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Nanoclay Performance on Resistance of Clay under Freezing Cycles

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ABSTRACT: This study aims to investigate effect of nanoclay on resistance of the exposed clay soils in freezing in vitro conditions. The clay sample was selected from the considered land. Then they were mixed on water in 1.5, 3, 4.5 and 6 percents as well as without nanoclay. There were prepared cylinders with 3.81 cm diameter and 7.62 cm height, which they have been placed in conditions without freezing, one cycle, two cycles and three cycles of freezing. Then they were tested under uniaxial experiment. Then they were analyzed by SPSS software. The results show that adding nanoclay with 1.5, 3, 4.5 and 6 percents will reduce soil strength during freezing cycles. It can be occurred because adding nanoclay will result to increase special surface of the samples; consequently, increasing electrical load increases water absorption, which it can be partly cause of non-effective increasing nanoclay in soil resistance. There is also a significant difference between pressure strength of soils with lower humidity and those with higher humidity. It confirms that increasing humidity decreases strength level, which increasing water absorption of samples by nanoclay is reason of decreasing strength. There is an inverse significant relationship between increasing nano and soil water absorption, which its reason may be that adding nanoclay because of increasing samples special surface and consequently, increasing electricity load will increase water absorption and samples' plasticity. It can be expected that samples' permeability will decline by increasing their plasticity. There is also a significant relationship between increasing nano and soil liquid and doughiness limit that its reason can be increasing rate of water absorption in samples due to presence of nanoclay.© JASEM

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Nanotechnology has created a new movement in food production systems. Materials will be very small materials, while they get significant new properties, which these properties are not visible at micromolecular or greater levels. A nanostructure material is a solid material with the spread atomic layout, size of forming crystals and chemical composition around the body in few nanometers scale. The ultimate goal of examining materials at nano scale is to achieve a new class of materials, which they can be defined as materials with high performance and versatility (Lines, 2008 and Bouhashen, 2004). Modifying behavioral parameters in different soils is one of the major problems facing researchers in geotechnical engineering. Adding some additives to soil has been always considered as one of effective methods to improve some behavioral characteristics of soil such as relationship between tension-strain- strength, permeability and self-repairing especially in some geotechnical structures including mud dams, road embankments, artificial slopes and landfill sites. Other researchers have examined conventional additives such as cement, lime, calcium chloride, windy ash, bitumen; enclose ion polymers in their studies (Dermatas, 2003; Goitoz, 2005 and Naderini, 2009). In nano field, materials show a very different physical behavior in comparison to atoms and mass materials. Specifications of nano scale materials cannot be necessarily predicted by considering materials' specifications in larger scale. Major changes in materials' behavior are not occurred because of their behavioral constant changes in small sizes, but because of emerging new phenomena such as

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quantum size limitation, wave-like transportation and overcoming surface phenomenon (Goitoz, 2005). Although there have been done few studies to estimate advantages of adding some types of nano-materials to soil, but there is a major problem in doing empirical experiments and applicable data. Adding the obtained nano-soil of ball mill process to variety of fine-grained soils and doing Atterberg Limits tests on them indicate increasing doughtiness and liquidity limits as well as decreasing doughtiness range. Adding nano-soil to the stabilized samples with cement has increased their compressive strength (Mirkazemi, 2010). Clay nano-particles, which they are used in business affairs frequently, are one of nano-materials that there have been performed many studies about it. Nano-clays are clay powders are clay powders, which they are filtered many times and are used to increase strength, resistance against UV, increasing thermal strength and absorbing environmental pollutants (Owhadi, 2011; Speeding, 2005). According the resulted data of compressive experiment on windy ash, increasing organosilan in nano dimensions led to decrease optimal humidity and increase maximum dry special weight. Field studies indicated that soil reform with organosilan led to increase strength, decrease swelling potential and decrease hydraulic conductivity significantly (Dynels, 2009). Doughtiness behavior of fine-grained soils plays a decisive role in many geotechnical constructions such as mud dams. Some of them include effect to reduce cracking, prevent piping and ultimately, increasing stability of mud dams with clay core. Improving uniaxial strength in fine grade soils can increase soil load bearing capacity and foundations' load bearing capacity (Khosravani Moghaddam et al, 2011). As there have not been carried out comprehensive studies about effect of nanoclay on mechanical specifications of clays under freezing, results of the research can provide a better understanding about nanoclay behavior in soil; in this way, nanotechnology can be used in geotechnical engineering effectively.

