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Relationship of roughness of building stones on the effective thermal conductivity determined by transient hot-wire method

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Alteration of inorganic materials in monuments is mainly related to relative humidity change in the porous network. Characterization of water content is a complex issue, specially in case of non-intrusive measurement. An innovative method is developed to quantify the water content using a direct calculation of the thermal conductivity. In order to validate the non-intrusive application to heritage stone, a control of the influence of the rock-sensor interface is required. The study was carried out on five sedimentary french rocks : three limestones (lithographic, oolithic and micritic), a sandstone of Fontainebleau and the so-called Tuffeau limestone. The textural properties are characterized by optical and electronical microscopy, X-ray diffraction, and mercury intrusion porosimetry.
The transient hot-wire method is useful to obtain a quick value of effective conductivity of material. Initially used in liquids and gas, It's now more and more used for solid materials. The calculation of one effective thermal conductivity is formulated by the slope of recorded DT/ln(t) diagrams. In case of continuous and homogeneous media, only one slope can be measured. For heterogeneous solids a typical curve present two slopes : the first one measured in the short time acquisitions (<1s) mainly depends on the contact between the wire and grains and thus micro texture of the material. The second one, measured for longer time acquisitions, characterizes the mean effective thermal conductivity of the material.
In the case of surface measurement, the first part of curve is relevant from the texture and roughness of the material. Roughness properties are determined by an interferometer system on different polished surfaces of the materials. For all studied stones, the arithmetic average roughness (Sa) is ranged between 44 μm and 1 μm, respectively for the coarse-grained limestone (Bretigny) and the finest one (Migné). According to the relative error of the apparatus (10%), the conductivity value is constant, independently of the surface polishing state. Thus, this evolution confirms that the method could be used on many stony materials as they are present in the built cultural heritage.