Investigation of Nano-clay effect on geotechnical properties of rasht clay

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Abstract

One of the Nano material´s application that can be mentioned is enhancing different soils resistance .Adding some pieces of additives to soil, as one of the effective technique to improve some behavioral parameters of soil, such as stress- strain, strength, permeability and self-repairing, specially in some geotechnical structure like soil dam, embankments, site of trash burning, projects of producing land and so on. have always been had in mind. These additive such as lime, calcium chloride, have been considered by researchers[1].In this experimental study a different percent of Nano-clay Montmorillonite has been used in order to check out created changes in soil characteristics with increasing percent of Nano-clay. For gaining optimal water percent and maximum specific weight compaction test have been done on soil and the direct shear test, unconfined compression test ,CBR test and Atterberg limits have been implemented on soil at the given percent of water. Test have been done in two ways, first by using Nano-clay for different percent and second by not using Nano-particles soil. The consequences of implemented test of the study show the improvement of soil properties by increasing low percent of Nano-clay; this improvement are kept fixed after a definite amount.

Keywords: Soil Improvement, Montmorillonite ,Atterberge limits, Direct Shear,

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1.INTRODUCTION

On of technics for improving soil properties that was not investigated before was to use Nano- material. Used additive used to be cement, tar, lime, chloride calcium, fly ash and so on[1]. By adding these materials to soil we can accomplish increasing strength, decreasing deformation, massive stability, increasing durability and decreasing permeability. Beside these mentioned materials, Nano material having unique features and using them causing fundamental changes in other branches of engineering science ,are less considered in geotechnical engineering. In this study Nano-clay impact on engineering features of Rasht soil have been studied.

Using these material tend to increase in another branch of civil engineering that one of them is to enhancing concrete resistance. The used Nano- material is usually smaller than finest particles about 1 to 100 nm. Nano- particles is more reaction able than soil particle

itself due to their high specific area. Because of this very high specific area and superficial loads we can gain a high percent of properties improvement by using a low percent of theseparticles[2].

Nano-particle attribute to bit having at least one dimension on Nano scale. Considering that Nano-particle has several dimension on Nano-scale, these particles are divided in three general category: Nano sheet having a dimension on Nano-scale(such as some sheet clay particle), Nano-tubes having two dimension on Nano scale(Fiber particle) and Nano dots having three dimension on Nano scale. According to definition, Nano-material are determined on the basis of their farting sizes. Generally, when the size of particle reduces to Nano-meter scale, it shows very different behavior or much more promoted characteristics as compared to their opposite point on larger scale. These difference are caused by two reasons:

1- The area of much increased surface
2- Quantum impact

When particle size decreases, the more percent of atoms and molecule appears on surface; thus the features of surface (such as physical, chemical, electrical and reactivity) grow important and dominant ; as much as their mass feature get less significance. Nano particles if present much little in soil can influence engineering properties and physical-chemical behavior of soil considerably because of having characteristic such as area of high specific surface, superficial loads and Nano-porosity sometimes[2]. Soil having Nano-particle with enter-particle porosity shows higher plasticity and liquid limits. This presence of fiber Nano particle cause to increase Thixotropic in soil so that it enhance te shear strength of soil.

In limits of Nano-particle, objects often show very different physical behavior to atoms. The features of Nano-scale material necessary can not be predicted by concerning material features in a larger scale. Important changes in material behavior can be made not only by continuous changes of behavior of material in small scale but also by emergence of new phenomena like quantum size limitation, semi –wavy transportation and by overcoming superficial phenomena[3].

In this paper, soil properties have been studied by doing experimental tests for sample containing aNano- clay. Considering that plasticity behavior of clay soil affects in many cases like applying core of earth dams ,controlling leakage , and avoiding the phenomena of piping and so on, we can find out the importance of investigating this subject. The importance of studying resistant properties of clay soil can be considered because of constructing roads whose sub base are composed and because of homogeneous dams formed by clay soil and large-seed soil.Broad studies in the field of Nano- particle effect for improving parameters of soil strength was conducted. ION Cora and Miwa[1992]used these particles for strengthening pressure resistance of soil [4]. NOL et al [1992] studied the effect of silica Nano- particles for enhancing resistance against permeability and strengthening [5]. In 2005 these particles was for increasing cohesion and reducing viscosity. Finally it appeared that the amount of cohesion related to the percent of Nano-silica particle [6]. Patricia et al[2007] used Nano materials experimentally where the soil was the kind of sand with high viscosity ,reported 40% reduction in deposit by applying artificial earthquake [7]. Zhang[2004] persisted the fact that increasing Nano- structures in soil cause to enhance the Atterberg limits[8].

