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Stabilization of clayey soil using lignosulfonate

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ABSTRACT

Many customary soil additives (e.g., cement, lime, fly ash and gypsum) are generally used to improve the mechanical properties of the soils. The applicability of most of these traditional stabilizers of soil is limited to particular soils. Moreover, traditionally stabilized soils in some cases exhibit high brittle behavior, which is oftentimes inappropriate for projects such as airport runways and embankments of railroads. This article presents the results of a research study in which an alternative stabilizer -Lignosulfonate (LS)- is investigated. Several basic properties of high plasticity clay, such as Atterberg limits, proctor compaction, unconfined compressive strength (UCS), effect of cyclic wetting/drying on the strength properties, stress-strain behavior and secant modulus of elasticity (E_{50}) are assessed. To clarify the strength development due to the LS-treatment, scanning electron microscopy is performed on LS-treated and untreated clay. The LS contents were 0.5, 0.75, 1, 2, 3 and 4% by weight of the dry soil and specimens were cured for 0, 4, 7, 14, and 28 days. Results show that the LS-treatment leads to a considerable reduction in plasticity index (PI) of the soil. Also, stabilization with LS has slightly increased the optimum water content and slightly decreased the maximum dry unit weight of the soil. This stabilization has increased the stiffness and UCS of the soil without leading to a considerable brittle behavior. The increase in strength properties is ascribed to the electrostatic reaction that occurs between the mixture of LS-water and soil particles.

Introduction

When the geotechnical engineering projects have to be built on soft and low shear strength weak soils, problems related to bearing capacity and settlement arise. Stabilization of soils is an economical and lasting method to achieve the desired geotechnical properties. Chemical stabilization of the soil is a popular and effective technique that enhance the workability and shear strength of soil. Cement, lime, gypsum, slag, alum and fly ash are examples of chemical additives that have been used effectively to improve the compressibility and strength characteristics of soil. In literature, numerous researches have been conducted on the mechanical properties of treated soil with traditional admixtures [25,24,11,10,28,20,33,21,27]. However, the use of this chemical stabilizers may cause damage to the environment, limits the growth of plants and alters groundwater quality [15,2]. In addition, soil stabilization with traditional stabilizers could cause a very brittle behavior in the soil and this affect the seismic stability of geotechnical projects [15]. To show the effect of traditional admixtures on the brittleness of the soils, the results of some studies that have been conducted to investigate the effects of chemical stabilization (gypsum and cement) on the mechanical properties of the soil including peak/residual strength, stiffness and brittleness are summarized in Table 1 [19,26,35,17,1]. As can be seen from Table 1, most of the soils have become highly brittle after being stabilized with traditional admixtures.

Nowadays, an industrial by-product (Lignosulfonate) as a preferable soil stabilizer increasingly used [15,16,2,32,37,23,22,13,14]. This lignin-based chemical, lignosulfonate (LS) lead to increase strength and durability of the soil. Additionally, its use does not harm the environment [15]. Annually more than 50 million tons of this agent is produced over the world [39]. Since LSs are byproducts of other processes, they are relatively cheap and can compete on a cost basis with any other stabilizers. Moreover, in comparison with usual chemical admixtures, LS is non-toxic, and soil stabilization with this agent does not increase brittleness of the host soil [23]. Vinod et al. [38] conducted a series of micro-chemical analysis on the LS-treated soil. Their results revealed that the betterment of performance showed by the

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Table 1
Summary of the effect of cement and gypsum stabilization on the behavior of soils reported in recent literature.

Stabilizer	Test condition	With increase the amount of stabilizer				Reference
		Peak strength	Stiffness	Residual strength	Brittleness	
Gypsum	Consolidated, drained, at dry condition	Increases	Increases	Higher for treated soil	Increases	Haeri et al. [19]
Gypsum	Saturated, consolidated, drained triaxial tests	Increases at higher level of cementation	–	Not affected	Higher for higher cementation level	Lee et al. [26]
Cement	At MDD[a] and OMC[b], 7 days cured, Saturated, drained triaxial tests	Increases	Increases	Not affected	Increases (become highly brittle)	Schnaid et al. [35]
Cement	At MDD and OMC, 7 days cured, Saturated, drained triaxial tests	Dramatically increased	Dramatically increased	Not affected	Strongly brittle	Consoli et al. [17]
Cement	Compacted, dry triaxial tests	Increases	Increases	-	Increases (become highly brittle)	Abdulla and Kiousis [1]

[a] MDD: Maximum dry density.
[b] OMC: Optimum moisture content.

