The Strength Characteristics of Silty Soil Stabilized Using Nano-Clay

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Abstract

This paper describes a study on silty soil stabilization to improve its engineering properties. To evaluate the strength characteristics of stabilized silty soil, laboratory investigation on early strength gain of the stabilized soil was conducted to formulate a suitable and economical mix design that could be effectively used for the silty soil stabilization. To achieve such purpose, the study examined the effect of Nano-Clay on the California Bearing Ratio and unconfined compressive strength of silt. The results showed that of the Nano-Clay increased the strength of silt. The California Bearing Ratio of the soil and unconfined compressive strength were found to increase significantly with increasing in the Nano-Clay. It could be summarized that the Nano-Clay particles in the vicinity of moisture can cause soil stabilization by fastening the particles together.

Key words: Silty Soil, Stabilization, Nano-Clay, California Bearing Ratio, Unconfined Compressive Strength.

1. Introduction

There are different methods used for strengthening soil bases, which are categorized under soil treatment and stabilization methods. The desired performance of treated soils is a major factor in selecting of the most useful method for soil stabilization [Arabani and Veis Karami, (2007), Nikookar et al., (2012)].

All ground improvement techniques seek to improve those soil characteristics that match to desired results of a project, such as increase in density and shear strength in order to aid problems of stability, reduction of soil compressibility, influencing permeability to reduce and control ground water flow or to increase the rate of consolidation, or to improve soil homogeneity [Moseley and Kirsch, (2004)].

Stabilization by admixture is one of ground improvement techniques that was developed in Japan during 1970s and 1980s. The treated soil has greater strength, reduced compressibility and lower hydraulic conductivity than the original soil [Raison, (2004)]. The conventional method of soil improvement is to replace the soft soil by suitable imported fill materials. However, this practice is naturally very expensive due to the cost of excavation, dumping and the filling material [Kazemian and Huat, 2010].

Silty soils are highly moisture sensitive and their stability is (being) influenced considerably by the degree of densification achieved during compaction. Silty soils are often hydrophobic and difficult to cost-effectively moisture condition for compaction. Deformation of wet silt subgrade is often problematic during pavements' constructions as well as under regular vehicular traffic loads.

Nanoparticles of usually 1 to 100 nm are the smallest particles in soil environments and exist in one of the three different forms: nanoplatelets, nanowires or nanotubes, and nanodots. Due to their tiny size, soil nanoparticles usually exhibit special enhanced surface properties and hence interact more actively with other soil particles and solution. Owing to the extremely large specific surface area, surface charges, and sometimes nanoporosity, these particles, even preset at a small fraction, may significantly affect soil's physico-chemical behavior and engineering properties [Zhang, (2007)]

Numerous studies have been conducted regarding (to) use of nanoparticles for improving of soil strength parameters. The nanomaterials which has been more frequently used for changing the geotechnical properties is silica nanoparticles which influence the consolidation, permeability, indices, and strength properties of soil. In 1992, Yonekura and Miwa [22] utilized silica nanoparticles to increase sand compressive strength. Also, Noll et al. [23] investigated the use of silica nanoparticles in 1992 for enhancing soil's strength against consolidation and permeability. In 2005, silica nanoparticles were utilized by Gallagher for increasing soil's cohesion/adhesiveness and decreasing its viscosity, and behavior of the sand improved by nanomaterials was analyzed in cyclic loading conditions.

In the present research the application of nano-clay in improving silty soil geotechnical's properties is being investigated. In order to evaluate the development of unconfined compressive strength and the California Bearing Ratio, laboratory investigation on stabilized silt was performed. Silty soils for this laboratory testing investigation were at two types, ML and MH that were obtained from mouth a river leading to Caspian Sea, Beach of Rezvanshahr County in Guilan province.

2.Material and Methods

2.1.Silt

The parent soil is silt which is a natural estuary deposit. The parent soil was brought into the laboratory and spread out on a number of small trays for oven-drying. The soil was then sieved through a 2.6 mm sieve to remove occasional gravel and lumps of clay. The sieved material was mixed again and placed in a large container. A number of samples were taken for the determination of some physical properties and grading curves and the results are presented in Table 1 and Fig. 1.

