

Quantitative study and modelling of pozzolanic processes in lime-treated clayey materials for earthworks

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Sustainable development in earthworks for railway and road constructions is marked by an increasing need of re-using the natural materials directly encountered in the environment, though their macroscopic behaviour can be poor. In this context, lime stabilization is known to reduce the swelling of expansive soils and to improve their mechanical properties. A quantitative investigation and modelling of the long-term interactions between lime and the clay-type minerals of the soils is a key-step to optimize such earthwork treatment and management.

The effects of lime content (2–10 wt.%), duration (1–100 days) and temperature (20–50 °C) on the pozzolanic reactions were assessed from batch tests for two materials: a natural Ca-bentonite (montmorillonite, 80 wt.%, calcite, cristobalite and K-Feldspar) and a kaolin material (kaolinite, 85 wt.%, muscovite and quartz). The pozzolanic process was monitored over time by ²⁹Si solid state nuclear magnetic resonance, thermogravimetric analysis, X-ray diffraction, as well as chemical analysis of the batch solutions. Modelling was performed with the geochemical code CHESS considering thermodynamics and kinetics of the mineralogical transformations, cation exchange of clays, and aqueous chemistry. The kinetic rate laws were selected from the literature data on aluminosilicate dissolution and dependent on both pH and temperature (activation Arrhenius energy).

Modelling is globally in good agreement with experiment. Lime hydration occurs within a few hours, modifying the cation exchangeable population of the clay phases and increasing the pH of the batch solution. These alkaline conditions initiate the pozzolanic reactions in a second stage, which proceeds over several weeks. Bentonite reactivity is characterized by a relatively fast and total consumption of cristobalite and an exacerbated dissolution of montmorillonite. The higher the temperature, the faster the kinetics. The dissolution of the kaolin material is comparatively slower. Cement-type phases, essentially calcium silicate hydrate (C–S–H) and monocarboaluminate (C–A– \bar{C} –H), are formed consequently to the dissolution of the primary phases. Their stoichiometry and relative proportions evolve with time, the lime content and temperature. Application of the present pozzolanic model to more complex natural soils shows promising results.