

Effects of NaCl and NaNO₃ on the capillary suction, drying kinetics and vapour permeability of three building stones

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ABSTRACT

Salt decay is closely related to drying of porous materials, not only as a consequence but also because the salts are an influencing factor in drying processes. This influence, however, is not yet totally clear, as are not in general the effects of soluble salts on liquid and vapour transport through complex pore networks such as those of porous building materials.

Here, we analyse the role of two soluble salts, NaCl and NaNO₃, on the capillary suction and drying kinetics of three natural stones. The physical morphology of the efflorescence layer occurring in each case and the effect of such layer on vapour transport are also analysed.

Sodium chloride and sodium nitrate are among the most common salts in decayed buildings and also, particularly sodium chloride, two of the most used in laboratory experiments. Despite of their distinct composition, their equilibrium relative humidity is similar: 75.47% for NaCl and 75.36% for NaNO₃ at 20°C [1]. Four solutions with different concentration were tested in the case of NaCl and three in the case of NaNO₃.

The natural stones were the Bentheimer sandstone (B) and two Portuguese limestones that correspond to the Ançã limestone (CA) and a current limestone of lower porosity (CC).

The experiments followed RILEM procedures [2] and consisted on performing sequentially, on the same specimens, the following three types of test: determination of the absorption coefficient with water and the salt solutions, measurement of the evaporation curve, and determination of the coefficient of water vapour conductivity of the uncontaminated and salt contaminated specimens.

As regards the influence on liquid capillary transport, the results show that, for the three stones, the sorptivity of the salt solutions scales precisely as $(\sigma/\eta)^{1/2}$, where σ is the surface tension and η the viscosity of the liquid, as predicted theoretically [3]. The greatest sorptivity reduction occurs thus for NaNO₃: the values for the saturated solution are around 60% of those obtained for pure water, whereas for NaCl they are around 70%.

In relation to the drying kinetics, although for the concentrations closer to saturation the differences are sometimes less clear, a general trend can be observed: the higher the salt concentration the slower the drying. However, some isolated specimens deviate from this general trend, depicting a markedly slower drying kinetics. There were occurrences for the three materials and the two salts, which have an apparently random nature: the drying curves of the affected specimens diverge suddenly, triggered by some unidentifiable event or character.

At the end of drying, a layer of efflorescence was observable on the surface of the specimens. Its morphology was often similar for the two salts but varied significantly with the type of stone. As revealed by optical microscopy:

- CA developed thick crusts of vertically oriented crystals, apparently more compactly packed for the chloride than for the nitrate;
- CC presented shrivelled NaCl salt crusts which possessed holes at most of the hills and occasional fissures; the holes tend to develop at areas where dark clasts are present on the stone surface, which should correspond to a less porous mineral; for NaNO₃, most surfaces were covered by a porous coat of whisker-like efflorescence.

- B developed nodules of cauliflower-like efflorescence lying on a thin vitreous coat of salt; the two specimens which had much slower drying showed a different efflorescence morphology consisting on a thick and compact vitreous layer.

The vapour permeability of the efflorescence-covered materials, overall, decreases linearly with the concentration of the salt solution used, i.e., with the thickness of the efflorescence layer. The changes, however, are mostly irrelevant in all cases except for CA with sodium chloride. This difference seems to be closely related to the morphological characteristics, and particularly the porosity, of the efflorescence layer. What probably happens is that for CA with sodium chloride the efflorescence layer is compact enough to significantly disturb the transport of vapour. In all the other cases the porosity of the efflorescence layer is higher, either because the packing of the crystals is less compact or because the salt crust possesses holes and fissures, therefore, there is not much influence on vapour transport

In general, the variations in drying kinetics are consistent with the differences in vapour permeability or efflorescence morphology, inclusively in the cases of the specimens with random deviant behaviour.

Summarizing, the work done until the present moment indicates that:

- The changes induced by soluble salts in capillary transport are due to their effect on the surface tension and viscosity of the liquid and are proportional to $(\sigma/\eta)^{1/2}$, as predicted theoretically.
- The vapour transport hindering effect of salt deposits is very dependent on the habit and packing of the crystals. This was observed for external salt deposits (efflorescence crusts) but it is logical to expect that a similar effect may happen at the pore level, i.e., for internal deposits (subflorescence).
- Compact crusts of salt may relevantly hinder the passage of vapour. However, porous efflorescence layers with a negligible influence on vapour transport are probably also frequent. The difference between the two types is not easily detected by the naked eye and can be elusive in current site observations.
- Efflorescence morphology depends on factors such as the type of salt and the characteristics of the porous material, as previously concluded also by other researchers. However, it seems to incorporate also random causal factors, which may prove to be ultimately significant, probably derived from small casual inhomogeneities in the environmental conditions or in the complex pore network of the building material.

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