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The Effect of Combined Nanosilica and Lime on ImprovingMarl Soil Engineering Properties

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1. Introduction

Marls are soils with highly complex behavior which have been observed in many parts of the world, such as Italy, Spain, the United States, Britain, Canada, France, the Gulf states, and Iran (from north and northwest to southeast). In Iran, Marl soils can be abundantly observed in the marginal regions of the Persian Gulf, East Azarbaijan Province, Hormozgan and Qeshm Island.

Marl profile is a function of the carbonate content and the type and amount of minerals in the clay section. Generally, the marl clay part consists of Palygorskite and Sepiolite that controls marl performance. Unlike other clay minerals, these two minerals have chain structure and are commonly associated with other non-silicate minerals, such as carbonates and sulfates. Marls exhibit collapsible, divergence and swelling behaviors in the presence of water. In the Persian Gulf and Qeshm Island, widespread ruptures, including erosion, rupture of foundations and slopes, tensile cracks, extensive instability in natural and artificial slopes, and finally soil washing have been observed. In many hot areas of the world, cement and lime are used to stabilize and overcome the problems of marl.

due to its effective and economical nature, soil modification with lime is a common method for improving soil resistance properties. Studies have shown that lime-soil stabilization changes soil structure, soil plastic properties, liquidity, dispersion, swelling and contraction, settlement behavior and permeability and improves the geotechnical properties of the soil; on the other hand, the formation of swelling compounds such as etringite and tomosite in the lime-soil stabilization process in the marl soils has failed the stabilization process. Also, the effect of nanosilica on the effectiveness of the stabilization process has not been evaluated comprehensively. Accordingly, the objectives of this study were to determine the effect of nanosilica on the intensity of the marl stabilization process in the stabilization process and determining the lime and nanosilica contents needed for the cation exchange process (short-term reaction) and the growth rate of pozzolanic reactions (long-term reaction) of marl-lime in the short and long term, from a microstructure perspective.

2. Materials and Methods

The soil used in this research is the marl sample of the western part of Qeshm city. The structure and minerals of the marl soil can be the main cause of such problems. Observations in the region indicate that most of the damage occurred after rainfall or weathering of the marl soils. Based on the United Soil Classification System (USCS), the studied marl soil is high plasticity clay soil (CH) and 95% by weight passed through the sieve No. 200 (less than 75 microns). Some geotechnical and physical characteristics of the studied samples have been presented in this study in Table 1. Most of the tests performed in this study are based on the ASTM standard.

Table 1. Some geotechnical and physical characteristics of South Marl

Physical properties of South Marl (Qeshm Island)	Quantity measured
Diameter less than 0.075 mm (%)	95
Clay (%)	40
Liquid Limit (%)	58.6
Plasticity Index (%)	30.6
Surface area (m^2/ kg*10^{-3})	44.2±3
Carbonate content (%)	33
Color	Brown
Classification	CH
Maximum dry density. γd (gr/cm^3)	1.67
Optimum water content (%)	19.5

3. Results and discussion

pH changes of the reaction environment in the stabilization process. Minimum lime content needs to be added to the soil to have cation exchange (Na^+ and Ca^{++}) and as a result of a massive change in soil properties in the short time is called the lime fixation point. In this study, determination of this minimum lime content according to pH measurements and validation was done by X-ray diffraction and single-axial compressive strength tests. pH is an important indicator for the effectiveness of lime fixation. Based on the results presented in Fig. 1, the soil pH is 6.93 and by adding only 2% of lime, the soil-lime mixture pH increased after 72 hours to 11.85 and the environment pH reaches 12.34 with 4% of lime. moreover, based on the results of Fig. 1, in samples containing 10% lime, the pH of the suspension medium increased to 12.68 after 72 hours. As can be seen from the results, an increase in the lime content has increased the pH of the soil and in fact, the cation exchange reaction was carried out in a short time with the increase of slaked lime ($Ca(OH)_2$). Considering that according to the pH method, the minimum percentage of lime necessary for soil stabilization is the lime percentage, which results in environment pH of 12.4, therefore, according to the results, the minimum percentage of lime used should be about or more than 4 weight percent of the soil.

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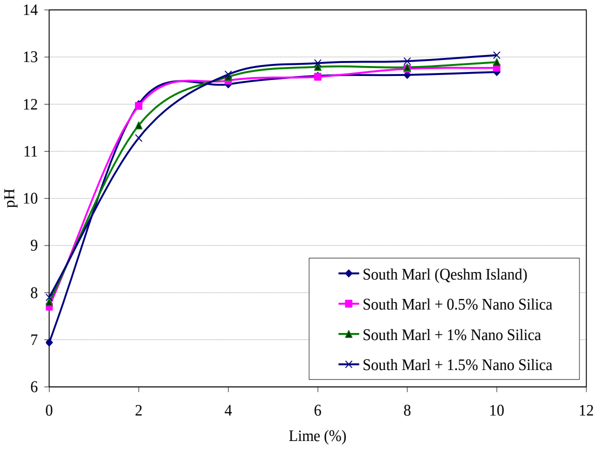

Fig. 1. Changes in pH of samples modified with lime and nanosilica after 72 hours

Investigation of geotechnical parameters in the stabilization process. Fig. 2 shows the hydrometric curve of samples modified with different percentages of lime after 7 days of curing. Based on the results presented in Fig. 2, the flocculation process is carried out with the increase of lime due to chemical reactions and the formation of bonding between particles. As observed, with a 2% increase in lime, the percentage of particles smaller than 5 microns decreased from 60% to 38%. However, this amount decreased by about 12%, 4% and 3% by increasing 6%, 8% and 10% of lime. The diameter of the particles increases due to the cohesion of silt and clay particles to each other by cementitious compounds as a result of pozzolanic reactions of lime and soil.

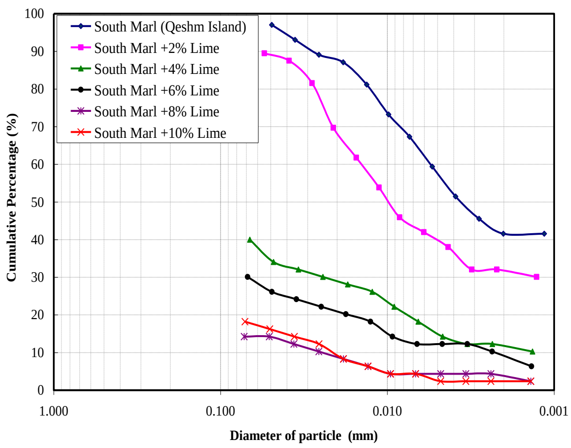

Fig. 2. Hydrometric curve of samples modified with different percentages of lime after 7 days of curing.

It is worth noting that the soil particle flocculation occurs immediately after the fixation of lime and causes a sharp decrease in surface area and an increase in particle size. In fact, the presence of the electrolyte facilitates the clay colloid particles tolerance which causes them to accumulate and thus reduce the surface area. According to Van Elfen (1987), the thickness of the dual layer between particles decreases with increasing electrolyte concentration.

4. Conclusion

Based on the experimental studies performed in this study, the following results can be obtained:

1) In samples containing nanosilica the initial pH of the reaction medium increased compared to the nanosilica-free sample in the first 10 days. However, after 10 days, the pH of the reaction medium is lower than that of nanosilica-free samples. In fact, it can be stated that nanosilica in the short term increases the pH of the reaction medium, or in other words, nanosilica in the short term (less than 14 days) has intensified the pozzolanic reactions.