ARTICLE IN PRESS

Journal of King Saud University – Engineering Sciences (2016) xxx, xxx–xxx

King Saud University

Journal of King Saud University – Engineering Sciences

www.ksu.edu.sa
www.sciencedirect.com

ORIGINAL ARTICLES

Effect of curing time on strength development in black cotton soil – Quarry fines composite stabilized with cement kiln dust (CKD)

A.A. Amadi [a,*], A.S. Osu [b]

[a] Department of Civil Engineering, Federal University of Technology, Minna, Nigeria
[b] Department of Civil Engineering, Federal Polytechnic, Nasarawa, Nigeria

Received 4 December 2015; accepted 4 April 2016

KEYWORDS

Cement kiln dust;
Compaction;
Curing time;
Quarry fines;
Unconfined compressive strength

Abstract Combined treatment techniques have been adopted by many pavement designers and site engineers to improve the strength and stability of subgrades or foundation soils of expansive sites. In this regard, research was conducted to investigate the effect of curing time on strength development of black cotton soil (BC soil) stabilized with 10% quarry fines (QF) and varying percentages (0–16%) of cement kiln dust (CKD). Preliminary tests such as Atterberg limits, compaction parameter test together with a series of unconfined compression tests were conducted on soil mixtures. Specimens for unconfined compression tests were prepared at their respective optimum moistures, compacted using British standard light (BSL) compaction effort and tested at curing times of 7, 14, 21 and 28 days. Data from the study revealed that the curing duration exerted a significant influence on the stress–strain behavior of soil mixtures together with the strain at failure which decreased by about 30–50% as the curing time increased. Unconfined compressive strength data showed improved strength values ranging from 1.25 to 5.25 times higher than the value for specimens tested immediately after preparation. Data developed in this study are expected to be useful to pavement designers and site engineers in the field implementation of the stabilization scheme such as when to open the stabilized layer to construction traffic or when to proceed with further construction works.

1. Introduction

Black cotton soils (BC soils) are inorganic clays characterized by very low bearing capacity, high compressibility, low permeability and high volume change under changing moisture conditions. They tend to lose strength further upon wetting and other physical disturbances. These soils are especially troublesome as pavement sub-grades and unsuitable for construction of embankments, buildings or other load bearing engineering

* Corresponding author. Tel.: +234 8034516603.
E-mail addresses: agapitus.amadi@futminna.edu.ng, agapitusahamefule4@yahoo.com (A.A. Amadi).
Peer review under responsibility of King Saud University.

Production and hosting by Elsevier

http://dx.doi.org/10.1016/j.jksues.2016.04.001
1018-3639 © 2016 Production and hosting by Elsevier B.V. on behalf of King Saud University.

structures in their natural state (Arora, 2009; Murthy, 2009; Nelson and Miller, 1992; Amadi et al., 2013a).

In Nigeria, BC soils form a major soil group in the north – eastern region (Ola, 1983; Osinubi, 2000a; Ijimdiya et al., 2009; Oriola and Moses, 2011) where their presence accounts for the high incidence and frequency of road pavement failures and instability to lightly loaded engineering structures (Ola, 1983; Amadi et al., 2013b). Specifically, the BC soils of north-eastern Nigeria derive their origin from basalts of the upper Benue trough and quaternary sediments of lacustrine origin from the Chad basin consisting mainly of shales and clay sediments. The clay mineralogy of BC soil in this area is dominated by montmorillonite with a low percentage of kaolinite and/or illite minerals with the resultant manifestation of expansive tendencies (NBRRI, 1983; Ola, 1983; Osinubi and Medubi, 1997).

