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Influence of Nano-Silica on Unconfined Compressive Strength of Marine Clay with Curing Time

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Abstract*: This paper presents the influence of nano-silica on unconfined compressive strength of soft marine clay with curing time.Soft marine clay is highly problematic regarding to engineering projects due to high compressibility, low shear strength and low permeability. Marine clay used for the study was collected from Vyppin Island, Cochin. Nanoparticles are one of the recent materials that can be used in soil stabilization. Drastic growths have been taken in the field of nanotechnology, and much nanotechnology-based advancementhas been made in geotechnical engineering. Nano-silica possess higher surface area to volume, this enhances cation exchange capacity and reaction with particles of clay. Nano-silica contents varied from 0.5% to 1%. The unconfined compressive strength of treated soil increased with curing time. Curing time taken for the study of variation in UCS were 3, 7, 14, 28 days. Nano-silica gel increased the cohesion between particles there by improvement of unconfined compressive strength. Minute quantity is just sufficient for noticeable changes in properties of soil in the case of nano-silica particles. Nano-silica as recent chemical additive also showed a rapid development in engineering properties of marine clay. So the modifications by chemical additive in marine clay had shown better improvement in UCS of soil.

***Index Terms*: Marine clay, Nanotechnology, Nano-silica,Unconfined Compressive Strength**

I. INTRODUCTION

Marine clays are highly compressible fine grained soils. Higher compressibility and lower shear strength are the main engineering problems related to this soil. So modification of properties of soil is necessary for improving the engineering behaviour. Modifications of engineering properties are done by stabilisation technique by different methods.

Cochin marine clay from Vyppin Island was taken for study. Cochin industrial capital of Kerala, whichisundergoingrapid industrialization,consistsofextremely softmarineclay poses serious problemin the geotechnical engineering practices. Mainly this effect can be observed in the foundation related issues while construction of structures, Bridges, Highways and Dams. Various stabilisation techniques are using to overcome this serious issue regarding engineering practices.

As per researches liquidity index is as high as 0.87, and marine clays are moderately active clays.The compression indices of clay are high for undisturbed samples and are higher than those obtained for remoulded samples. Also shear strength of clay is much lower. [Babu et.al.1988]. Various stabilising agents such as lime, flyash, cement etc... are using for enhancement of properties of marine clay. Nanomaterials are recent in the ground improvement field of geotechnical engineering.

The idea of nanotechnology was first introduced by Richard Feynman in his lecture entitled “There’s Plenty of Room at the Bottom” in 1959.Numerous studieshavebeenconductedregarding useofnanoparticlesforimprovementofsoilstrength parameters [Kadiver et.al.2011].Recently nano-silica, because of its suitable performance compared with micro-silica, has frequently been used in soil improvement projects.

A series of tests on clayey soils by adding nano-silica and found that the addition of nano-silica leads to a reduction in the swelling index of clay. Addition of nano-silica increases the shear strength and Atterberg limits of clay and decreases its permeability [Pham et.al. 2014]. Increase in nano-silica content improved the unconfined compressive strength and elastic modulus of soft clay [Changizi et.al. 2015]. Nano-silica develops a stronger connection by viscous gel leading to an increase in frictional strength and also reduces the distance between clay particles. This improves the shear strength of soft clay [Garcia et.al. 2017].

Moreover, research on pozzolanic activity of silica nanoparticles indicated a high pozzolanic activity of nano-silica compared to micro silica, flyash. Since silica nanoparticles act as an accelerator, structure of cementitious materials becomes denser and more uniform even in a short time of curing [Changizi .et. al. 2017].

This paper evaluates the improvement of unconfined compressive strength (UCS) by nano-silica addition in marine clay with curing time. Study on the effect of nano-silica on marine clay was not performed. Effect of nano-material will change according to the behaviour of clay.The unconfined compressive strength of clay samples was improved with curing time by the increase in nano-silica content.

II. MATERIALS USED

The main additives used for stabilization of marine clay from Cochin are nano-silica.Marine clay was sampled from Vyppin, Ernakulum. Table 1 shows the properties of marine clay. Nano – Silica was obtained from ASTRA chemicals, Chennai.Table 2 shows the chemical composition of nano-silica.

