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A REVIEW OF GEOTECHNICAL CHARACTERISTICS OF NANO ADDITIVES TREATED SOILS

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ABSTRACT

The use of techniques for soil stabilization has increased significantly in recent decades to adopt cost-effective solutions, to achieve reductions in quantities of material used and etc. Soil stabilization by adding materials such as lime, cement etc. is one of the effective methods commonly used for improving the geotechnical properties of poor soils. Nanoparticles are one of the latest additives and many investigations about using Nanoparticles in soil improvement have been done. The use of Nano additives in some fields such as soil improvement, grouting, liquefaction risk mitigation, seepage has offered a great advantage in geotechnics. This paper review the major Nanoparticles or Nano Additives used for improving geotechnical characteristics of soil.

Keywords: ***Nano Additives, Nano-Clay, Nano-Silica, Soil Stabilization***

INTRODUCTION

A soil is one of the most abundant construction materials available. Almost all construction is carried out with or upon the soil. When poor construction conditions are encountered, suitable measures have to be taken such as; finding a new construction site, redesign the structure, remove and replace the poor soil with suitable soil or improving the engineering properties of the site soils. Improving an on-site (in situ) soil's engineering properties is generally referred to as soil stabilization. Soil stabilization is a method of improving engineering properties and other elements, including the increasing shear strength, reducing settlement, compressibility, and increasing the density. A wide variety of soil improvement has been used from a long time including soil replacement, dynamic compaction, lime/cement columns, stone columns and soil reinforcement with fibers. There are many methods of soil stabilization used today: Mechanical and Chemical or Additives etc. A proper understanding of the geotechnical properties of soils is a required prior to any engineering construction work. Nanoparticles are one of the newest additives being used in the field of geotechnics.

Nanotechnology is a rapidly originating technology with a huge potential to create new materials with unique properties and to produce new and improved products for numerous applications. In recent years Nanotechnology is also gaining popularity in the field of Civil and Geotechnical Engineering. Nanotechnology in geotechnical engineering in dealing with soil can be seen in two ways: 1) The structure of the soil at the

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Nanoscale and 2) at the atomic or molecular level through the addition of Nanoparticles as an external factor to soil.

Many of the soil and rock minerals are in form of Nanomaterial at Nanoscale and their chemical reactions occur at Nanoscale level. As a result of this fact, there is a great potential of Nanotechnology's application in the field of geotechnical engineering and soil mechanics. Mixture of soil with some Nano additive or Nano material or Nano-Particle could improve the soil strength parameters, and this procedure has been performed in the past for stabilization and improvement of weak soils. The main strategy of Nanotechnology in geotechnical engineering to improve the engineering properties of weak soils with the application of Nano materials. Due to a very high specific surface area of Nano materials, surface charges and their morphologic properties, Nano material in the soil could influence significantly the physical and chemical behavior of soil**.**

II. REVIEW OF LITERATURE ON NANO ADDTIVIES IN STABILIZATION OF SOIL

Nano additives have been used either directly with the soil or being an additive with the stabilization material, like cement. Cement is an important resource and common for stabilizing, it is being used widely in many construction applications. Even with using additives whether Nano or else, cement is acting like a binder and strength material. Some researchers studied the effect of adding Nano additives to the soil in presence of optimum cement content and study the effect of the added Nano additives; others used the Nano additives directly with the cement to enhance the behavior of cement on its own. Nano-Silica, Nano-Clay, Nano-Zeolite, Nano-MgO and Nano-Copper are the major additives that is been studied in soil stabilization, few researches studied other additives, like Nano-CuO, Carbon-Nanotube, Nano-MgO, or Nano-alumina.

Rodríguez and Antonio (2004) investigated that a small amount of colloidal silica increases significantly the cyclic strength of untreated sands. For the loose sands the addition of silica in colloidal form greatly reduces the potential for particle reorientation and movement. The behavior of treated loose sands is similar to that of dense untreated sands. The beneficial increase of the cyclic strength of loose Lázaro Cárdenas sand by using colloidal silica grout is demonstrated clearly from the results of pore pressure development curves.

Gouping and Zhang (2007) studied the effect of nanoparticles in the engineering properties of soil. Nanoparticles can influence soil properties more dramatically, even present at a small fraction, sometimes as low as a few percent. Owing to large specific surface area, surface charges, and sometimes Nano porosity, these particles, even present at a small fraction, may significantly affect soil's physico-chemical behaviour and engineering properties.

