical material with 0% porosity (P=0).

These results show that the CDRP drying rate varies among the different materials. In some cases it is lower than that of the free water surface, which is inconsistent with the presence of a liquid film covering the whole surface of the material during this period. In other cases, it is higher than that, as was also found in other studies [1-3].

It can be concluded that the drying rate is a function of the capillary porosity. If we consider only materials with porosity up to 27%, i.e., the common building materials (natural stones, bricks and mortar), the relationship is almost linear, as reported in a previous article [3]. However, when we consider also the materials with higher porosity (above 80%) and the free surface of water (100% porosity), a linear relationship is no longer able to describe this relation. In this case, a better approximation can be made by parabolic function.

We hypothesize that changes in drying rate are due to the variation of the effective surface of evaporation. Roughening with sand or polishing were not successful in creating significant differences in the drying rate of a same material [3]. However, surface texture measurements performed with an optical method revealed that the surface area of the materials increases exponentially as the measurement scale decreases, tending to infinity as the scale approaches zero. This behavior indicates that the measured surfaces have fractal properties, which is in accordance with previous studies. Hence, surface irregularity due to internal features (i.e., porosity) could be relevant to explain the observed differences in the CDRP drying rate. This hypothesis will be discussed based on the obtained results.

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