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A Study on Strength Properties of Expansive Soil Treated with Lime and Nano Silica

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Abstract: ***There are little investigations in the literature on the nanotechnology's application in the geotechnical field. Since, lots of soil and rock minerals are Nano material and their chemical reactions are in the Nano-silica, there is a great potential for the use of this technology in different fields of geotechnical engineering such as seepage, grouting, soil stabilization and etc. In this study the stabilization of a weak soil was investigated using nanomaterial. The weak soil was obtained from prodduturu, Kadapa district and classified as low plasticity clay. CBR tests were conducted in this study. At the first step the effect of lime on the stabilization of the weak soil was investigated. The results proved a little effect of lime in the soil improvement. At the second step, the effect of Nano-silica on the stabilization of the soil-lime mixture was studied. The results illustrated the important effect of Nano-silica in the soil-lime mixture, in which adding Nano-silica increased the CBR strength of the soil and soil-lime mixture. The effects of curing time were also evaluated in this study and the results showed that the CBR strength of the soil-lime mixture increases more rapidly with adding Nano-material.***

Keywords: soil, lime, Nano Silica, Atterberg Limits ,OMC and MDD, Soaked and Un Soaked CBR

1. Introduction

The nanotechnologies idea was suggested by Richard Feynman for the first time in 1959, with this sentence "There's plenty of room at the bottom" (Feynman 1959). This technology then progressed significantly in all sciences. The presence of only a small amount of nanoparticles in the soil have significant effect in the physical and chemical behavior and engineering properties of soil. Soil stabilization refers to the procedure in which a special soil, a cementing material, or other chemical material is added to a natural soil to improve one or more of its properties. One may achieve stabilization by mechanically mixing the natural soil and stabilizing the material together so as to achieve a homogeneous mixture and also it may be obtained by adding the stabilizing material to an undisturbed soil deposit so that it interacts with the soil and permeate through soil voids. Soil stabilizing additives are used to improve the properties of less–desirable rood soils. When used these stabilizing agents can improve and maintain soil moisture content, increase soil particle cohesion and serve as cementing and water proofing agents. Difficult problem in civil engineering works exists when the sub-grade is found to be a clay soil. Soils having high clay content have the tendency to swell when their moisture content is allowed to increase.

2. Literature Review

Ghazi et al (2011) performed a study on the plasticity and strength characteristic of a fine soil and its mixture with a nanomaterial. They reported the results of a series of Atterberg limits and unconfined compressive strength tests. The results showed that adding Modified Montmorillonite Nano clay into the soil increases the liquid limit and plasticity index and 5meaningfully improves the unconfined compressive strength of the soil.

Pham H and Nguyen QP (2014), concluded that Effect of silica nanoparticles on clay swelling and aqueous stability of nanoparticles dispersion. (2014) carried out a series of tests on the clayey soils by adding nano-SiO2, and founded that the addition of nano-SiO2 leads to a reduction in the swelling index of clay.

Taha (2009) reported that Soft soil has the smallest particle sizes usually less than 2mm, possess up 85% for moisture content that have high moisture content, approaching that of liquid limit and has a shear strength less than 25kPa.

Abdullah and Abadi (2005) concluded that Soft soils are identified as problems soil due to their low shear strength, high compressibility, low permeability, high of swell and shrink potential. Soft soil considered undesirable engineering properties and unpredictable behavior in construction.

Yonekura R and Miwa M (1993), reported that fundamental properties of sodium silicate based grout indicated that the addition of Nano- SiO2 increases the strength and the Atterberg limits of clay and also decreases its permeability

3. Materials and Methodology

3.1 Materials

In the present study the fallowing materials are used
a) Soil
b) Lime
c) Nano silica

a) Block cotton soil
The Black cotton soil used in this investigation is of having high clay content. The soil was brought from Proddutur Kadapa district. The soil can be find by conducting corresponding the experiments according to IS code specification.

