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主　論　文　の　要　旨

論文題目 Effect of elevated temperature on water uptake behavior in cement-based materials （セメント系材料の吸水挙動に及ぼす昇温の影響）

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論　文　内　容　の　要　旨

In this thesis, non-destructive techniques of (^{1}H-NMR relaxometry and X-ray computed radiography) were used to understand the behavior of water in cement-based materials.

During sorption, the microstructural evolutions of two different cement pastes (with water-to-cement ratios of 0.40 and 0.55) are studied via proton-nuclear-magnetic-resonance relaxometry. The water uptake test is performed for samples dried at 105 °C under three different temperatures of 20 °C, 40 °C, and 60 °C for the first twenty-six days of sorption. It is observed that the water went first to the larger pores before migrating to the finest ones. This behavior is accelerated with increasing temperature. The rate of water exchange between fine and large pores is estimated and found to increase with temperature for both studied mixtures. The activation energy corresponding to this water movement is calculated and found to be higher for the lowest water-to-cement ratio, owing its finer microstructure. Finally, the activation energy related to the local water transport in re-distribution from large pores to fine pores is calculated and found to be inferior to the experimental results, which can be explained by the dynamic microstructure not being considered in the classical theories.

X-ray computed radiography (X-ray CR) is used, which is a non-destructive technique for visualizing water movement and quantifies the depth of penetration and cumulative water absorbed in mortar specimen. This experimental and numerical study aims to evaluate the penetration depth of contaminated water in concrete structures involved in the Fukushima Daiichi power plant. The influence of mortar mixture on water absorption was investigated by varying the composition: mortar containing aggregates from river sand and crushed limestone sand was compared, and 15% of the cement in the mixture was substituted with fly ash. The effect of temperature in nuclear conditions is also significant; therefore, water uptake at temperatures of 20 °C and 60 °C was considered. Finally, pre-drying conditions were studied by drying the sample at two different conditions: at 105 °C and at 40% RH (relative humidity) and 20 °C. Water uptake was monitored using x-ray computed radiography in combination with mass measurements. In all cases, anomalous sorption, or a nonlinear relationship between penetration depth and the square root of exposure time was observed, with the sorption curves showing bimodal behavior. The aggregate type had no significant effect on the water uptake results. However, the samples containing fly ash clearly had lower water uptake rates, which can be explained by the differences in the calcium silicate hydrate (C-S-H) structures. With increasing temperature, the penetration was slightly accelerated at the beginning of the experiment, with the rate of penetration then decreasing rapidly. The densification of C-S-H at higher temperatures could contribute to this phenomenon. Microstructural rearrangements can also explain why the highest uptake rates occurred for samples that were exposed to severe drying conditions (105°C). The experimental results were consistent when the microstructural rearrangement was considered, further confirming these conclusions.