One of problems of soils, especially fine-grained soils containing clays and silts, is their sensitivity against freezing. In freezing conditions on construction projects, usually increasing the project's height protect soil against freezing. It leads to increase costs of soiled operations in road construction projects. However, some studies have shown that nanoclay improves mechanical properties of clays, particularly their resistivity. This study objective is to investigate effect of nanoclay on strength of clays exposed to freezing in vitro. It is clear that increasing strength the exposed soils against freezing, and in other words, reducing their freezing sensitivity can have a great impact on reducing costs of road construction projects.

There has been emphasized erosion (concrete-soil-rock) by erosion factors (water-air-freezing, etc.) in nature. If we can close erosion, we will provide structure durability and stability. As a result, we want to increase soil durability by reforming soil in the thesis. In order to evaluate impact of durability in short-term, we will perform freezing cycle tests to study effect of nanoclay on increasing clay durability. Purpose of this study is to increase durability of the reformed clay by nanoclay with comparing uniaxial strength of the made samples with different nanoclay percents in diverse freezing cycles.

LITREATURE REVIEW

Majed and Taha (2011) studied effect of nano-materials' behavior on geotechnical properties of soft soils. They used three types of nano-materials (nano-calcium, nano-magnesium and nanoclay) in their investigation. They used nano-materials with 0.05% to 1% to make samples. Then they performed uniaxial and Atterberg Limits tests on samples. Results showed that the samples' Atterberg Limits will be reduced by increasing nano-materials, while compressive strength of the samples will be increased.

Yonkura and Miwa (1992) increased compressive strength of sand samples by using nano-silica. Noll and colleagues (1992) studied effect of nano-silica on strength behavior and permeability of cohesive soils. Galgar (2005) investigated effect of nano-silica on strength behavior and permeability of cohesive soils under dynamic loads. Results showed that adhesiveness power would be increased by increasing percent of nano-silica. In USA, Galgar and colleagues (2007), by using dynamic tests such as dynamic triaxial test, investigated effects of nano-particles on embarking sand soil after earthquake's loads. Zhang (2004) said that soil Atterberg Limits will be increased by adding nano-particles to soil. In 2007, he also studied strengthening effect of nano-particles on soil. His research results showed that adding nano-particles to soil enhance samples' strengthening steadily.

Patel (2012) investigated using nanoclay in cement mortars. He examined samples without nanoclay as well as samples containing 1% and 2% nanoclay

under pressure and permeability tests. The results showed that the permeability constant of samples containing 1% and 2% nanoclay is 150% and 200% higher than samples without nanoclay. In equal conditions, samples containing nanoclay are dried sooner and they have higher compressive strength.
Taha and Ying (2012) investigated effect of carbon nano-tube on kaolin basic geotechnical properties. They performed uniaxial and Atterberg Limits tests on samples without nano-particles as well as samples containing 1% and 2% nano-particles. They found that uniaxial compressive strength and Atterberg Limits of samples would be increased by adding nano-particles.

Fakhri and colleagues (2012) examined effect of nanoclay on clay basic geotechnical properties by using standards density and Atterberg Limits tests.

They used kaolinite clay in their study, which it was CL type based on the unified classification. This type of soil has a low plasticity and therefore, different percentages of nanoclay were used to increase its plastic doughy properties. They built and tested samples containing 0%, 1%, 2%, 4% and 8% nanoclay by using the Monte Morillonite nanoclay.

Results showed that adding nanoclay will increase water absorption as well as samples' plasticity because of increasing special surface of the samples and consequently, increasing electrical load. It can be expected that samples' permeability will be reduced by increasing plasticity, which the properties are very appropriate and expected in core of mud dams.