Soil type	Gs	MDD (gr/cm³)	OMC (%)	LL (%)	PL (%)
ML	2.64	1.6	20		
MH	2.58	1.5	22		

Table 1: Physical properties of soils

MDD=Maximum Dry Density, OMC= Optimum Moisture Content, LL= Liquid Limit, PL= Plastic Limit

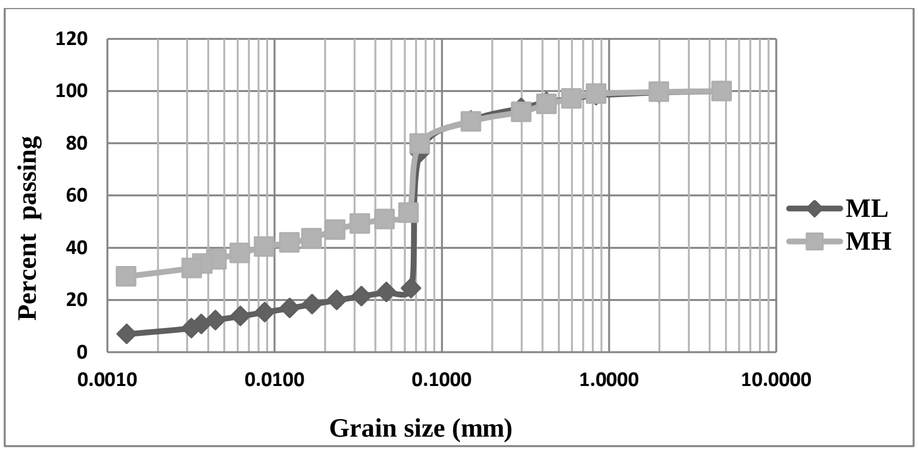

Fig 1: The grain size distribution curve of silts

For providing MH silt, 30% Rasht clay added to ML silt. Rasht clay MDD, OMC, LL and PI are 1.5 gr/cm^3, 23%, 65%, 32%.

2.2.Nano-Clay

Nano-clay which used as stabilizer in this study is modified montmorillonite Na^+. Chemical and physical details are presented in Tables 2~3.

Chemical formulation: $(Na,Ca)0,3(Al,Mg)2Si_4O_{10}(OH)_2 \bullet n(H_2O)$

Parameters	**Value**
Specific Surface Area	750 (m^2/g)
Particles Size	10-100dtr (nm)
Density	235 (gr/cm^3)

Table 2: Physical properties of Nano Clay

Chemical Compound (Oxide)	**Montmorillonite**
Na_2O	1.13 %
CaO	1.02 %
Al_2O_3	18.57 %
SiO_2	43.77 %
H_2O	36.09 %

Table 3: Chemical compound of nano-clay

2.3.Sample Preparation and Test Procedure

Homogeneous dispersion and distribution of nano-clay particles in soil sample is very important for improving of mechanical properties of stabilized soil. To achieve such purpose, in this laboratory investigation, ball-mill is used for combining and mixing nano-clay with soil.

For unconfined compressive strength (UCS) test, the oven- dried pulverized soils were mixed with the required amount of the stabilizer and the required amount of water. Specimens with optimum moisture content and 96% of maximum dry density and diameter of 50mm with the height of 100mm were prepared by static compaction. Then the specimens were loaded at a constant strain rate of 1mm/min for strength test. The UCS values reported are the average of the three tests. The prepared specimens were tested for the UCS based on ASTM D-2166.

For California bearing ratio (CBR), the specimens were prepared by a standard CBR mold of internal diameter of 152.4 mm and a height of 177.8 mm. Specimens were compacted 96% maximum dry density at the optimum moisture content determined by standard proctor. The specimens were compacted in 3 layers. The CBR tests were carried out in accordance with the standard of ASTM D 1883 – 99.

In this laboratory work, five combinations of ML and MH with nano-clay for carrying out experiments were considered.

3. Results and Analysis

3.1. Unconfined Compressive Strength test

Figure 1 shows the test(s') results and effect of nano-clay content on the unconfined compressive strength of treated silt. The UCS increases with increasing nano-clay, and the most important parameter affecting strength of stabilized silt is homogeneous dispersion and distribution of nano-clay particles in soil.

Diagram related to unconfined compressive test for ML and MH in Fig. 2~3 has been shown.