Figure 1: Black Cotton Soil

Table 1: Physical and index Properties of the natural clay soil

Soil Property	*Value*
Free swell Index	63.33%
Specific Gravity	2.68
Clay size Fraction	64%
Silt size Fraction	26%
Sand size Fraction	10%
Uscs classification	CH
Max Dry Density(g/cc)	1.49
Optimum Moisture Content(OMC)in %	26%
Liquid Limit, LL (%)	78%
Plastic Limit,PL(%)	33%
Plasticity Index, I(%)	45%

b) Lime

Lime kiln is available a plenty in Kadapa District and number of lime butties are located in and around Kadapa and Proddutur. Quick lime is available plenty in this region and the same has been used for stabilizing expansive soil in this investigation.

Figure 2: Lime

Table 2: Chemical and physical properties of the lime

Property	*Value*
Cao (%)	87.20%
Mgo (%)	2.13%
Other Compounds (%)	9.42%
Loss in Ignition (%)	1.25%
Practical size(µm)	<90
Partical Density (g/cc)	1.15

c) Nano silica

Nano silica is very active super-pozzolanic additive, pozzolanic reaction between hydrated lime, silica and alumina from the clay minerals leads to the formation of additional calcium silicate hydrates and calcium aluminate hydrates. Nanoparticles of SiO2 exhibit high pozzolanic activity due to high amount of pure amorphous SiO2.the silica nanoparticles promoted the pozzolanic reaction by transforming portlandite into calcium silicate hydrate (C-S-H) gel. The size of the Nano silica is (100-200) nm. Silicon Oxide Nanoparticles are used in many cases as paint, plastic, color rubber, magnetic materials, in addition, Nano-silica can be widely used in ceramics (sugar) porcelain, gypsum, batteries, paints, adhesives, cosmetics, glass, steel, fiber, glass, and many other fields.

Figure 3: Nano Silica

Table 3: Chemical composition of Nano silica

Material	Content (%)
sio2	99.7
TC	0.012
Ca	0.007
Na	0.005
Fe	0.002

4. Methodology

Testing program

To evaluate the effect of Nano-silicaadditive on the improvement of the weak soil strength, a total of tests were conducted. As first step, the effect of lime on the stabilization of soil was investigated. The trial-and-error approach was used to find optimum amount of lime in the mixture. The amount of lime for each mixture was calculated based on the dry soil mass, and selected as 0-2-4-6-8. Curing time for these series of test was taken as 4days in which was equal to curing time. To evaluate the effect of curing time for the optimum amount of lime, the samples were tested immediately, and at 4days after preparation. These series of tests were conducted with the optimum amount of lime in the mixture. In the second step, effect of Nano-silica on the improvement of the soil-lime mixture strength was studied, based on the optimum amount of lime determined in the previous step. To reach to this aim, % of dry soil mass of Nano-silica was added to the soil-lime mixture. Considering the effect of curing time, the samples were tested immediately and at 4days after preparation.

Molding and curing of specimens:

To perform the CBR tests, the soil, soil-lime and soil-lime-Nano-silica compacted specimens used in the tests were prepared by hand-mixing of dry soil, lime and Nano-silica. As mentioned in the previous part, the amounts of additive to the soil were based on the dry weight of soil. In each sample, the optimum amount of water was determined in

standard compaction test and the CBR specimens were prepared base on desired moisture. After mixing the dry soil and additives, the water was added to the dry soil mixture by spraying into the samples. After preparation of the mixture for one specimen, the mixture was stored in a covered container for 4days.

CBR Tests

California bearing ratio (CBR) is one of the useful and common methods in evaluating the strength of soil for the design of subgrade, sub base and base of roads. This test, which is simple, fast and reliable have been used to verify the stabilization of weak soils by adding physical and chemical additives.

