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The exploration into the effect of nanoclay additive on soil geotechnical-engineering basic properties

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ABSTRACT

The present article is conducted in order to examine the impact of adding a type of Nanoclay on plasticity properties in fine grained soils. For this purpose, a group of Atterberg limit tests have been carried out on low-limit plasticity clays, which have been extracted from borrow-pit supplies in embankment dam with clay core (Mamloo Dam) and their mixtures were obtained with several percentages of Modified Montmorillonite Nanoclay (MMN). The results indicated noticeable increase in Plastic Limit (PL) by adding small amounts of the given Nanoclay that is due to exertion of main modification in Liquid Limit (LL) at the aforesaid mixtures. The similar results from the conducted experiments on soil and betonies, which mainly included non-modified Montmorillonite mineral, verified the observed trends of changes but it has shown fewer changes.

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INTRODUCTION

One of the important issues to which many researchers are exposed in geotechnical engineering is the modification of behavior in various soils. Adding some additives to soil has been always considered as one of the effective methods in improvement some of soil behavioral parameters like stress-strain-strength relationship, penetration and self- remediation, particularly in geotechnical structures such as soil dams, road embankments, synthetic gables, landfill centers, land exploitation projects etc. The current additives like cement, lime, calcium chloride, fly ash, tar (bitumen), and polymer inclusions etc have been explored in studies by other researchers [1-4]. Along with this trend, nanomaterials possess unique properties and their application has led to fundamental transformations in other branches of engineering sciences but they are less noticed in geotechnical engineering.

Within nano range (one billionth or 10^{-9}m), the objects may often show a very different behavior from the atoms and massive materials. The properties of material at nano scale may not be necessarily predicted with respect to properties of matters at larger scales. The important changes are not only exerted in behavior of materials with constant behavioral changes of materials in small sizes, but also due to emerging new phenomena like restriction of quantum size, pseudo-wave transfer, and dominance of surface phenomena [5].

The investment in Developed Countries at macro level for conducting researches on nanotechnology represents the special importance of this modern technology at present time. About 5.5 billion $ are annually spent for investment in studies on nanotechnology throughout the world [6].

Although, few limited studies have been carried out in order to evaluate the advantages of adding some types of nanoparticles to the soil, a great gap is seen in conducting empirical tests and practical data in this field. Addition of the obtained nano soil from ball mill process to many types of fine grained soils and doing Atterberg limit tests on them may indicate rising of plasticity and liquid limits but it has led to reduced Plastic Limit (PL). Similarly, adding nano soil to the stabilized samples with cement has increased their compressional strength [7]. According to the given data from test of compression on fly ash, the increase in Organo-Silane amount at nano dimensions has led to reduced optimal moisture and rising of the maximum specific dry weight and field studies indicated that soil modification (remediation) by Organo-Silane will be followed by rising strength, reduction in inflation potential, and noticeable decrease in hydraulic conductance [8].

The plastic behavior of fine grained soils may play determinant role in many geotechnical constructions like embankment dams. Out of them one can refer to reduced capability for creation of crack, prevention from

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occurrence of piping effect, and eventually increase in strength of embankment dams with clay core. The experiments have been conducted in the current essay in order to evaluate plastic behavior of fine grained soils when they are mixed with nanoclay additive. Thereby an efficient step was taken in employing nanotechnology in geotechnical engineering and to draw attention by the researchers in this modern field.

Materials:

Clay soil:

The selected clay soil was extracted from borrow pit supplies of clay core in Mamloo Dam. The Mamloo reservoir dam has been constructed in 35km distant from northeastern side of Tehran city in order to control and regulate the water flow of Jajrood River in a location after its crossover with Damavand River. This dam is made of soil type with clay core that its shell made of fluvial materials, which are placed on an alluvium with maximum 23m diameter. The grading of the used materials is described in Fig (1).

Modified Montmorillonite Nanoclay (MMN):

The used clay in this product includes (Ca++, Na+, Mg++- MMT) in its structure. The mean diameter in each of its elements is less than 25 nm and it comprises of more than 95% montmorillonite mineral. The physical and chemical properties of this product are given in Table (1).

Table 1: Specifications of Modified Montmorillonite Nanoclay (MMN).