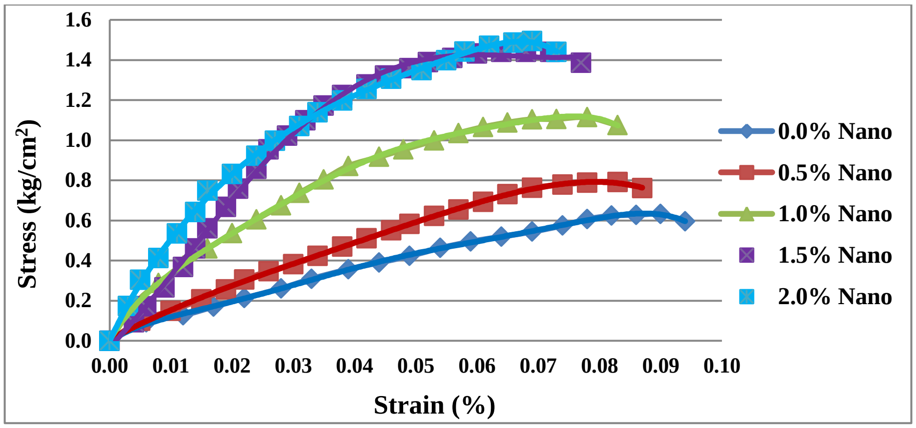

Fig 2. Unconfined compressive test results on treated and untreated soils for ML

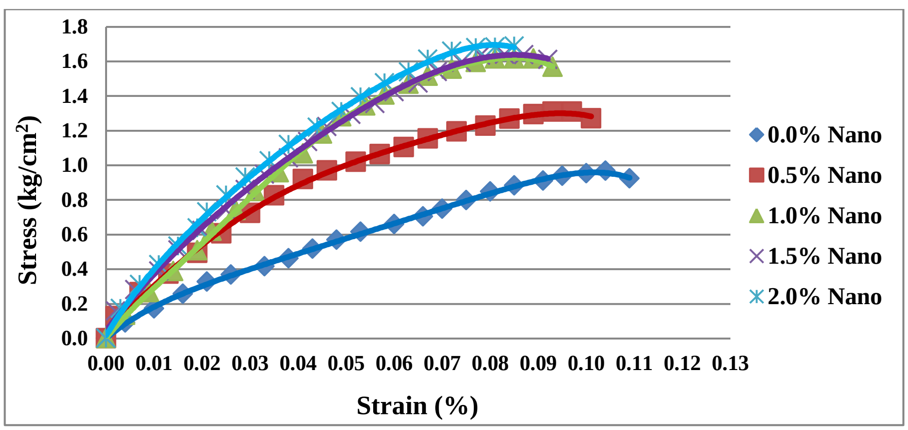

Fig 3. Unconfined compressive test results on treated and untreated soils for MH

Regarding unconfined compressive test results, there is an optimum nano-clay content of about 1.5% by weight for ML and 1% by weight for MH that produce maximum strength; increasing the nano-clay content beyond this is not beneficial. The maximum strength increases by increasing optimum dose of nano-clay but not recommended economically.

3.2. California Bearing Ratio Test

Regarding unconfined compressive strength test, CBR test performed on samples which are provided using 1% and 1.5% of nano-clay (optimum percent of ML and MH) for treated soil and untreated soil. Fig. 4~5 present the results of the CBR tests conducted on specimens with various percentages of nano-clay.

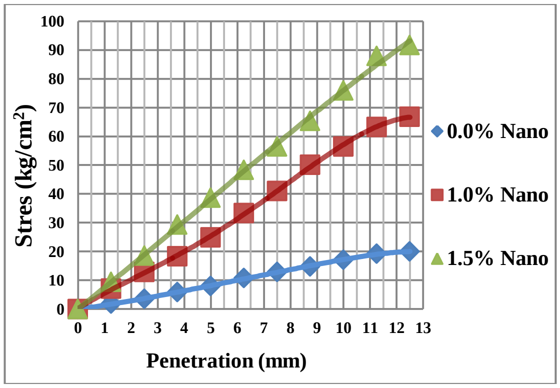

Fig 4.The CBR results on treated and untreated soils for ML

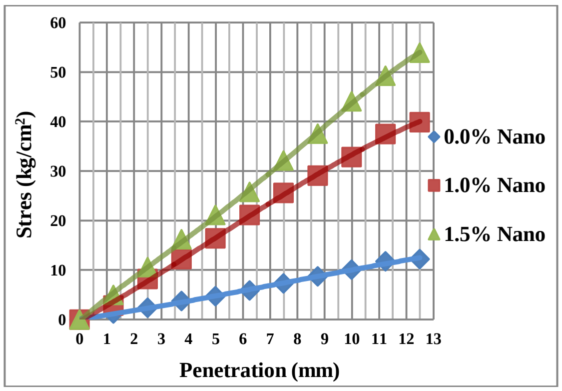

Fig 5. The CBR results on treated and untreated soils for MH

The CBR values for untreated soils are: 8 for ML and 5 for MH respectively, which are unsuitable for road construction. After treating with nano-clay, these values increased up to 36 for ML using 1.5% nano-clay and 16 for MH using 1% nano-clay. The CBR value obtained for ML is suitable for road construction and MH soil CBR value seems good but not as well as ML.

5. Conclusions

According to concluded results, the problematic silt can be effectively improved by using nano particles such as nano-clay and play significant roles for the early strength of stabilized soil. Also, suitable Strength and Bearing capacity for silty soil during civil projects are achievable with adding and homogeneous distributing of Nano particles.

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