Measurement 91 (2016) 46–54

Contents lists available at ScienceDirect

Measurement

journal homepage: www.elsevier.com/locate/measurement

Strength measurement and textural characteristics of tropical residual soil stabilised with liquid polymer

Nima Latifi [a,*], Ahmad Safuan A. Rashid [b], Sumi Siddiqua [c], Muhd. Zaimi Abd Majid [a]

[a] Institute for Smart Infrastructure and Innovative Construction (ISIIC), Faculty of Civil Engineering, Universiti Teknologi Malaysia, 81310 UTM Skudai, Johor, Malaysia
[b] Geotechnic & Transportation Department, Faculty of Civil Engineering, Universiti Teknologi Malaysia, 81310 UTM Skudai, Johor, Malaysia
[c] School of Engineering, The University of British Columbia, Okanagan Campus, Kelowna, BC, Canada

ARTICLE INFO

Article history:
Received 23 November 2014
Received in revised form 31 January 2016
Accepted 10 May 2016
Available online 10 May 2016

Keywords:
Laterite soil
Liquid polymer
N_2-BET surface area
Texture
UCS
Plasticity index

ABSTRACT

The stabilisation of soils with additives is a chemical process that can be used to improve soils that contain weak engineering properties. The effects of non-traditional additives on the geotechnical properties of soils have been the focus of much investigation in recent years. It has been well established that the plasticity index and also the size, shape, and arrangement of soil particles will affect the treatment process of natural soils with additives. In this study, a commercial liquid polymer (SS299) was used to improve the strength of Malaysian residual soil. Unconfined compressive strength (UCS), field emission scanning electron microscopy (FESEM), N_2-BET surface area, and particle size analysis tests were used to investigate the influence of SS299 and the plasticity index on the time-dependent compressive strength and textural characteristics of tropical residual soil. The UCS results showed that the addition of 6% (as the optimum amount) of the selected additive increased the compressive strength of laterite soil noticeably, after 7 days of curing period. In addition, the increased compressive strength of the treated samples with the curing time was evident. Based on the FESEM results, it was found that the stabilisation process modified the porous network of the laterite soil. Furthermore, new white layers of reaction products were formed on the surface of clay particles.

1. Introduction

Soil improvement is the process of improving the physical and engineering properties of soil to obtain some predetermined values. It can be done in various ways such as mechanical, biological, physical, chemical and electrical [1–4]. Nowadays, using chemical additives for soil stabilisation is becoming more popular. The aims of soil treatment using chemical stabilisers are to improve stress–strain and strength properties, control of volume stability, hydraulic durability and conductivity [5–12].

A stabiliser is a chemical compound that immediately or gradually enhances the soil's engineering properties through a number of mechanisms. There are two general groups that exist as soil stabilisers: traditional stabilisers and non-traditional additives [13]. Traditional stabilisers include cement, lime, fly ash, and bituminous materials; non-traditional additives consist of various combinations such as enzymes, liquid polymers, resins, acids, silicates, ions, and lignin derivatives [14–19]. It should be noted that the exact chemical compositions of non-traditional additives are not disclosed due to the proprietary nature of commercial stabilisation additives. In addition, it is well established that the majority of these products contain secondary additives such as catalysts, surfactants and ultraviolet inhibitors. There is generally a dominant or primary stabilisation mechanism supported by secondary mechanisms due to the insertion of complementary additives [20–22].

Currently, non-calcium-based liquid soil additives are actively marketed by a number of companies. Besides being cheaper to transport compared to traditional bulk stabiliser materials, these products are a potentially attractive alternative for soil treatment. They are mostly sold as concentrated liquids, which are diluted with water at the site. Some are directly applied to the soil before compaction while others are pressure injected into deeper layers. It should be stressed that the results of previous studies have indicated that non-traditional liquid additives can help to increase soil strength with curing time [23–30].

On the other hand, each type of chemical additive has different mechanisms and influences on soil properties. For instance, there have been noticeable important dissimilarities in the stabilisation mechanism of tropical soils from the moderate climates. Rock weathering in tropical areas is very rigorous and is characterised by the speedy disintegration of feldspars and ferromagnesian, the

* Corresponding author.
E-mail address: En_Latifi@yahoo.com (N. Latifi).

http://dx.doi.org/10.1016/j.measurement.2016.05.029
0263-2241/

displacement of silica and bases (Na_2O, K_2O, MgO), and the absorption of iron and aluminium oxides [31]. This process is referred to as laterisation and includes leakage of SiO_2 and deposition of Fe_2O_3 and Al_2O_3 [30]. Generally, laterite soils are highly weathered reddish tropical soils that have concentrated oxides of iron and aluminium with kaolinite, the predominant clay mineral [18].

