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Efficient liquid transport induced by drying paste/substrate systems

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Poultice technology is currently mainly used for the desalination of masonry structures in the field of architectural heritage conservation [1]. Wet poultices are coated on the porous material to be treated, and kept in place before being removed when dry. The efficiency of the process basically depends on the drying behavior of the system poultice/substrate, but so far little is known concerning drying of systems composed by soft materials applied to substrate surface. Here we show that, in contrast with various other materials (polymers, smectite clay, silica gel, latex, cellulose, etc) kaolin clay pastes have unique absorption properties as they may extract almost all the liquid (and the suspended elements) from the porous medium at a high rate.

We followed drying of different poultice systems coated on a substrate (glass microbeads with two different pore size), with Nuclear Magnetic Resonance (NMR). Different NMR sequences were used which provided the evolution of key internal characteristics in time: 1) the water saturation distribution; 2) transverse and longitudinal relaxation spectrum; 3) the poultice shape (shrinkage). From this information we identified the different drying regimes of poultice/substrate systems in relation with their microstructure evolution.

The remarkable properties of kaolin pastes appear as follow. In a first period, the paste shrinks axially (along the direction of evaporation) without fracturing, so that it maintains a full coverage of the porous medium surface. At the end of this period the material has formed a solid porous structure which, interestingly, will resist capillary pressure during the next steps of the process. When the pore size of this system is smaller than that of the substrate the liquid is progressively extracted from the substrate, while the poultice apparently remains (on average) saturated. In fact, air necessarily penetrates the kaolin paste in the form of transient paths reaching the substrate then closing back. This period lasts until almost 90% of water initially in the substrate is evaporated. A third period starts once capillary forces inside the poultice and the substrate are balanced. The water saturation now decreases almost homogeneously throughout poultice and substrate. Surprisingly, despite these complex processes, the drying rate in both the first and second period remains constant (i.e. at its initial, possibly high, level). This implies that almost all the water contained in substrate moves through the poultice to be evaporated at its free surface under approximately constant conditions [2]. This also implies that in general the elements suspended in the liquid will be transported and finally accumulated inside the poultice, which means that such a material is remarkably efficient.

References

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