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Behavior of Soil–Fly Ash–Lime Blends Under Different Curing Temperatures

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Abstract

Compaction of layers of soil–fly ash–lime blends is often used to improve soil conditions for infrastructure projects. Such understanding is the starting point to develop more rational dosages that allow for a more efficient use of resources. To achieve this objective the present research aims to quantify the influence of curing temperature (T), amount of lime (L), porosity (η), and porosity/lime ratio (η/L_{iv}) on the assessment of splitting tensile strength (q_t) and unconfined compressive strength (q_u) of sand–coal fly ash–lime blends. A series of splitting tensile and unconfined compression tests were carried out in the present work. The results show a linear function fits well the relation between q_t and qu with L, and a power function fits well as the relation between q_t and q_u with η for all curing temperatures of the specimens. It was also shown that the porosity/lime ratio (η/L_{iv}) is a good parameter in the evaluation of q_t and q_u of the studied blends for the whole range of lime, porosities and temperature studied, at specific amount of coal fly ash (25%) and curing time period (28 days). The volumetric cementitious material content (L_{iv}) is adjusted by an exponent (0.30 for all curing temperatures blends) to end in unique correlations for each temperature. For the sand, coal fly ash, lime, curing time period and curing temperatures, a unique relationship was achieved linking q_t as well q_u to η; L_{iv} and T. For a given curing time period (28 days), the relations q_t-η/L_{iv} and q_u-η/L_{iv} versus T are shown to vary linearly up to a threshold, when asymptotes occur. Finally, the relation between q_t/q_u is a constant and equal to 0.19 for the whole range of L, η and T studied.

Keywords: Temperature, porosity, lime, splitting tensile strength, unconfined compressive strength

1 Introduction

Improvement of local soils is usually necessary to meet the mechanical requirements of infrastructure projects such as foundations and subgrades of roads. Soil–fly ash–lime blends are often used for such improvement particularly as compacted layers over low bearing capacity soils (Thomé et

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al. 2005, Consoli et al. 2008) and as pavement layers (Cetin et al.2010). Although there are no dosage methodologies based on rational criteria considering the effect of different variables (e.g., amount of lime, porosity) and the effect of local climate (e.g., temperature).The first rational dosage methodology for soil-fly ash-lime was developed by Consoli et al. (2011a) considering the porosity/lime ratio (η/L_{iv}), defined by the porosity of the compacted mixture divided by the volumetric lime content, as an appropriate parameter to evaluate the unconfined compressive strength (q_u) of soil-fly ash-lime mixtures. On the other hand, even though it is already recognized by previous studies (e.g., Rojas and Cabrera 2001, 2002; Consoli et al. 2001; Al-Mukhtar et al. 2010a, b) that strength of soil-fly ash-lime mixes (based on pozzolanic reactions) is dependent on temperature (T), which acts as a catalyzer of pozzolanic reactions. It is still unknown if the effect of curing temperature should be inserted in a rational methodology. So, this study aims at approaching this issue by quantifying the influence of T, L, η and adjusted η/L_{iv} on q_t, q_u and q_t/q_u of a sand-fly ash-lime blend.

2 Experimental Program

The experimental program was carried out in three parts: geotechnical characterization, splitting tensile tests and unconfined compression tests.

2.1 Materials

The soil used in this study was rounded wind transported sand (named Osorio sand). The sample was collected in a disturbed state, by manual excavation. The results of the characterization tests are shown in Table 1. This soil is classified as uniform fine sand (SP) according to the Unified Soil Classification System.

The fly ash (FA) selected [type F according to ASTM C 618] was a residue of burning coal in a thermal power station, located near Porto Alegre. The main characteristic of Class F fly ash is the amount of calcium oxide (CaO) in the ash, which is typically less than 12% (in the present case CaO percentage is 0.8%). The results of the FA characterization tests are presented in Table 1. The FA is classified sandy silt (ML) according to the Unified Soil Classification System. A chemical analysis has shown that the fly ash is 65.2% SiO_2, 23.3% Al_2O_3 and 6.1% Fe_2O_3. X-ray diffraction showed that the material is composed predominantly by amorphous minerals. Insertion of fly ash in the mixture increases availability of alumina and silica from amorphous minerals (which promptly solubilize under high pH due to lime addition), growing reactions with lime and consequently increasing strength. Dry hydrated lime [$Ca(OH)_2$] was used throughout the whole study. The specific gravity of the lime grains is 2.49. Distilled water was used both for molding specimens for the tensile tests and for the characterization tests.

PROPERTIES	Osorio sand	Fly Ash
Specific Gravity	2.63	2.28
Medium Sand (0.2 mm < diameter < 0.6 mm)	-	1.00%
Fine Sand (0.06 mm < diameter < 0.2 mm)	100.00%	13.60%
Silt (0.002 mm < diameter < 0.06 mm)	-	84.90%
Clay (diameter < 0.002 mm)	-	0.50%
Effective Diameter (D50)	0.16 mm	0.018 mm

Table 1- Physical properties of Osorio sand and coal fly ash samples