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Effect of adding natural pozzolana on geotechnical properties of lime-stabilized clayey soil

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ABSTRACT

Clayey soils in Syria cover a total area of more than 20,000 km^2 of the country, most of which are located in the southwestern region. In many places of the country, the clayey soils caused severe damage to infrastructures. Extensive studies have been carried out on the stabilization of clayey soils using lime. Syria is rich in both lime and natural pozzolana. However, few works have been conducted to investigate the influence of adding natural pozzolana on the geotechnical properties of lime-treated clayey soils. The aim of this paper is to understand the effect of adding natural pozzolana on some geotechnical properties of lime-stabilized clayey soils. Natural pozzolana and lime are added to soil within the range of 0%–20% and 0%–8%, respectively. Consistency, compaction, California bearing ratio (CBR) and linear shrinkage properties are particularly investigated. The test results show that the investigated properties of lime-treated clayey soils can be considerably enhanced when the natural pozzolana is added as a stabilizing agent. Analysis results of scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDX) show significant changes in the microstructure of the treated clayey soil. A better flocculation of clayey particles and further formation of cementing materials in the natural pozzolana-lime-treated clayey soil are clearly observed.

1. Introduction

Clayey soils usually have the potential to demonstrate undesirable geotechnical properties, such as low bearing capacity, high compressibility, shrinkage and swell characteristics and high moisture susceptibility (Sakr et al., 2009). Several methods have been adopted to improve the geotechnical properties of such soils so that the stability and serviceability requirements can be met. Among these methods, stabilization of the clayey soils using different additives can basically be considered, because the replacement of the unsuitable soil with good quality soils becomes more and more uneconomical and non-ecological practice. In addition, cement stabilization is nowadays not preferable because of the increasing cost of cement and the environmental concerns related to its production.

Lime is the oldest traditional stabilizer used for soil stabilization (Mallela et al., 2004). Many significant geotechnical properties of clayey soils can be beneficially modified by lime treatment, as lime decreases the plasticity index (PI), increases the workability, shrinkage limit, strength and California bearing ratio (CBR) as well as eliminates almost all swelling problems (Rogers and Glendinning, 1996; Sakr et al., 2009). Lime stabilization refers to the stabilization of soil by the addition of burnt limestone products, either calcium oxide, CaO, or calcium hydroxide, $Ca(OH)_2$. Quick lime is the most frequently used lime product for lime stabilization in Europe (Bell, 1989).

Extensive studies have been carried out on the stabilization of clayey soils using lime (Bell, 1996; Kassim and Chern, 2004; Rao and Shivananda, 2005; Sakr et al., 2009; Ghobadi et al., 2014). Bell (1996) indicated that the optimum addition of lime needed for maximum modification of the soil is normally between 1% and 3% lime by weight, and further addition of lime does not bring changes in the plastic limit (PL), but increases the strength. However, other studies reported the use of lime between 2% and 8% in soil stabilization (Basma and Tuncer, 1991). When lime is added to clayey soils in the presence of water, a number of reactions will occur, leading to the improvement of soil properties. These reactions

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include cation exchange, flocculation, carbonation and pozzolanic reaction. The cation exchange takes place between the cations associated with the surfaces of the clay particles and calcium cations of the lime. The effect of cation exchange and attraction causes clay particles to become close to each other, forming flocs; this process is called flocculation. Flocculation is primarily responsible for the modification of the engineering properties of expansive clayey soils when treated with lime (Ghobadi et al., 2014).

In Syria, clayey soils cover more than 20,000 km^2 of the country, most of which are located in the southwestern region (Abed, 2008). The clayey soils in this region are generally brown to red in color. These clayey soils are the weathering products of the volcanic rocks particularly the basalts. In many places in Syria, these clayey soils caused severe damage to infrastructures. In view of this, the need to improve these soils is necessary. Syria is rich in both limestone and natural pozzolana with estimated reserves of about 12 billion cubic meters and one billion tonnes, respectively (GEGMR, 2007, 2011). Few studies have been carried out to investigate the influence of adding natural pozzolana on the geotechnical properties of lime-treated clayey soils (Hossain et al., 2007; Harichane et al., 2011). However, the recent encouraging results obtained by Al-Swaidani and Aliyan (2015) on adding natural pozzolana as cement replacement were the motivation for this study. According to their study, adding natural pozzolana as a partial substitute for cement can provide economic and ecological benefits. In addition, durability of natural pozzolana-based cement concrete has significantly been enhanced. Better acid, chloride ions penetration and reinforcement corrosion resistances have been proved. Furthermore, cements with higher dosages of natural pozzolana can be used instead of sulfate-resisting Portland cement (SRPC) in sulfate-bearing environments (Al-Swaidani and Aliyan, 2015).