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Table1. Properties of soil sample

Properties	Marine clay
Specific Gravity	2.65
Liquid limit	80%
Plastic limit	34%
Shrinkage limit	14%
Free swell	50%
Clay fraction	49.25%
Soil classification	CH
OMC	32.37%
Dry density	1.42g/cc
UCC	97.07 kPa

Table 2. Chemical Composition of nano-silica

Constituent	%
Silicon dioxide	99.7
Titanium	0.012
Calcium	0.007
Sodium	0.005
Iron	0.002

III. METHODOLOGY

To evaluate the effect of nano-silica on strength of soft clay sample, two groups of specimens need to be taken. One group of natural specimen, next group of three set of specimens stabilised with nano-silica. UCS are tested to find the variation in properties of soil.Soil sample was air dried for a week, pulverized manually using weights, sieved through 425 micron sieve and preserved in large containers in an enclosed room.Soil specimens were mixed with nano-silica in the ranges 0.5%, 0.8%, 1% cured up to four weeks in air-tight bags. A series of unconfined compressive strength tests were conducted on clay treated with different contents of nano-silica.The Optimum nano-silica Content was determined from the test results. The reason for the maximum limit of 1% of nano-silica is due to the fact that tests were performed under constant moisture content and due to the absorption of water by nano-silica, mixing of soil with more than 1% nano-silica content led to a lack of water in the soil /nan-silica mixture; this will results in the bad workability of amended clay [Changizi et al. 2017].

IV. RESULTS & DISCUSSIONS

A. Unconfined Compressive Strength of Natural Marine Clay

The results of unconfined compression test of marine clay sample are shown in Figure 1. Three trials are performed to found out the UCS of clay sample. The peak value obtained for the natural clay is 97.07kPa and cohesion is 48.2kPa. Marine clay sample belongs to the medium strength class based on UCS.

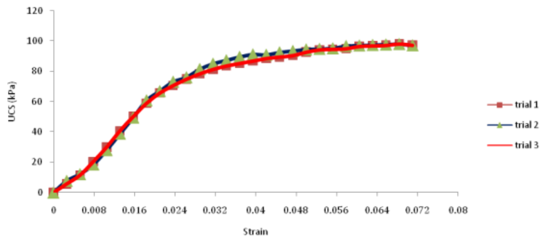

Fig.1. Unconfined Compressive Strength of natural sample

From the figure 1it can be inferred that the peak increase in resistance is obtained after a drastic strain increase in soil sample. From the three trials nearly equal strain was observed. Medium consistency of clay and high compressibility of clay can be found out from the UCS test of natural sample

B. Variation in Unconfined Compressive Strength of 0.5% Nano-Silica Amended Marine Clay

The results of unconfined compression test of marine clay stabilized with 0.5% nano-silica are shown in Figure 2. The peak value of UCS increases with increase in curing time. At the end of 14, 28 days peak resistance of stress-strain curve had shown closeness in strength. Addition of nano-silica improved strength compared to the natural marine clay sample.

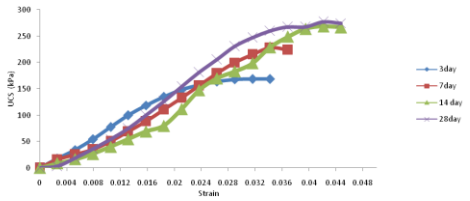

Fig.2. Unconfined Compressive Strength of 0.5% nano-silica amended clay

C. Variation in Unconfined Compressive Strength of 0.8% Nano-Silica Amended Marine Clay

The results of unconfined compression test of marine clay stabilized with 0.8% nano-silica are shown in Figure 3.

The figure 3 indicates that increase in nano-silica content improved the UCS characteristics of nano-silica amended clay. 0.8% nano-silica amended clay improved UCS better than 0.5% nano-silica amended clay. At the end of 28days UCS attained peak strength of 300kPa.