Owhadi and Amiri (2012) investigated nanoclays' capability to uptake environmental pollutants. They used two commercial cloisite nanoclay in their studies. Their experiments' results showed that compounds containing cloisite have higher power to uptake pollutants. It can be increased by adding carbonate to nanoclay.

Ganji and colleagues (2012) examined changes in soil shear tension before and after applying nanoclay. Their examples included silt clay and the montmorillonite nanoclay. They examined the samples by using standard density and uniaxial compressive tests. Results of standard density test showed that optimal special weight is decreased by adding nanoclay, while optimum moisture content is increased. The shear tension of soil is increased by adding nanoclay, while its angle of refraction is reduced.

Khosrawani and Ghorbani (2012) evaluated effect of nanoclay on engineering properties of adhesive soils. They used commercial kaolinite clay and silt clay, Rasht, as well as the Monte Morillonite nanoclay in their study.

MATERIALS AND METHODS

Nanocloisites are natural montmorillonites that modified by quaternary ammonium salt and are very applicable in asphalt mixtures' physical and mechanical specifications improvement as additives. Their organic modifier is MT2EOH that is formed from methyl, tallow, bis-2-hydorxyethyl and quaternary ammonium. Physical and mechanical characteristics of Nanocloisite are based on table (1). It's need to mention that nanocloisite which is used in this research is supplied from Nanosany company, agent of Rockwood Additive company products, USA .

Table 2. Physical and Mechanical Properties of Nanocloisite

Properties	Specification Data
Treatment	Nanocloisite-30B
Mineral	Montmorilonite
Organic Modifier	MT2EOH
Moisture, %	Less than 2%
Weight Loss on Ignition, %	About 30%
Density	5-7 (gr/cm^3)
Particle Size	1-2 nm
Specific Surface Area	500-750 m^2/gr
Space between the particles	60 A^0
PH	7.3-7.6
The electrical conductivity	25 MV
Modifier concentration	90 meg/100 gr clay

The clay sample was selected from the considered land and they have been prepared as described by subsamples' table. The samples diameter is 3.81 and 7.62 cm.

Table 1. Experiment Samples

Three cycle	Two cycle	One cycle	Without cycle	Freezing Cycle Sample
*	*	*	*	Sample without nanoclay
*	*	*	*	Sample with 1.5% nanoclay
*	*	*	*	Sample with 3% nanoclay
*	*	*	*	Sample with 4.5% nanoclay
*	*	*	*	Sample with 6% nanoclay

EXPERIMENTS AND RESULTS

The clay sample was selected from the considered land. Then they were mixed on water in 1.5, 3, 4.5 and 6 percents as well as without nanoclay. There were prepared cylinders with 3.81 cm diameter and 7.62 cm height, which they have been placed in conditions without freezing, one cycle, two cycles and three cycles of freezing. The freezing cycles were defined as follows:

One freezing cycle: a period from 12 to 24 hours that includes a stage to freeze sample and a step containing 4-12 hours in normal air of melting the sample; Two freezing cycles: two periods from 12 to 24 hours that includes two stages to freeze sample and two melting steps as mentioned; Three freezing cycles: three periods from 12 to 24 hours that includes three stages to freeze sample and two melting steps as mentioned. Total numbers of samples are 40 that they must be tested with uniaxial system.

Fig 1. Sample with 1.5% of nanoclay under one freezing cycle

DESCRIPTIVE STATISTICS

Descriptive statistics refer to all ways to collect, classify, analyze and finally, conclude raw data. Descriptive statistics include a set of tables, charts and indicators. In fact, descriptive statistics provide primary information regarding raw data that normally are not understandable. In other words, descriptive statistics are considered more than other parts of statistics. Perhaps its reason is that all people, even those have no information about statistical and mathematical (no statistical and mathematical insight) can also understand generally by glimpsing a statistical table or various statistical charts. For example, in indicators such as average, standard deviation etc, if we want to provide figures and numbers and even symbols as a statistical table, we should recognize measuring scales and type of the studied data and variables firstly to summarize them properly. In this part of data analysis, there has been listed the most important explanatory indicators of the survey data.