Nano-particle that used is Nano-clay(reformed Montmorillonite na+). It is much used in geotechnical engineering.; Nano-clay is also outstanding since this Nano is made of clay which its characteristic are well-known.
In order to lab checking out of the effect of Nano-particle on different properties of soil, divergence tests are selected. So the Atterberg limit tests is used to study the effect of mentioned Nano-particle on plastic features of soil. I this test two different weight percent of Nano-clay is applied in soil.(1% & 2% Nano-clay). Unconfined pressure test ,direct shear test and CBR test are used as strength tests to study the influence of Nano-clay on features of soil strength. In these tests four different weight percent of Nano-clay(0.5%, 1% , 1.5% , 2% Nano-clay) used to study created changes by increasing of Nano-clay percent.
Plastic behavior of tiny-particle soil play important role in many geotechnical structure such as soil dams. For example it causes to decrease the capability of cracking, to prevent liquefaction and finally to increase stability of soil dams with clay core. It this study by using lab tests, change of soil behavior is studied after being mixed with Nano-particle. If Nano-particle soil such as Nano-clay is used for improving soil features, the problem of environment pollution is going to be demolished completely since the origin of particles is natural soil in fact.
Laboratory studies
Materials:

1- Nano-clay (Montmorillonite)

Needed Nano-clay in this research is reformed (Montmorillonite) (na+). Chemical combinations and physical features of Nano-clay are shown in table 1 and 2.
Formula and chemical combination:

$(Na,Ca)0,(Al,Mg)2Si4O10(OH)2•(H2O)$

Table 1:chemical combination of Nano-clay

chemical combination	percent
Na2O	1.13
CaO	1.02
Al2O3	18.57
SiO2	43.77
H2O	36.09

Table 2: physical features of Nano-clay

Specific area	750(m2/g)
Particle size	10 (nm)
Density	2.35 (gr/cm3)

2-Soil

The tested soil in this study have been gained through the excavation in Rasht city; the curve of soil graining is shown in the figure 1 that gained by hydrometer test. After doing

the test of Atterberg and hydrometric test on the sample, the given soil was gained clay with high liquid limit according with Unified Soil Classification.

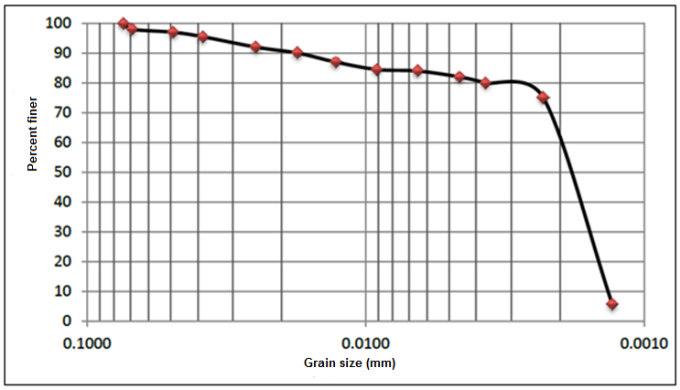

Figure 1: diagram of soil graining in hydrometer test

The test results of Atterberg limit containing plastic limitliquid limit and plasticity index of soil is shown in table 1.