Apparent density	Thickness of crystalline film	The amount of existing moisture	Density	color	Distance of sheets	Montmorillonite percentage	Dimensions of layers
0.45 gr/cm³	< 25 nm	< 3%	1.8 gr/cm³	Light white	1.2- 3.5 nm	95- 985	1×25×1000nm

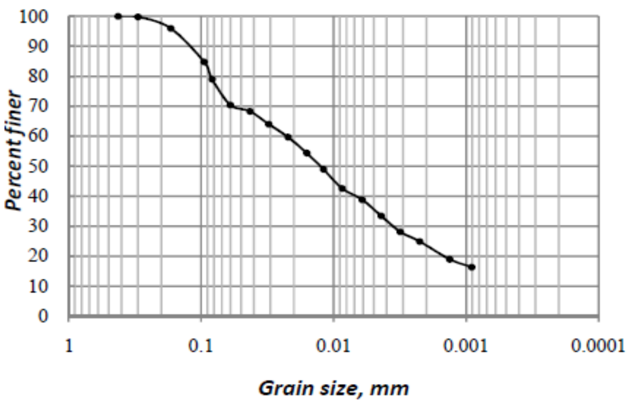

Fig 1: Grading of the used clay soil by the aid of sifter and hydrometric technique.

Bentonite:

The specifications of this material are given in Table (2). Given this fact that bentonite mainly includes natural montmorillonite (non- modified), it was selected in order to evaluate the effect of dimensions of particles in additive materials to compare them with the tests in which MMN was used.

Table 2: Specifications of the used bentonite.

Water soluble solid materials	Specific weight	The percentage of left residue on sifter 200	The percentage of left residue on sifter 325
1.0%	4.2 gr/cm³	3%	155

Method of implementation:

To prepare the given sample, 1, 2, 4, and 8 wt % of MMN were added to the soil that was passed through mesh sifter 40. The mixture operation should be continued up to acquisition of a homogeneous sample and this required consuming about 45 min time. Electric mixer (low speed) was utilized in such a way that not to separate additives in foamy form and also the sample was stirred up manually. Then distilled water was added to the sample within the plastic limit and the resultant sample was stored in air-tight vessel for 16 hours. It is because of this fact that absorption of moisture from clay particle is a time- consuming process.

Afterwards, according to BS1377-2-1990 standard in sections 4 and 5, the tests were done to determine Plastic Limit (PL) and Liquid Limit (LL). Plastic Limit was acquired based on 3mm Edge Wicking

Measurement Technique and Liquid Limit was derived according to fall cone test (penetration). To verify the precision of the given results for Liquid Limit, test of Casagrande Cup was also carried out for some states. In all cases, the derived figure from liquid limit was about 1 unit greater than the figure that was obtained from fall cone test compared to corresponding test by Casagrande experiment. At last, tests were repeated by means of bentonite instead of MMN.

Results and their interpretation:

The results indicate that the given nanoclay has not exerted a remarkable change in amount of Plastic Limit (PL), but it has increased noticeably Liquid Limit (LL); therefore, addition of Modified Montmorillonite Nanoclay (MMN) has caused increase in Plasticity Index (PI) in the soil (Table 3 and Fig 2). Addition of 8% MMN to soil has increased plasticity index (PI) up to 68% and this is considered as a major change.

Table 3: Plasticity Limit (PL), Liquid Limit (LL), and Plasticity Index (PI) of soil with various percentages of MMN additive and betonies.

PI (%)		LL (%)		PL (%)		Additive (%)
Bentonite	MMN	Bentonite	MMN	Bentonite	MMN	
12.58	12.58	31.62	31.62	19.04	19.04	**0**
15.14	14.16	34.14	33.03	19.00	18.86	**2**
16.20	15.45	35.65	35.50	19.45	20.04	**4**
19.44	21.09	38.76	40.74	19.32	19.64	**8**

The conducted tests on soil and bentonite mixtures confirm rising trend of plasticity index (PI), but the rate of this change is smaller than in soil and MMN mixtures (Fig 3). This phenomenon may be assumed as the effect of dimensions of MMN additive.