Table 3. Descriptive statistics of different nano content on soil compressive strength

Item	Frequency	Average	Standard deviation	Min	Max
Sample without nanoclay	40	2.474	0.638	1.94	2.774
Sample with 1.5% nanoclay	40	2.604	0.896	1.863	3.9
Sample with 3% nanoclay	40	2.693	0.977	2.248	3.908
Sample with 4.5% nanoclay	40	2.702	0.976	3.321	4.47
Sample with 6% nanoclay	40	2.687	0.906	1.635	3.98

As shown in Table 4-1, it can be seen that soil compressive strength has been identified with different percentages of nanoclay. According the table, average of compressive strength in soils without nano as well as with 1.5%, 3%, 4.5% and 6% nano is 2.474, 3.604, 3.693, 3.702 and 3.687 respectively.

Table 4. Descriptive statistics of freezing cycles on soil compressive strength

Item	Frequency	Average	Standard deviation	Min	Max
Sample without cycle	40	2.501	0.748	2.474	3.010
Sample with 1 cycle	40	1.824	0.556	1.442	2.05
Sample with 2 cycle	40	1.678	0.519	1.278	1.821
Sample with 3 cycle	40	1.040	0.637	0.997	1.605

As illustrated in Table 4.2, soil compressive strength has been identified with different with different levels of freezing cycles. According the table, soil compressive strength without freezing cycle as well as with one, two and three freezing cycles are 2.501, 1.824, 1.678 and 1.040 respectively.

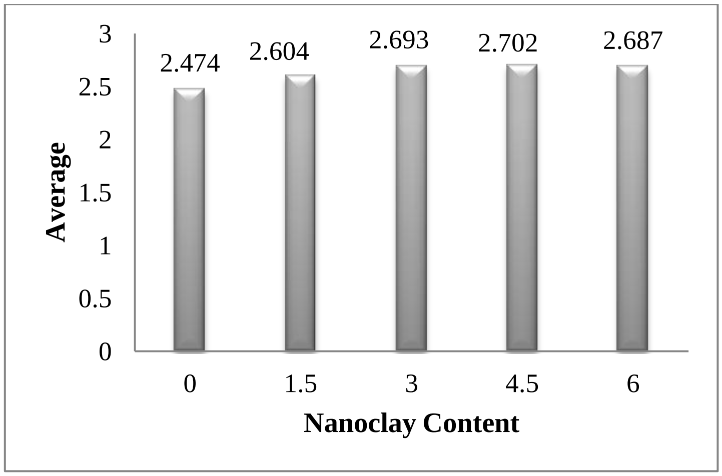

Fig 2. Soil compressive strength with different percents of nanoclay

According to Figure 4.1, soil compressive strength has been identified with different percents of nanoclay. Based on the Figure, compressive strength of soil without nanoclay is lower than all, and compressive strength of soil with 4.5% and 6% nanoclay is more than all.

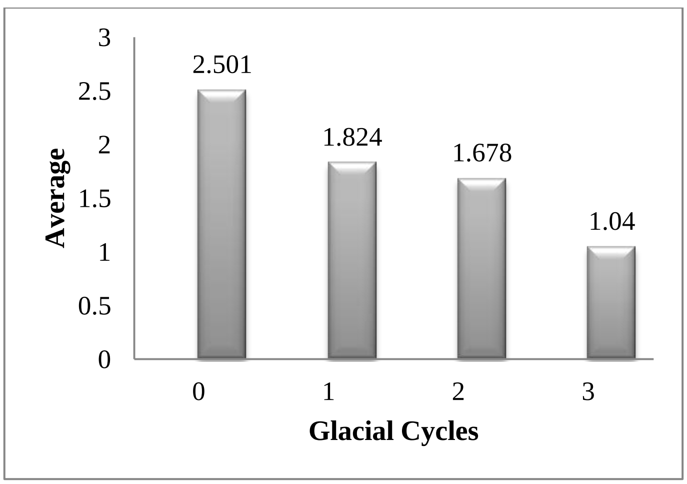

Fig 3. Soil compressive strength with different levels of freezing cycles

As shown in Figure 4.2, soil compressive strength has been identified with different levels of freezing cycles. Based on the Figure, compressive strength of soil without freezing cycles is more than all, and compressive strength of soil with three levels of freezing cycles is lower than all.

