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Multiscale analysis on the behaviour of a lime treated bentonite

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Abstract

An insight into the microstructural evolution of clay-lime-water systems and its influence on the hydro-mechanical behaviour of treated bentonite has been presented. The time-dependent mineralogical and microstructural changes induced by lime addition on a natural bentonite have been investigated in order to provide a better understanding of the kinetic of the ongoing reactions. The effects of lime addition on the clay particle arrangements have been inferred from dynamic light scattering measurements, whereas the mineralogical changes have been monitored at increasing curing time by X-Ray diffraction and thermogravimetric analysis. The bentonite showed a high initial reactivity characterized by a rapid and total consumption of lime, which promoted the formation of new hydrated phases since the very short term (0 days of curing). Oedometer tests on not treated and lime stabilised saturated samples have been performed at increasing curing times. The results showed the combined effect of clay particles arrangement and bonding on the mechanical behaviour of treated samples.

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Keywords: Lime treatment; microstructure; pozzolanic reactions; hydro-mechanical behaviour

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1. Introduction

The addition of lime to a clayey soils has a strong impact on the geotechnical properties of the soils as results of

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the chemical reactions which take place after the treatment. In the short-term, the exchange of surface cation by calcium leads to flocculation of clay particles. In addition, the high alkaline environment induced by lime promotes the dissolution of siliceous and aluminous compounds from clay mineral lattice with the precipitation of secondary phases as a result of the development of the time-dependent pozzolanic reactions [1-5]. In order to provide a better understanding of the link between the ongoing of the reactions induced by lime and the macroscopic evolution of soil properties, a multi-scale investigation on the short and long term effects of a lime treated bentonite has been performed.

The effects of lime addition on the mineralogical changes have been monitored at increasing curing time by X-Ray diffraction and thermogravimetric analysis, whereas the clay particle arrangements have been inferred from dynamic light scattering measurements. The experimental evidences at particle level have been complemented by investigations at macroscopic level. The compressibility of not treated and lime stabilised samples have been investigated as a function of lime content and curing time by means of 1D compression tests.

2. Materials

Natural bentonite clay mainly composed of Ca-montmorillonite was supplied by SSB Srl, Sardinia, Italy. The specific gravity is Gs = 2.54, and surface area determined by nitrogen adsorption (BET) is 99.38 m^2/g. The pH value of the soil is about 7.55. The liquid and plastic limits are respectively 143% and 69%, with a plasticity index IP equal to 74%. The soil is mainly formed by Ca-montmorillonite, with minor amount of quartz and calcite. The chemical composition of bentonite is reported in Table 1.

Table 1. Chemical composition of bentonite

Constituent	Percentage (%)
SiO_2	64.85
Al_2O_3	24.33
CaO	2.14
K_2O	0.21
MgO	3.18
FeO	4.21

3. Experimental procedures

3.1. X-Ray diffraction analysis (XRD)

X-Ray diffraction analyses have been carried out on not treated and 3%CaO treated samples at increasing curing times, namely 0, 3, 7, 14, 28, 60, 90, 120 days. Samples were freeze-dried before testing [6]. XRD patterns were performed on randomly oriented powder using a Brucker AXS D8 Advance Diffractometer with CuKα (λ=0.154 nm) radiation and a step size of 0.021 degrees.

3.2. Thermo-gravimetric analysis (TGA)

The mineralogical changes induced by lime addition have been studied by means of thermo-gravimetric analysis (TGA). This technique provides a measure of the mass loss of the sample under a controlled atmosphere as a function of increasing temperature at constant heating rate. The change in mass is determined by the dehydration or decomposition of a mineralogical phase.

Thermo-gravimetric analyses were performed on not treated and 3% CaO and 5% CaO treated samples at increasing curing times using a Netzsch STA 449F3 Jupiter apparatus. Samples were first dried by freeze-drying technique. Approximately 100 mg of finely grounded material was subsequently heated at a rate of 10°C min^{-1}, under argon atmosphere, from ambient temperature to 1000°C. The Netzsch Proteus software was used to process the results.