Taha and M. R., (2009) carried out investigation to study the fundamental geotechnical properties of mixtures of natural soils and its product after ball milling operation. The end product formed after the ball milling process is termed Nano-soil here. SEM analysis showed that much more Nano size particles were obtained after the milling process. The properties of Original kaolinite, montmorillonite and UKM soil with regard to its liquid limit, plastic limit, plasticity index, and specific surface area were checked and after addition of its Nano-soil were checked and compared. Nano-soil was obtained from ball milling operations of a parent soil and used as a possible soil improvement material. After 10 to 13 hours of cyclonic milling operations, there were more Nano particles compared to the original soils evident from SEM analysis. The plastic and liquid limits of soil mixtures

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consisting of 98 % original soil and 2% Nano-soil increases compared to the values of 100 % original soil. However, the plasticity index reduces which is advantageous in geotechnical construction such as landfill liners and caps. A blend of 96 % UKM soil, 4 % cement and 2 % UKM Nano-soil results in almost doubling of the compressive strength compared with samples without UKM Nano-soil. Thus, Nano-soil or more generally Nanoparticles is an excellent candidate material for soil improvement.

Arabania et al. (2012) investigated results of unconfined compressive strength (UCS), indirect tensile strengths and California Bearing Ratio (CBR) of sand cement mixtures containing different amount of Nano-clay. The results showed that the reaction of alumino-silicate elements in Nano-clay with calcium hydroxide in cement increased bond strength and consequently giving in higher tensile strength of hardened cement paste. Due to the addition of Nano-clay, the structure of soil cement mixture has become denser and more homogeneous and even very small voids have been eliminated.

Majeed and Taha (2012) investigated to study the effect of addition of three nanomaterials (i.e., Nano-CuO, Nano-MgO and Nano-clay) on the geotechnical properties of soft soil. The liquid limit, plastic limit, linear shrinkage, compaction parameters and shear strength of the soft soil were determined. Addition of each of the nanomaterials caused the liquid limit, plastic limit, plasticity index and linear shrinkage of the soil to decrease. With increasing nanomaterial percentage, the dry density increased. On the other hand, with increase dosages of nanomaterial the optimum moisture contents of the soil-nanomaterials mixtures decreased. Increasing the amounts of nanomaterials reflected an increase in the unconfined compressive strength. The results showed, the maximum shear strength was obtained from soil treated with Nano clay. The soil to which Nano clay had been added showed hardening and improved strength compared with other soil specimens that contained other nanomaterial additives.

Mohammadi et al. (2013) studied different percent of Nano-clay Montmorillonite in order to check out changes in soil characteristics with increasing percentage of Nano-clay. Compaction test, direct shear test, unconfined compression test, California bearing ratio (CBR) test and Atterberg limits tests were conducted on soil at the given percent of water. According to performed tests, adding Nano-clay to soil increased the liquid limit and plastic limit of soil but plastic index reduces (PI=LL-PL) in soil. The effect of Nano-material in soil properties are caused by higher specific surface area and superficial loading, Nano-porosity of intra-particle and micro structure of mass and compacted form. Due to addition of Nano-clay shear strength of soil increase and that is because of increase in cohesion; this keeps increasingly to 1.5% and then no change happens. Final strength increased by increasing Nano-clay percentage in unconfined compression test (UCS) and CBR test. Soil has maximum final strength, When Nano-clay percent in soil reaches to 1.5% percent. The final strength of specimen reduces as Nano-clay increase to 2%. According to gained results it can be concluded that Nano-materials can influence in soil in the low percent. This material can be used for improving soil properties.

Bahari et al. (2013) investigated the physical and geotechnical properties of silt stabilized with Nano-clay through performing laboratory tests including Atterberg Limits, Compactibility, adhesion and internal friction angle for two types of silt (ML and MH). Results showed that Nano-clay has a considerable influence on

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increasing the liquid limit and plasticity index, increase in adhesion and internal friction angle. This increase attributes to consistency of Nano-clay when surrounded by water. This results in growth of interlocking forces between Nanoparticles in the presence of moisture which can cause stabilization of soil by fastening the particles together and filling pores.

Bahmani and Huat (2014) conducted an experimental study to determine the effect of SiO2 Nanoparticles on Atterberg limits, compaction, hydraulic conductivity, and compressive strength of residual soil treated with cement. It was observed that an increase in the Nanomaterial content resulted in a decrease in the maximum dry density but an increase in the optimum moisture content. Compressive strength of samples dramatically increased due to the addition of Nano-silica. However, small amounts of SiO2 Nano particle resulted in higher strengths. The maximum strength was 673 kPa, 1020 kPa, 1611 kPa at 4%, 6%, 8% of cement, respectively when Nano-silica particles of 15 nm were used. The compressive strength of the samples without Nano-silica was 424 kPa, 450 kPa, and 515 kPa at 4%, 6%, 8% cement, respectively. The addition of higher percentage of the Nanoparticles resulted in lower strength gain. According to the test results, Nanoparticles measuring 80 nm were less effective in terms of strengthening the soil than those measuring 15 nm. It was also seen that inclusion of Nanoparticles with smaller size resulted in a higher strength development rate at all cement levels at early ages of soil stabilization. The hydraulic conductivity increased with an increase in content of both sizes of Nanoparticles (15 and 80 nm). The Unconfined compressive strength (UCS) for the soil-lime mixture (5% lime) with adding 3% of Nano-Silica, increased up to three times (300%), after curing of 28 days. The same comparison made for Unconfined compressive strength (UCS) of soil and Soil-Lime-Nano-Silica mixture, and results showed an increase of 7.5 times (750%) in UCS of soil for 3% Nano-Silica after 28 days curing.