Discussion; For the present research and examining nanoclay effect on clay mechanical specifications exposed freezing effects, the clay sample was selected from the considered land, and there were caulked samples containing 1.5, 3, 4.5 and 6 percents as well as without nanoclay. There were prepared cylinders with 3.81 cm diameter and 7.62 cm height, which they have been placed in conditions without freezing, one cycle, two cycles and three cycles of freezing. Then, the hypotheses were studied by using uniaxial testing machine and obtain the density, permeability, Atterberg Limits and grain size data by using SPSS software. The first hypothesis deals with effect of nanoclay, freezing cycles and their combination on soil compressive strength. Its findings indicate that average soils compressive strength without nano is significantly lower than soils with 1.5%, 3%, 4.5% and 6% nano. Adding percent or decreasing nanoclay indicated significant difference. In other hand, soil compressive strength without freezing cycle is significantly greater than soils with one, two and three freezing cycles. In another test, independent T-test showed that there is a significant difference between average soil compressive strength with less freezing cycles and more freezing cycles.

Therefore the results illustrate that adding nanoclay impacts compressive strength of soils without freezing cycles, and strength of samples with nanoclay is significantly greater. During freezing cycles, soil strength will be reduced by increasing nanoclay. Recent result corresponds with results of Majed and Taha (2011), Taha and Ying (2012) and Khosravani and Ghorbani (2011).

The second hypothesis deals with effect of nanoclay, freezing cycles, soil humidity and their combination on soil compressive strength. Its findings indicate there is a significant difference between soil strength with lower humidity percent and greater humidity percent, as which soils with lower humidity indicate further strength. It approves the matter that strength level will be decreased by increasing humidity, and water absorption in samples by nanoclay is the reason of reducing strength.

By examining results of relationship between increasing nano and soil specifications (density, permeability and Atterberg Limits) in lateral findings of the research, it was concluded that there is a reverse and significant relationship between increasing nano and soil density and permeability in level of 99% confidence. It can be occurred because adding nanoclay will result to increase special surface of the samples; consequently, increasing electrical load increases water absorption and samples' plasticity. There is a significant difference between increasing nano and soil fluency and doughtiness limits, which can be occurred because of increasing water uptake in samples adding nanoclay will result to increase special surface of the samples due to nanoclays presence. These results correspond with results of Khosravani and Ghorbani (2011) and Majed and Taha (2011).

Conclusion: Results indicate that adding 1.5%, 3%. 4.5% and 6% nanoclay lead to reduce soil strength. It can be occurred because adding nanoclay will result to increase special surface of the samples; consequently, increasing electrical load increases water absorption, which it can be partly reason of non-effectiveness of increasing nanoclay. There is a significant difference between compressive strength of soils with lower humidity percent and greater humidity percent, as which soils with lower humidity indicate further strength. It approves the matter that strength level will be decreased by increasing humidity, and increasing water absorption is the reason of reducing strength. There is a reverse and significant relationship between increasing nano and soil density and permeability. It can be occurred because adding nanoclay will result to increase special surface of the samples; consequently, increasing electrical load increases water absorption and samples' plasticity. There is a significant difference between increasing nano and soil fluency and doughtiness limits, which can be occurred because of increasing water uptake in samples due to nanoclays presence. Examining effect of freezing cycles and thawing in clays with different salts; Evaluating effect of freezing cycles and thawing on springy modulus; Examining effect of other nanoclays on soil behavior in freezing and thawing cycles;
Evaluating effect of natural nanoclay on soil behavior in freezing and thawing cycles

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