Table 1: Atterberg limits

soil	Plastic limit	Liquid limit	Plasticity index
Rasht soil	30.11	62.5	32.39

The implemented tests

Considering that the combination of soil and Nano is carried out into the percent of optimum moisture of soil, Standard compaction test based on ASTM standard have been implemented on soil of clay. After gaining the percent of optimal humidity from standard compaction test , direct shear tests ,unconfined compression test and CBR test have been done in percent of optimal humidity based on ASTM standard.
The first test was direct shear test and it ought to be considered that the test soil is placed in box of 5.5 and 2.3 cm bilateral height .The process of this was strain control [9]. according to More –Colom theory, neither normal stress nor shear stress does not cause failure by itself ,but combination of these stresses causes failure of soil .According to this theory when in a pile of soil an failure happens , the following relation occurs in one of the its plates between shear tense and normal tense. More stated there is relationship between τ and σ and Colom proved this relation as a linear as followed.

$$\tau = C+\sigma \tan \varphi \qquad (2)$$

that c and σ are cohesion and normal stress respectively.

Another test is known by unconfined compression and simple pressure has defined according to standard no . ASTM 2166-87 .The purpose of this test is to measure the shear resistance of cohesive soil approximately. since in the test the sample is examined without side pressure; and grainy soil can not to be formed a cylinder without lateral pressure, this

test is just for cohesive soil .Unconfined compression test, indeed, is a kind of 3 - axialtest (uu) in which lateral pressure is zero .Through the test result we can compute the cohesion (cu) in clay soil.

$C_u = q_u/2$ (1)

Where q_u is unconfined strength

CBR test was implemented on the soil containing Nano-clay according to ASTM D1557 .the test is the most common method to determine the relative strength of the soil that used for road building. The result of this test shows the shear resistance of soil. It is clear that, this number is not constant and is relative to the compaction and moisture condition of the given soil. According to the standard CBR is defined as follows:
CBR=(Load used in test/standard Load)×100

Finally atterberg test on given soil have been implemented in two ways of using and not using of Nano-particle. Liquid limit and plastic limit tests have been done according to ASTM standard[9]. Liquid and plastic changes have been computed after and before adding Nano- clay and then compared. Concerning the research the test has been done in two ways of using two different percent of Nano-clay(1% and 2%)and not using of Nano – clay.
For better studying of Nano- clay affect on soil, SEM pictures and IDFix analyze have been taken form sample of compacted soil with 1% and 2% Nano-clay.

Test Result

The result of atterberg test on condition of using Nano-clay(1 and 2 percent) and not using Nano-clay are presented in figure (2). As figures appears adding Nano-clay to soil has caused to increase liquid and plastic limit so that the increasing process of plastic limit is more than liquid limit; consequently these changes cause to reduce plasticity index of soil(PI). I addition as Nano percent of soil increases, the role of changes enhance as well. The effect can be used in soil with high plasticity since this kind of soil after having been dried exposes to contraction [7] and show high hydraulic conductivity of soil that is going to be harmful for some soil structure .Nano-material influence plasticity features of soil in three conditions:

1- The area of very large specific surface and superficial loads: superficial loads of Nano- particles usually are connected with hydrated Cation. the very large specific surface causes a wide intra-particle interactions[2]. Nano-clay particles as compared to clay particle of micron size differentiate too much in a few feature like the area of specific surface, superficial loads and Nano-porosity
2- Nano-porosity of intra-particle usually exist in Nano-holes of intra particle because of absorbing and hydration within formation process of mineral water. Although this amount of water con not cooperate or take part in. superficial interaction of particles with particles so specially and prominently, it spoils within drying process in warming room; thus it can cooperate and participate in large atterberg limits of porosity Nano-particles[2].
3- Micro structure in compacted and mass form are strong and tight having some holes and filled up with water; they hardly ever scatter and fall while soil plastic

test are done for measuring atterberg limits. Similar water existing inside intra particle holes and laid water inside compacted structure in atterberg limits cooperate and participate[2].

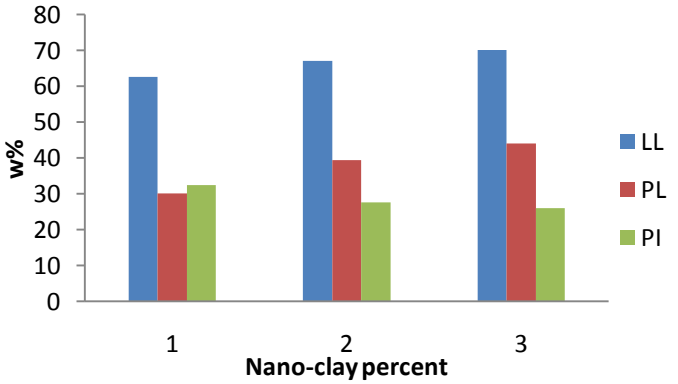

Figure 2: Atterberg limits (1, 2 and3 in diagram respectively shows a 0% , 1% and 2% of Nano-clay)

Doing direct shear and unconfined compression tests require percent of optimal humidity for soil. This percent have been gained from compaction test and presented in figure 3. As it appears in figure the percent of optimal humidity for soil is 23% and dried maximum specific weight of soil is 1.46 gr/cm^3 which are used to build some specimen of unconfined and direct shear tests.