LS-stabilized soil could be ascribed to the decline of the double layer thickness by the neutralization of surface charges of the soil particles and the following facilitation of a steady grain cluster. Alazigha et al. [2] to investigate the possible impressiveness of LS in treating a remoulded expansive clay carried out a series of swelling and durability tests. They found that the optimum LS content for making more appropriate improvement on the swelling percent is 2% of the soil dry weight.

Most of the past studies conducted on the LS treated soil, have mainly focused on the sandy silt, silty clay, low plasticity clay (CL) [15,16,32,37,13,14]. Few studies have been performed on high plasticity clay [2]. Moreover, no study has been carried out to investigate the shear strength behavior of LS-stabilized high plasticity clays (CH). The main purpose of this research, was to evaluate the influence of various dosages of LS on the compaction properties and unconfined compression strength (UCS) of the high plasticity clay. Also, the effect of moisture content, aging and wetting and drying cycles on the strength properties of LS-treated and untreated high plasticity clay was investigated. In addition, findings of this study were complemented with the microstructural analysis of the host soil before and after stabilization using scanning electron microscope (SEM).

Experimental investigation

Materials

Clay (CH)

The clay samples were collected from the suburbs of the Amol city, Iran. Fig. 1 shows the grain size distribution of the studied clay that was determined using sieve analysis and hydrometer test according to ASTM D 422 [5].

Based on the Atterberg limits tests results that were conducted using ASTM D 4318 [6] test method, the liquid and plastic limits were approximately 55% and 26%, respectively. This soil was marked as high plasticity clay (CH) according to ASTM D 2487 [4]. The result of compaction test that was performed in accordance with ASTM D 698 [7] revealed that the optimum water content and the maximum dry unit weight of the soil were equal to 21.25% and 16.3 kN/m^3, respectively. Also the specific gravity was 2.70 that was determined with the aid of ASTM D 854 [8].

Lignosulfonate (LS)

Lignosulfonates are made from the waste liquor byproducts of the wood processing industries (such as paper mills). LS is a

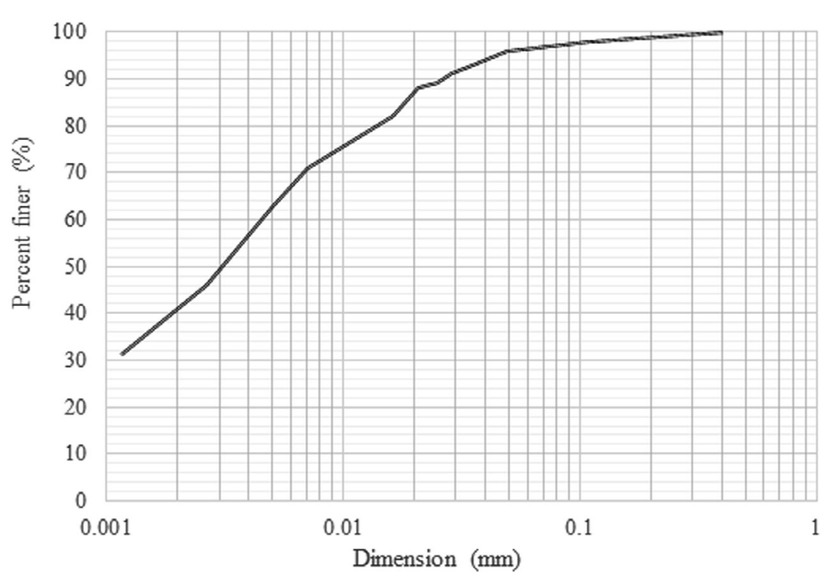

Fig. 1. Gradation of studied clay.