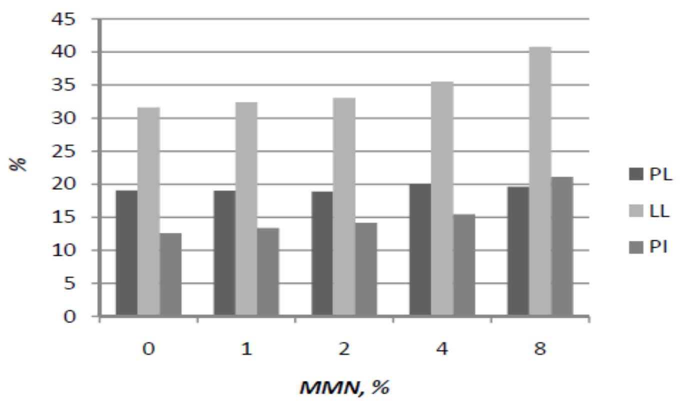

Fig. 2: Plasticity Limit (PL), Liquid Limit (LL), and Plasticity Index (PI) of soil with various percentages of MMN.

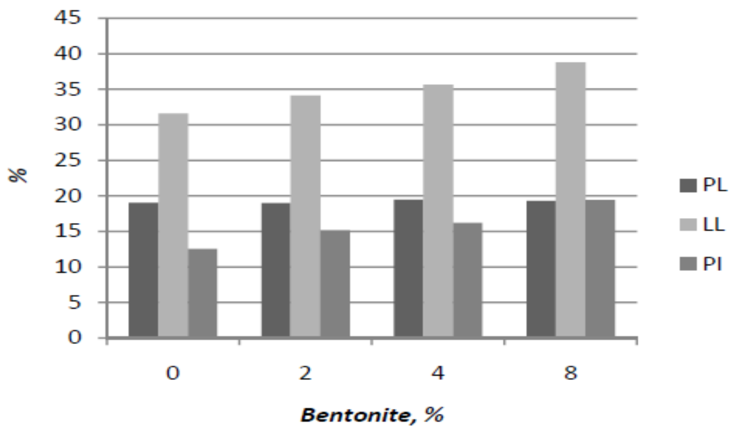

Fig 3: Plasticity Limit (PL), Liquid Limit (LL), and Plasticity Index (PI) of soil with various percentages of Bentonite.

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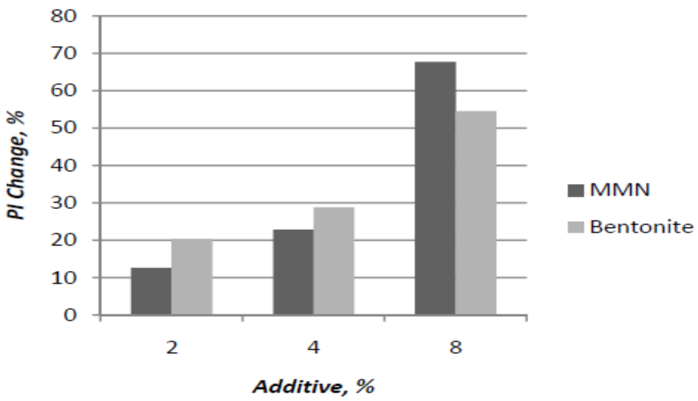

Fig. 4: Noticeable increase in Plasticity Index (PI) a comparison in rising trend of soil mixtures with MMN and Betonies.

Therefore, Modified Montmorillonite Nanoclay (MMN) may be assumed as an appropriate candidate for remediation (modification) of soils in which they requires plasticity properties at higher level. Some of these cases comprise of clay core of embankment dams when access to appropriate barrow- pit supplies may require consuming longer time with exorbitant cost [9].

Conclusion:

A group of Atterberg limit tests were done to evaluate the rate of Modified Montmorillonite Nanoclay (MMN) effect on plastic behavior of fine grained soils. For this purpose, barrow-pit supplies of clay core in embankment dam were employed. The results indicated a noticeable increase in plasticity index of the given mixture with lower percentages of nano additives. This fact may be useful in many geotechnical projects including clay core of embankment dams since higher plasticity index may lead to reduced capability for cracking property, rising of strength and resistance against piping effect, and finally increased strength of the dam.

In order to measure the effect of dimensions in additive material, similar experiments were carried out on soil and bentonite mixtures. Bentonite mainly comprises of non- modified montmorillonite minerals and it can be considered as an appropriate option to compare with MMN. The given results have approved the incremental trend of changes in previous tests but it indicated lesser amount of changes.

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