5. Results and Analysis

Table 4: Un Soaked & Soaked CBR values for Black Cotton Soil with varying % of lime

S.no	Samples	Un Soaked CBR Value(%)	Soaked CBR Value(%)
1	B c Soil	5.56	2.82
2	B c Soil + 2%lime	5.29	3.33
3	B c Soil + 4%lime	5.89	4.01
4	B c Soil + 6% Lime	6.15	4.44
5	B c Soil + 8% lime	5.81	3.59

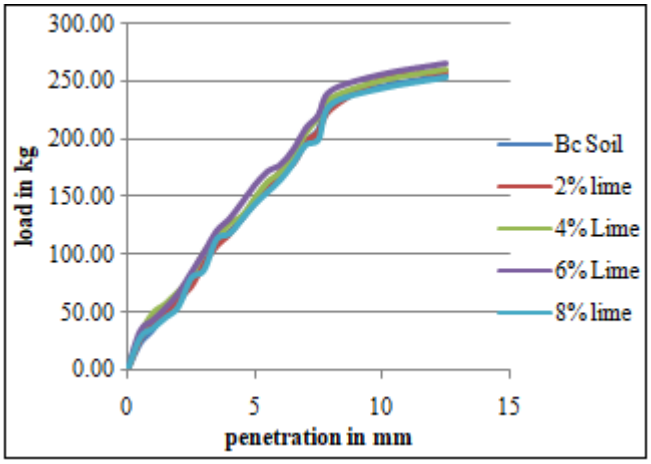

Figure 4: Un Soaked & Soaked CBR values for Black Cotton Soil with varying % of lime

Table 5: Un Soaked and Soaked CBR values at 6 % of lime mixture with different % of Nano Silica

S.no	Samples	Un Soaked CBR Value (%)	Soaked CBR Value (%)
1	Bc Soil	5.56	2.82
2	Bc Soil+6% Lime	5.98	4.44
3	Bc Soil+6% Lime+2% Nano Silica	6.40	4.95
4	Bc Soil+6% Lime+4% Nano Silica	6.74	5.89
5	Bc Soil+6% Lime+6% Nano Silica	6.92	6.15

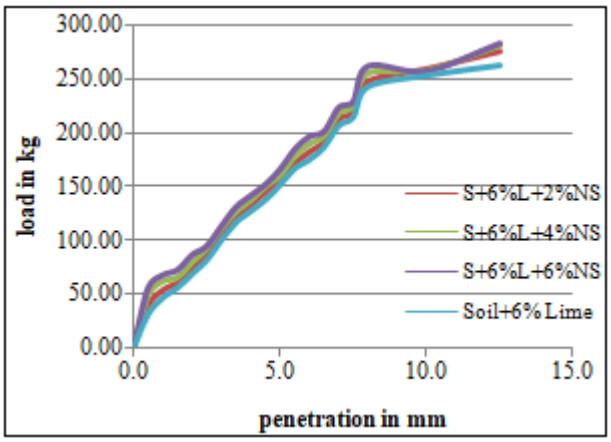

Figure 5: Un Soaked and Soaked CBR values at 6 % of lime mixture with different % of Nano Silica

6. Conclusions

- Soil improvement using additives is the most common method for soil stabilization. Improving soil properties using Nano-material can be applied to solve geotechnical problems.
- This study found that the high reactivity of Nano silica particles with lime is because of small size of particles which leads to improve properties of soil such as plasticity, compression, swelling and increasing strength in the shortest time.
- Due to small size of Nano-silica, the addition of these nanoparticles will increase samples' reactivity even at an early age, subsequently compressive strength is increase This can be very effective in projects which soil strength needs to be increased and its engineering properties to be improved in short term.
- Addition of silica nanoparticles alone to the soil does not have much impact on soil strength and another activator substance such as lime is needed.
- Soil plasticity is not improved with the addition of Nano silica particles alone; moreover because of high softness of Nano silica particles, addition of Nano silica up to high percentages can increase soil plasticity. However soil plasticity properties have been improved considerably in samples in which Nano-silica and lime are used
- Addition of Nano-silica alone caused a slight increase in soil optimum moisture content and a slight decrease in specific weight of samples. But because of rapid reactions and forming coarse particles as a result of adding Nano silica and lime, optimum moisture content and maximum dry density of samples substantially increased and decreased respectively.

Addition of Nano-silica without lime to clay not only has little impact on soil swelling but also high percentage of Nano silica can increase swelling due to particles` softness and more water absorption. Addition of Nano silica in presence of lime makes a significant decrease in the percentage of swelling of clays with high plasticity so that swelling of the soil

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