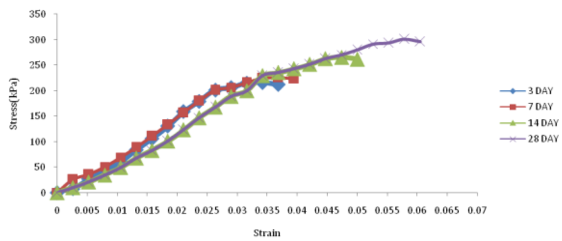

Fig.3. Unconfined Compressive Strength of 0.8% nano-silica amended clay

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D. Variation in Unconfined Compressive Strength of 1% Nano-Silica Amended Marine Clay

The figure 4 presented the variation of UCS of 1% nano-silica amended clay with curing time. The peak value of UCS exhibited an increasing trend with curing time. But the 0.8% and 1% showed nearly equal peak value of resistance. 1% nano-silica amended clay had shown a peak resistance of 305kPa. While considering the cost of stabilization 0.8%nano-silica content can be taken as optimum content.

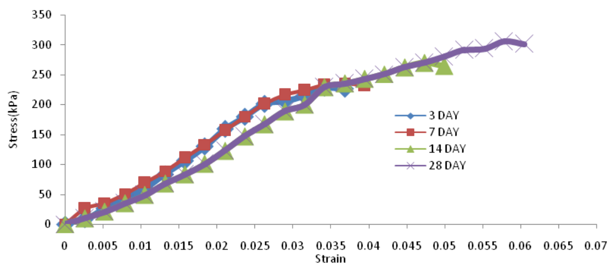

Fig.4. Unconfined Compressive Strength of 1% nano-silica amended clay

The results of unconfined compression test of marine clay stabilized with 0.5%, 0.8% & 1% nano-silica are depicted in Figure 5. The peak value of UCS increases with increase in curing time for all percentages of nano-silica content.

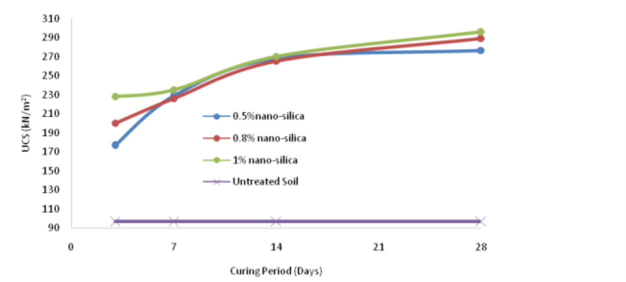

Fig.5. Variation of UCS for nano-silica amended clay

Table 3.UCS variation of nano-silica amended clay with curing time

Curing Time (Days)	Untreated Soil	0.5% nano-silica	0.8% nano-silica	1% nano-silica
3	97.07	176.80	216.03	228.51
7	97.07	228.83	226.38	235.37
14	97.07	268.45	265.32	270.45
28	97.07	276.81	300.87	305.74

The microstructural evaluation of the stabilized clay with nano-silica (Changizi et.al.2017) indicated that the nano-silica covers the clay particle surfaces, the interlock force between soil particle increases. The pores between clay particles are filled with the nano-silica viscous gel. The cohesion between clay particles due to the viscous gel is stronger than the cohesion between particles of clay due to absorbed water. Viscous gel leads to an increase in the frictional strength between the clay particles. The peak UCS resistance changed with curing time. So, the variation of unconfined compressive strength depends on the curing period. Due to large surface area for nano-silica, it is highly reactive, and this is suitable in improving the properties of soil. This leads to an increase in strength of soil.

V. Conclusion

The peak UCS of natural clay enhanced from 97kPa to300kPa for 0.8% nano-silica and for 0.1% nano-silica increased to 305kPa. Strength variation shown more proximity for these contents. The variation of UCS for 0.8% & 1% are close enough. From the economic point of view 0.8% can be considered as optimum content. The improvement of strength at 28 days for 0.8% nano-silica amended clay was more than 210% than natural clay. Short term strength for the amended clay was also noticeable. Specimens treated with nano-silica shown brittle behaviour Compared with the strain rate of natural clay, after the addition of nano-silica the strain rate was decreased. Amended clay shown increase in UCS at lower strain levels compared to natural clay.

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