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Control factors for the long term compressive strength of lime treated sandy clay soil

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ABSTRACT

This study aims to quantify the effect of curing time, lime content, dry unit weight, and compaction water content on the strength of a lime treated sandy clay, as well as to evaluate the use of the porosity/lime ratio to assess its unconfined compressive strength. The results showed that compressive strength increased with increasing lime content, decreasing porosity, and increasing curing time. It was shown that the porosity/lime ratio is a good parameter for the evaluation of unconfined compressive strength and a unique relationship was achieved linking unconfined compressive strength with both porosity/lime ratio and curing time.

Introduction

The improved characteristics of compacted lime treated soils may be very important to some geotechnical engineering applications such as canal lining, pavement structures, and engineered fills. Recent studies by Chittoori et al. (2012) clearly demonstrated the environmental and cost benefits of using an excavated material treated with lime rather than an imported material. Pedarla et al. (2011) studied the long-term engineering performance of treated soils exposed to wetting and drying cycles and measuring both the volume change and the unconfined compressive strength during at select wetting and drying cycles. Chittoori et al. (2013, 2014) studied soil strength and volumetric strain variations of chemically stabilized soils after several leaching cycles.

Several methodologies were established in the past decades (e.g. Hilt and Davidson, 1960; Eades and Grim, 1966; Rogers et al., 1997) in order to determine the appropriate amount of lime required to modify soil characteristics and introduce adequate strength and durability. Such methodologies usually intend to establish a threshold value, supposed to chemically satisfy the soil demand for lime, which has been often suggested as the starting content to adopt for construction expediency purposes. In spite of the numerous applications, there are no mix design methodologies for the assessment of a given target strength of lime treated soils, based on rational criteria as available in the case of concrete technology, where the water/cement ratio plays a fundamental role. The need for such methodologies results from the fact that compacted lime treated soils show a complex behavior that is affected by multiple factors, such as the physical–chemical properties of the soil, porosity, lime content, compaction

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Notation

Basic SI units are given in parentheses

L	lime content (expressed in relation to mass of dry soil)
L_v	volumetric lime content (expressed in relation to the total specimen volume)
D_{50}	mean particle diameter
q_u	unconfined compressive strength
γ_d	dry unit weight
n	initial porosity
n/L_v	porosity/lime ratio
w	water content

water content, and curing time (e.g. Mitchell, 1981; Transportation Research Board, 1987; Brown, 1996; Consoli et al., 2001, 2008, 2014; Ghosh, 2010; Tang et al., 2011; Verbrugge et al., 2011; Dash and Hussein, 2012).

The present study aimed at quantifying the influence of the curing period, the amount of lime and the porosity on the unconfined compressive strength of a lime treated sandy clay, as well as searching for a unique relationship linking the unconfined compressive strength (q_u) with both porosity/lime (n/L_v) and curing period. Such direct relationship was showed to exist and differ only by a scalar regarding the effect of curing time.

Experimental program

The experimental program was carried out in three parts. First, the soil and lime were characterized. Next, the minimum amount of lime required for stabilization, based on the modified Initial Consumption of Lime (ICL) (Rogers et al., 1997) was established. Then a number of unconfined compression tests and measurements of matric suction were carried out as discussed below.

Materials

The soil used in the present study, derived from weathered Botucatu sandstone, was obtained from the region of Porto Alegre, in southern Brazil. The results of the soil characterization tests are shown in Table 1. The soil is classified as low plasticity sandy clay (CL) according to the Unified Soil Classification System. X-ray diffraction showed that the fine portion is predominantly kaolinite.

Dry hydrated lime [$Ca(OH)_2$] was used as cementing agent. The specific gravity of the lime is 2.49.

Table 1
Physical properties of the soil sample.

Properties	Values
Liquid limit	24%
Plastic limit	15%
Plasticity index	9%
Specific gravity	2.81
Medium sand (0.2 < Diameter < 0.6 mm)	12.6%
Fine sand (0.06 < Diameter < 0.2 mm)	41.1%
Silt (0.002 < Diameter < 0.06 mm)	42.0%
Clay (Diameter ⩽ 0.002 mm)	4.3%
Mean diameter (D_{50})	0.07 mm
Uniformity coefficient (C_u)	33

For the characterization tests, distilled water was used, but for molding the specimens for the compression tests, tap water was used instead.

Modified initial consumption of lime

The minimum amount of lime required for the sandy clay stabilization, based on the modified Initial Consumption of Lime (ICL) (Rogers et al., 1997), was established from the interpretation of pH measurements performed on several sandy clay soil–lime–water mixtures (solids–water proportion of 1:3). By using the modified asymptotic ICL interpretation, it was concluded that 3% was the minimum lime content for the sandy clay stabilization.

Methods

Molding and curing of specimens

For the unconfined compression tests, cylindrical specimens, 50 mm in diameter and 100 mm high, were used. After weighing, the dry components (soil and lime) were mixed until the mixture acquired a uniform consistency. The water was then added until a homogeneous paste was obtained. The amount of lime for each specimen was calculated based on the mass of dry soil and the target water content.

After preparing sufficient material for molding one specimen, two small portions were taken for water content determination and the mixture stored in a covered container to avoid moisture loss before subsequent compaction. The time it took to prepare (mix and compact) each specimen was always less than 1 h.

The specimens were then statically compacted in three layers (each layer had controlled its height – 1/3 of the specimen per layer) into a lubricated 50 mm diameter by 100 mm high split mold, so that each layer reached the specified dry unit weight. After molding, the specimens were immediately extracted from the split mold, weighed and measured with accuracies of 0.01 g and 0.1 mm, respectively. The tolerances adopted for accepting specimens were the following: dry unit weight (γ_d) within ±1% of the target value; water content (ω) within ±0.5%; diameter within ±0.5 mm; and height within ±1 mm. Finally, the specimens were stored and cured, within plastic bags to avoid significant water content variations, in a humid room at 23 ± 2 °C and relative humidity higher than 95%. The authors have not observed any long term volume changes during the curing period.