Laterite soil can be found in six areas around the globe: Africa, India, Southeast Asia, Australia, Central America and South America. However, there is an emphasis that due to the movements of climatic zones in the geological past, relevant regions of laterite can be located in places that are not within the tropics [32,33]. This soil group usually exists at hillsides and offers brilliant borrow areas for wide adoption in many different construction operations. Optimum utilisation is determined by the quantity of issues encountered in construction connected to their workability, field compaction, and strength.

Studies have demonstrated that laterite soil forms a large part of the soil in Malaysia, and it has been used in different areas and projects as natural soil [34,35]. This study investigates the influence of a new non-traditional additive (SS299) – a cationic and alkaline polymer, the plasticity index, and curing time on the compressive strength and textural properties of tropical residual soil. Laboratory tests that were performed included sieve analysis, Atterberg limits, standard compaction, and unconfined compression strength (UCS) tests. Paired micro-characterisation was also used to study the structure and fabric of the soil-additive matrix using field emission scanning electron microscopy (FESEM), Brunauer, Emmett and Teller (BET) surface area and particle size analysis (PSA) tests.

2. Materials and methods

2.1. Materials

Residual laterite soil was chosen for this research as it is not only abundantly available but also used in many geotechnical engineering works in Malaysia. Laterite soil was obtained from a depth of 2–3 m below the ground surface. The particle size distribution and engineering properties of natural laterite soil are shown in Fig. 1 and Table 1, respectively. In addition, Table 2 presents the chemical characteristics of the used laterite soil in this study, as a result of the energy-dispersive X-ray spectrometry (EDAX) test. With reference to Table 2, the ratio of SiO_2 to Al_2O_3 yields a value of 0.81. The latter confirmed that the soil used in this study was residual laterite soil [36]. In addition, Fig. 2 illustrates the diffractogram resulted from the XRD analysis on the soil. The XRD result highlighted that the main minerals present in the soil were kaolinite ($2\theta = 12.5°, 20°, 35°, 38°, 46°, 55°$), quartz ($2\theta = 26°, 36.5°, 42.5°, 50°, 62°$), goethite ($2\theta = 21.5°, 37°, 41°, 53°$), and gibbsite ($2\theta = 18°, 19°, 27°, 39°$) [37]. Three different samples (referred to as soil A, soil B, and soil C) with different plasticity indexes were used in this experimental study. Soil A is the natural laterite soil, soil B is the same soil with the addition of 20% bentonite by weight, and Soil C is the same soil with the addition of 30% bentonite by weight. According to their properties, the soils lie below the A-line in the plasticity chart, thus classifying them as silty soils with different plasticity according to the Unified Soil Classification System (USCS). Additionally, the physicochemical properties of used bentonite are given in Table 3.

Table 1
Characteristics of the natural laterite soil.

Engineering and physical properties	Values
pH (L/S = 2.5)	5.35
Specific gravity	2.69
External surface area ($m^2\,g^{-1}$)	41.96
Liquid limit, LL (%)	75
Plastic limit, PL (%)	41
Plasticity index, PI (%)	34
BS classification	MH
Maximum dry density ($mg\,m^{-3}$)	1.31
Optimum moisture content (%)	34
Unconfined compressive strength (kPa)	270

Table 2
Oxides and chemical composition of laterite soil.

Chemical composition (oxides)	Values (%)
SiO_2	25.46
Al_2O_3	31.10
Fe_2O_3	35.53
CO_2	7.91

A cationic and alkaline polymer of a locally manufactured non-traditional additive, known as SS299, had been selected for this study. The additive had been prepared, sampled and sent to the laboratory by the manufacturer GKS PRO CHEM (M) Sdn. Bhd., a local company in the Johor state of Malaysia. The exact chemical composition of this additive has not been released, since it is a commercially registered brand. Table 4 shows the important physicochemical properties of this selected additive.

2.2. Sample preparation

The results of previous studies on laterite soils have revealed that the plasticity and compaction properties of this soil were changed significantly during the oven drying process [13]. Consequently, the present study has used the air-drying method

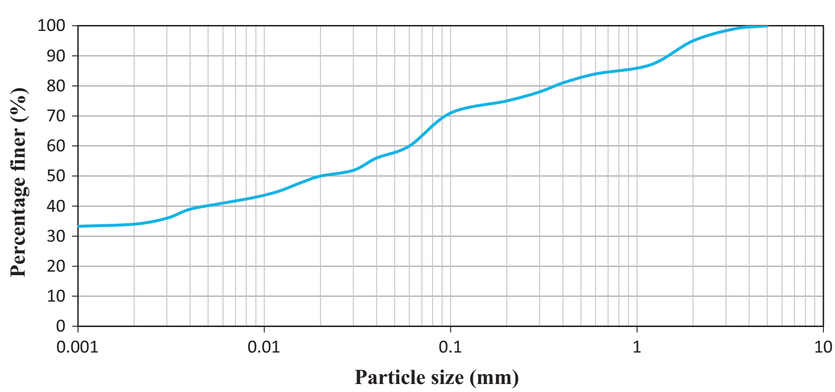

Fig. 1. Particle size distribution of laterite soil.