Experience of damages and continued failures of structures and pavements built on sites dominated by BC soils have given rise to intensive research to find ways of improving the strength of BC soils (Ola, 1983; Osinubi, 1998, 1999, 2000a; Osinubi et al., 2009; Eberemu et al., 2011; Amadi, 2014). The common practice is to use chemical additives to stabilize the soils before they are built upon. Cement kiln dust (CKD), an industrial waste from cement production similar in appearance to Portland cement is finding application in the stabilization of soils. Records from the literature show that CKD is an effective stabilizer in the improvement of the strength properties of fine grained soils (Peethamparan and Olek, 2008; Oriola and Moses, 2011; Amadi and Eberemu, 2012). Evidence of improvement has been found particularly on specimens cured over a period of time. In general, the longer the curing period, the better is the strength development, due to the pozzolanic reaction (Kezdi, 1979). Nelson and Miller (1992) suggested that curing periods should extend to at least 28 days in order to provide idealized conditions for the cementitious and pozzolanic reactions.

The pozzolanic reaction occurs once the pore chemistry in the soil system achieves a sufficiently alkaline condition. The resulting alkalinity of the pore water promotes dissolution of silica and alumina from the clays, which then react with the Ca^{2+} ions, forming calcium silicate hydrate (CSH) and calcium aluminate hydrate (CAH). These compounds crystallize and harden with time, thereby enhancing the strength of the soil mixtures.

For problematic soils such as BC soil, a single additive may not result in maximum improvement in the required properties of the soils (Amadi et al., 2013a; Amadi, 2014; Osinubi, 2000b; Osinubi et al., 2009; Eberemu et al., 2011; Ijimdiya et al., 2009). Consequently, incorporation of quarry fines which recently has become useful in improving the geotechnical properties of deficient soils such as the grading curve with consequent enhancement in the strength, compaction characteristics, reduction in the plasticity and swell characteristics was considered (Soosan et al., 2005; Amadi, 2011, 2014; Eze-Uzoamaka and Osondu, 2010). Combining the two treatment techniques has the potential to provide an improved strength and stability of subgrade soils or foundation soils thereby presenting a sustainable and cost effective solution to the engineering problems associated with this soil.

The present study however focussed on improvement in the stress strain and strength behavior under unconfined compression strength of the stabilized soil as a function of time. Knowledge of how the strength varies with time can provide a basis for field curing requirements for projects located in areas with these unsuitable soils. This guides the site engineer on when to open the stabilized layer to construction traffic or other construction activities.

2. Materials and methods

2.1. Soil

The BC soil used in this study is greyish black in color, obtained from Damsa Local Government Area of Adamawa State, Nigeria. Samples were collected by open excavation from a trench with the following dimensions: 1.5 × 1.5 × 1 m.

2.2. Cement kiln dust (CKD)

The cement kiln dust (CKD) used was obtained from freshly deposited heaps of the by – product at the Benue Cement Factory located in Gboko, Nigeria and stored in – air tight bags.

2.3. Quarry fines (QF)

The QF used for the study was obtained in Abuja, Nigeria. It was sieved through British Standard No. 4 (4.75 mm) sieve and stored before usage.

2.4. Testing methods

The laboratory tests conducted on the natural soil sample and soil mixtures include: particle size distribution, Atterberg limits, specific gravity, compaction, and unconfined compressive test (UCT). For the UCT, specimens were compacted using the British standard light (BSL) compaction effort adopting curing periods of 7, 14, 21 and 28 days. All tests were carried out in accordance with the specifications contained in BS 1377 (1990) and BS 1924 (1990).

2.4.1. Preparation and testing of specimens

Part of the air dried soil samples were pulverized to pass through British Standard No. 4 (4.75 mm) for compaction and strength tests while samples for Atterberg limit tests were passed through BS No. 40 (425 μm). The air dried and pulverized soil was first mixed with 10% quarry fines prior to mixing with varying percentages of 0%, 4%, 8%, 12% and 16% of cement kiln dust on dry weight basis. Laboratory tests listed above were conducted on thoroughly blended mixes after hydrating with water in the required quantity depending on the test.

2.4.2. Unconfined compression testing (UCT)

UCT samples were prepared at the optimum moisture contents determined from the compaction curves. The prepared UCT samples were sealed in a plastic bag to cure in the humidity room where the temperature was maintained at 20 ± 2 °C for 7, 14, 21 and 28 days before conducting the test. Unconfined compression tests were conducted on a strain-controlled triaxial testing frame at a strain rate of 1%/min without application of the cell pressure (σ_3 = zero). The