Firoozi et al. (2014) conducted an experimental study, performed on a clayey soil mixed with Nano Zeolite of varying percentages (0.0, 0.1, 0.3, 0.5, 0.7, 1.0, 2.0, and 3.0%). The Atterberg's limits tests showed that the Atterberg's limits vary with addition of different percentage of Nano Zeolite.

Priyadharshini and Arumairaj (2015) studied the effect of nanomaterials on the bearing capacity of soft soil and concluded. It has been observed that increase in Nano clay content increases the Atterberg's limits. Increase in Nano-MgO and Nano-Alumina results in decrease in Atterberg's limits. The increase in Atterberg's limits is due to the higher specific surface area of nanoparticles encompassing large amount of water to the outer surface. With the increase in the percentage of Nano clay and Nano-Alumina, the optimum moisture content increases. With increase in Nano-MgO, optimum moisture content decreases. The presence of nanopores causes water accumulation in these pores, resulting in increase of optimum moisture content. Soft clay attains the OMC at lower energy as the Nano-MgO content increases. With the increase in the percentage of Nano clay and Nano-Alumina, the maximum dry density decreases. The maximum dry density increases, with the increase in Nano-MgO content. Increase in moisture content decreases cementing property of soil and decreases dry density. The unconfined compressive strength increases up to 48% for 1% nanoclay,41% for 0.3% Nano-MgO and 43% for 0.75% of Nano-Alumina. The strength increase is due to thixotropic behaviour of the Nano particles. The consolidation settlement behaviour is reduced upto53% for optimum dosage of Nano clay,57% for optimum dosage of Nano-MgO and 54% for optimum dosage of Nano-Alumina. Thus Nano-MgO reduces the

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consolidation settlement when compared to the other two materials. The load carrying capacity of the footing for soft clay with optimum dosage of nanomaterials is increases up to 45.53% for Nano clay, 61.70% for Nano-MgO and 55.32% for Nano-Al2O3. Thus Nano-MgO shows an improved result in reducing the settlement and improving the load carrying capacity compared to the other two materials.

Hareesh and Vinothkumar (2016) assessed the geotechnical properties of clayey soils treated with Nano materials as the expansive nature of soil gets decrease on addition of Nano silica and Nano zeolite. It is observed the Atterberg's limits increases with increase of Nano silica. On addition of Nano zeolite decreases the Atterberg's limits. With the increase in the percentage of Nano silica and Nano zeolite, the optimum moisture content increases and dry density gets decreases. The shear strength characteristics of soil are improved on addition of Nano silica and Nano zeolite.

Changizi and Haddad (2016) investigated the effect of adding nano-SiO_2 on the strength behaviour of clay soil. The effects of nano-SiO_2 on clayey soil were studied on the basis of the results obtained from a series of compaction and direct shear and unconfined compression tests. Based on the results presented in this paper, the following conclusions are drawn. By adding nano-SiO_2, the maximum dry unit weight and the optimum moisture increase by factors 1.13 and 1.2 respectively for nano-SiO_2 content of 1.0 %. As the Nano-SiO_2 content increases, the peak shear strength of stabilized soil increases in such a manner that by adding 0.7 % nano-SiO_2, in normal stress 300 kPa, the peak shear stress increases by factors 1.74. The increase in strength for the soil with 1.0 % nano-SiO_2 is only about 14 % in comparison with the soil with 0.7 % nano-SiO_2. As per the result, an increase in nano-SiO_2 content increases both angle of internal friction and cohesion. For all of the results, the maximum increase in both angle of internal friction and cohesion is observed at 1.0 % nano-SiO_2 content. By adding 1.0 % of nano-SiO_2, the angle of internal friction and the cohesion of soil stabilized increase by factors 2.1 and 1.23 respectively.

III. CONCLUSION

This paper provides a review of the stabilization of soil using Nano additives, with different soil types and amounts, and their effects and results. Nano-silica, Nano clay, Nano zeolite, Nano alumina, Nano MgO are the major used additives in the researches. Different Nano additives exhibit different properties. Having smaller dimensions, nanoparticles possess a very high specific surface area and therefore react more deliberately with other particles in the soil matrix. The existence of even a very small amount of these Nano additives can result in extraordinary effects on the engineering properties soil. This review showed that Nano additives greatly influence the strength, permeability, compressibility, density of soil. Future researches are recommended to cover other nanoparticles and different soil types with different percentages.

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