Developments in Investigating the Durability of Porous Building Materials Under the Chemical & Physical Modes of External Sulfate Attack

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External sulfate attack has been long recognized as one of the factors threatening the soundness of porous building materials located in residential, industrial, marine environments, etc. Among the numerous sulfate-bearing salts, sodium sulfate is known as the most aggressive one which can initiate both chemical and physical modes of external sulfate attack. The chemical mode of external sulfate attack in cement-based composites possesses a relatively rich literature of knowledge. Whereas, the physical mode of external sulfate attack, also known as salt crystallization damage, became a topic of interest in building materials within the past few decades. Despite the previous attempts in the literature, there still exist considerable methodological knowledge gaps concerning both mentioned modes of aggressions. Accordingly, the present thesis provided novel methodological developments for the durability assessment of porous building materials against the chemical and physical modes of external sodium sulfate attack. Red clay brick, sandstone, ordinary Portland cement-based, and limestone calcined clay cement-based composites, were among the studied materials. In particular, four hypotheses were explored. The first hypothesis was concerning the destructive impacts of the pore solution extraction on the microstructure of the Portland cement pastes subjected to chemical sulfate attack. It was found in the present thesis that oven and vacuum drying, even at mild temperatures of 30-40°C, plus solvent exchange via pure ethanol, led to the partial decomposition of the sulfate-induced ettringite and gypsum crystals of the paste. The optimum method, with the least degree of microstructural disturbance, was indicated to be solvent exchange via pure isopropanol in cool environments (i.e. 5°C). The second hypothesis was to develop a novel accelerated method to simulate and investigate the durability of cement-based mortars under physical sulfate attack. The sole temperature-controlled mirabilite (Na_2SO_4-$10H_2O$) phase transitions inside the pore system of fully saturated mortars was found to be a proper method for initiating an accelerated physical sulfate attack (i.e. damage in less than 1 month). Furthermore, assessing the strain of the mortars under the designed physical sulfate attack was indicated to be a suitable criterion for following the progress of the damage. While Portland cement mortars with water/cement (W/C) of 0.5 and 0.4 collapsed under the designed physical sulfate attack, Portland cement mortars with W/C of 0.35 and limestone calcined clay mortars with W/C of 0.5 were proved resistant due to their lower volume & narrower pores, respectively. In the third hypothesis, it was proved that the content of in-pore mirabilite of fully saturated red clay brick and sandstones under physical sulfate attack (experimentally measured via differential scanning calorimetry - DSC) could be well related with their P-wave velocity. Accordingly, a novel non-

destructive method employing DSC and ultrasonic pulse velocity was developed for assessing the content of in-pore mirabilite of porous building materials. In the fourth and final hypothesis, the random hierarchical capillary bundle (RHCB) model was improved. Different probability density functions of its random variable were taking into account. It was found that the improved RHCB model could well-simulate the gas permeability rise of Portland cement mortars under physical sulfate attack. The input data of the model was the pore structure properties of the mortars before and after the damage.