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Investigating the Effecting of Nano Aluminum on Mechanical and Volumetric Properties of Clay

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ABSTRACT: In this paper, the effects of gamma oxide nano-aluminum as the cement modifier; on volumetric and mechanical properties of problematic clay using an experimental research were described. Initially, the impact of cement was evaluated for soil improvement and in the following the impact of cement mixed with nano-aluminum on soil properties were investigated. Evaluation of these effects was done in curing period from 1 day to 28 days. Properties evaluated in this study included Atterberg limits, density and proctor compaction, uniaxial compressive strength, California bearing ratio and the power of hydrogen (pH). Scanning Electron Microscopy (SEM) analysis had also been used to monitor and evaluate the impact of nano-scale materials. Results of this study indicated that in the short-term behavior, the effect of nano-aluminum in increasing the strength and setting speed was very tangible. Also the very small percentage of nano-material could be alternative for a significant proportion of cement in the improvement and modification of soil, which reflects the economic impact of nano material as well.

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1- Introduction

Soil improvement is one of the most challenges in geotechnical engineering during past century. Clays and also silts are one of the low-grade construction materials, which find use in impervious elements such as cores (dams), cut-offs, they are poorly drained, and they shrink and swell. Also, clays when wet lose all strength; they are highly compressible, producing undesirable settlement as sub-grades of highways. One of the ways to solve the soil weakness problem is soil improvement [1-7].

The purpose of soil improvement include: increasing strength, reducing deformability and settlement, increasing durability and so on. In the past, to improve soil properties, additives such as cement, lime, tar, fly ash, etc. have been evaluated in studies of other researchers [8-14].

In addition, one of the new additives materials which are used in the reclamation of soil by engineers from different countries of the world is nano-material. Materials in the range of nano often reveal very different physical behavior with atoms and mass material [9-18]. Properties of nano-scale materials can not necessarily be predicted with respect to the material properties on a larger scale. Nanoparticles have very high specific surface area due to their small size and because of the very high specific surface area and surface charges, even use very few of these particles in the soil environment influence on physical-chemical behavior and soil engineering properties specially and significantly [19-22]. In recent years, nano particles such as, nano-silica, nano-aluminum, nano-copper, nano-titanium, nano-magnesium, carbon nanotubes, nano-soil and nano-clay have been used to improve problematic soils [23-28].

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2- Materials

The soil used in this study through boreholes digging manually in the south area in Tehran that the physical characteristics of the soil are summarizes in Table 1.

Table 1. Physical Properties of Base Soil

Soil Classification	CL
Specific Gravity	2.649
Plasticity Index	12.34 %
Plastic Limit	19.26 %
Liquid Limit	31.6 %

Cement used in this study is taken from the Tehran Cement company and is a Portland cement type 425-1.

Nano-aluminum used in the study is a product from US Research Nanomaterial research that is purchased from an intermediary company. In Tables 2 and 3, physical and chemical properties of aluminum nanoparticles are shown.

Table 2. Physical properties of gamma oxide aluminum nano

Purity	More than 99 %
Bulk Density, gr/cm^3	3.89
Specific Surface Area, m^2/gr	More than 138
Average Particle Size	20 nm
Color	White

Table 3. Chemical composition of gamma oxide aluminum nano

Al_2O_3	>99 %
Ca	<25ppm
Fe	<80ppm
Cr	<4ppm
Na	<70ppm
Mn	<3ppm
Co	>2ppm

3- Test Methods

Crucial issue associated with the use of nanoparticles in improving problematic soils is suitable dispersing of nanoparticles. If problem of nanoparticles in soil mass is not resolved correctly, these particles will not correctly display their great impact on soil properties. To run experiment, different weight percentages of nano-aluminum (2%, 4% and 6% relative to the weight of cement used) in the composition of the soil-cement is used.

4- Evaluating and Discussion the Results

According to result, due to adding cement to the base soil, liquid and plastic limit of modified soil with different percentages of cement has increased compared to the unmodified soil. While, their plasticity index (the difference between liquid and plastic limit) has not reduced comparing the unmodified soil. The changes process of Atterberg limits shows that volumetric and plastic properties of soil influenced sharply with adding cement and nano-material.

According to test results, adding cement to the base soil reduces the maximum dry density and increase optimum moisture percent, so that by increasing the percentage of cement it becomes more pronounced. The lowest maximum dry density is related to 8 percent cement that occurred at optimum moisture percent of about 33 percent. In addition, it can be seen that by adding nano-alumina to samples, the optimum moisture percent compared to the base soil improved by 8% cement reduced, while its maximum dry density increases.

Adding cement to the base soil cause increasing unlimited compressive strength, and this increase has a direct correlation with the passage of time. For example, in the curing time of 28 days, unlimited compressive strength of soil improved with 8 percent cement is about 68 percent more than the soil strength improved by 4 percent cement. The results also reveal that also reveals that axial strain corresponding to samples fracture in uniaxial testing is proportional to the amount of cement and curing time, so that increasing cement decreases uniaxial strain of sample fracture. In addition, it is seen that the samples failure strain increases with increasing duration of curing.

However in the processing time of 28 days, the maximum amount of unlimited compressive strength in the sample improved by 8% cement occurs; so that the unlimited compressive strength compared to the base soil 467% and the soil-cement composition with 6 percent nano-alumina 17% have been more.

The results showed that the addition of nano-aluminum to the composition of soil-cement increasing California bearing resistance of samples. It is shown that the value of California bearing correlates directly with the percentage of nano-alumina; so that the maximum value of California bearing for 6% nano-alumina relative to the weight of cement is obtained. For example, the presence of 6 percent nano-alumina in the composition of the soil-cement has increased sample California bearing resistance more than 50 percent compared to the soil improved with 4 percent cement and more than 91 percent compared to the base soil.

5- Microscopic and Chemical Properties

In order to understand the type of structure (microstructure and macrostructure) on exemplary behavior, SEM analysis on the three samples (un-modified, modified with 8 percent cement and modified with 4 percent cement with 6% gamma oxide nano-aluminum) was done. These images captured from samples with curing time of more than a day.

In order to determine the power of hydrogen or pH value of samples, samples with more curing time of 28 days is used. It can be seen that the pH value of base soil is equal to 8.46 which show that the base soil is alkaline. By adding cement to the soil, pH of samples begins to increase.

6- Conclusion

Laboratory tests conducted in this study showing considerable improvement in the soil engineering properties contain nanoparticles. The main results obtained in this study are as follows:

Atterberg limits test results showed that plasticity index of base soil reduce with adding cement, so the slightest indication of plasticity is occurred for 8% of the cement.

The study showed that adding cement to the soil increases the optimal moisture percent and reduce maximum dry density, which these changes increases with increasing used cement.

Uniaxial compressive strength test results showed that adding cement and nano-aluminum are both increase uniaxial strength of samples. It was also seen that by increasing the percentage of cement and nano-aluminum, uniaxial strength will further increase and this increase has a direct relationship with the passage of time.

Addition of cement and nano-alumina increase CBR value of samples. However, the rate of increasing resistance in mixtures containing nanomaterials in early hours and days was very high that this property in many projects that have time limitation is very useful.

SEM images showed that by adding cement to the soil, the soil particles adhere to each other by cementation gel causing agglomeration of the particles and cause increasing pores in the soil-cement composition. The study found that adding cement led to increasing pH value and thus, pH value increases by increasing cement percent.

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