The objective of this paper is to investigate the influence of adding natural pozzolana on some geotechnical properties of lime-stabilized clayey soils. Consistency, compaction, CBR, and linear shrinkage properties have particularly been investigated. Scanning electron microscope (SEM) fitted with energy-dispersive X-ray spectrometer (EDX) was employed to identify the microstructural modification and to analyze the chemical composition of the investigated lime-stabilized clayey soil after adding natural pozzolana. The study is of particular importance not only for Syria but also for other areas of similar geology, e.g. Harrat Al-Shaam, a volcanic field covering a total area of some 45,000 km^2, third of which is located in Syria (Fig. 1). The rest covers parts of Jordan and Saudi Arabia.

2. Materials and methods

2.1. Materials

2.1.1. Soil

The soil samples used in the study have been obtained from a site called Aalqeen situated at about 40 km southwest of Damascus.

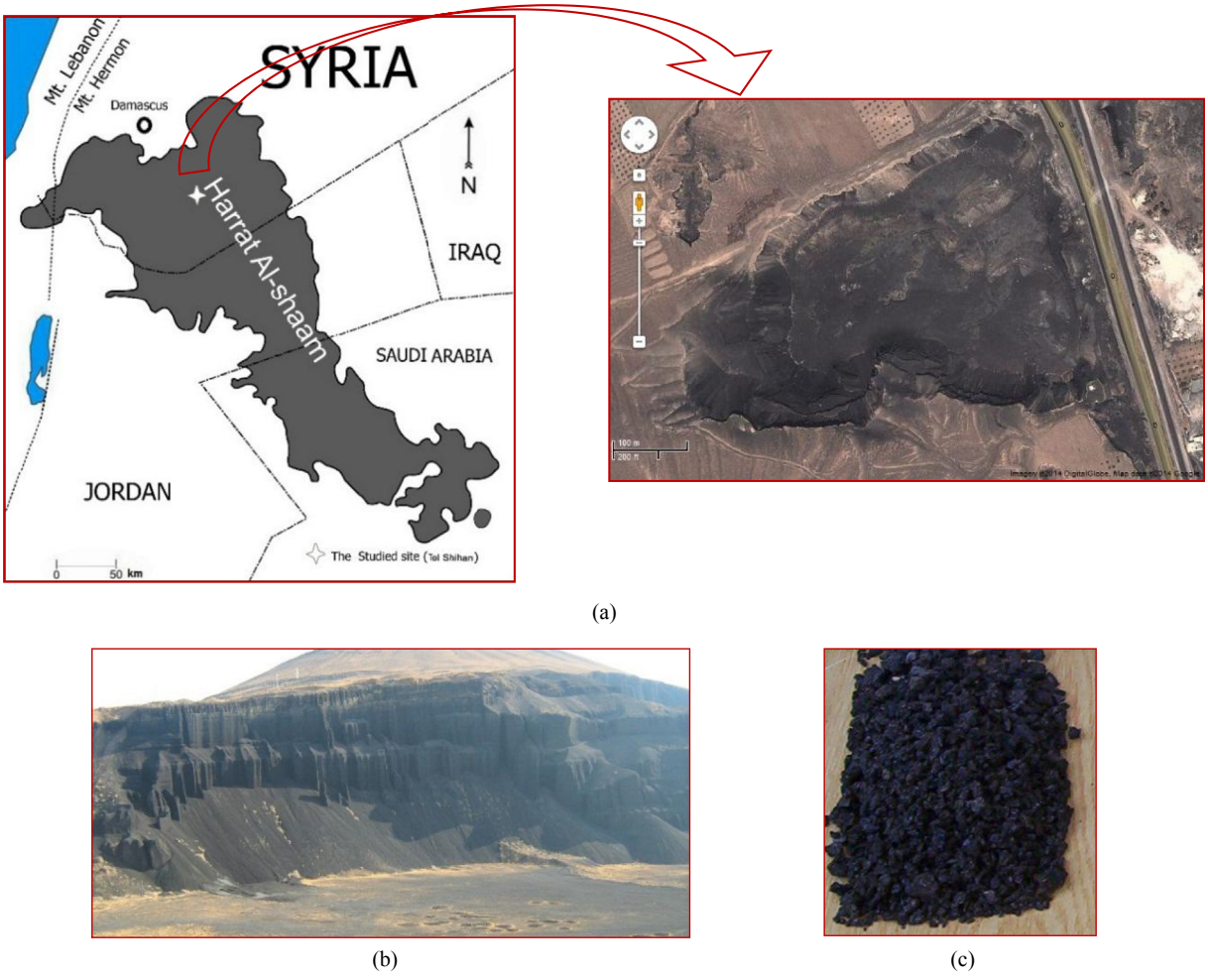

Fig. 1. (a) Map of Harrat Al-Shaam with a satellite view of the studied area. (b) Photo of studied natural pozzolana quarry. (c) Photo of studied natural pozzolana aggregate.