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Lime treatment of an Italian pyroclastic soil: a multi-scale analysis for the correlation of mechanical and chemo-mineralogical effects.

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In recent years, the ever-growing need to minimize costs and environmental impact in the construction of major civil infrastructure has led to the development of a large amount of methods based on the reuse of local materials. In particular, one of the most diffused methods is represented by lime treatment, widely applied in earthwork field to achieve mechanical improvement of otherwise unsuitable fine grained soils. However, unlike fine grained soils, many other types of world-wide common natural soils still represent a geotechnical obstacle. Among these, pyroclastic soils are a typology widely spread in Central and Southern Italy that finds marginal applications in earthworks practice due to the intrinsic complexities in terms of nature, heterogeneity, microstructural features and unsaturated hydro-mechanical behaviour.
The need to overcome the described limitations motivates the focus of this work on the geotechnical characterization of pyroclastic deposits along with the increasing attention on the volume-scale and micro-scale features characterization and correlation.
The main goal of the present study is to highlight the effects of lime treatment on a zeolite rich pyroclastic soil, focusing on the relationship between macro and micro modifications induced by lime addition. Within this research, an extensive experimental work was developed on a zeolitic pyroclastic soil coming from Orvieto cliff (Vulsini volcanic district, Central Italy). The overall investigation was organized in three phases: the first phase was devoted to the thorough chemo-physical and mineralogical characterization of the raw soil; subsequently, conventional direct shear tests were performed on reconstituted specimens of both raw and lime treated soil (2% and 5% Ca(OH)2) at increasing curing times and stress levels; finally, a wide chemo-mineralogical investigation was carried out on the lime treated samples to gain a more complete knowledge of the reactions responsible for the mechanical improvements.
Direct shear tests on treated soil samples revealed a brittle and dilatant behaviour; both features are more evident with increasing lime content, curing time and stress levels. Mechanical and chemo-mineralogical observations were coupled to obtain a better comprehension of the treated soil system evolution.
During the chemo-mineralogical investigation phase, the ongoing system modifications at particle level were extremely stressed mixing soil and lime in the same weight proportions. This also led to a clear identification of the reaction products and kinetics through μX-Ray Fluorescence, X-Ray Diffraction, Thermogravimetry, Fourier Transformed Infra-Red and 29Si Nuclear Magnetic Resonance spectroscopy.
The performed multi-scale analysis of the treated pyroclastic soil revealed the high reactivity of the system to lime addition, and the occurrence of pozzolanic reactions since the very beginning. The availability of secondary phases, in both crystalline and gel-like state, and their structural features are the main responsible for the observed mechanical behavior of the treated soil, showing the effectiveness of the treatment and the key role of zeolites in the chemo-physical evolution of the system. The obtained results, validated and supported by a deep comprehension of the micro-scale processes induced by lime treatment might open new perspective for future fruitful applications of pyroclastic problematic soils.