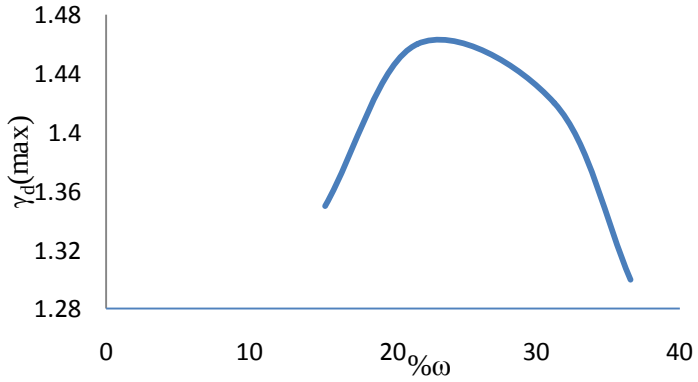

Figure 3: compaction test on primary soil

Specimen of direct shear have been taken in 4 different percent of Nano-clay (0.5,1,1.5,2 percent) and in the condition on not using Nano-clay. As appears on figure 4, when Nano material increases, shear strength of soil increase, This increasing in outstanding to 1.5 percent. After that it dose not change in shear strength of soil. Although Nano-materials cause to increase interlocking of intra-particle and angle of friction of soil, this change is low and shear strength increase in added soil to Nano material occurs as a result of cohesion enhance.

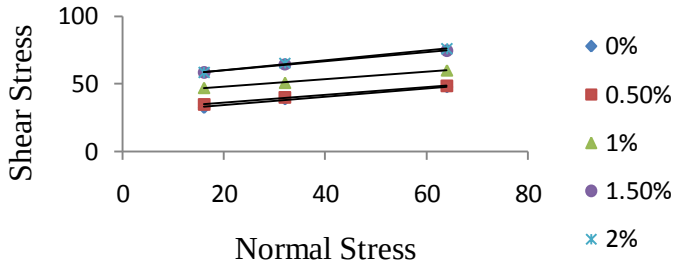

Figure 4: the process of shear strength in direct shear test.

Cohesion increase in soil and being filled up of holes are clear in figure 5 and 6(SEM picture). As we can see in picture below Nano enhancement from 1 percent to 2 percent causes to fill holes within soli; so this being filled appears in shear strength .

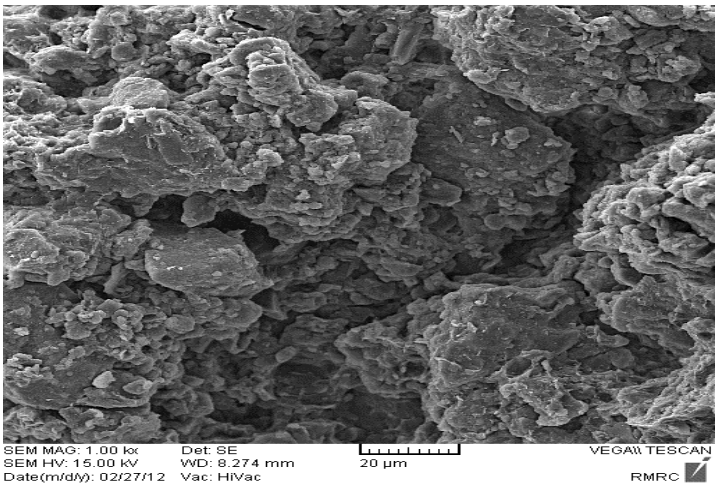

Figure 5: picture SEM from sample containing 1% Nano-clay

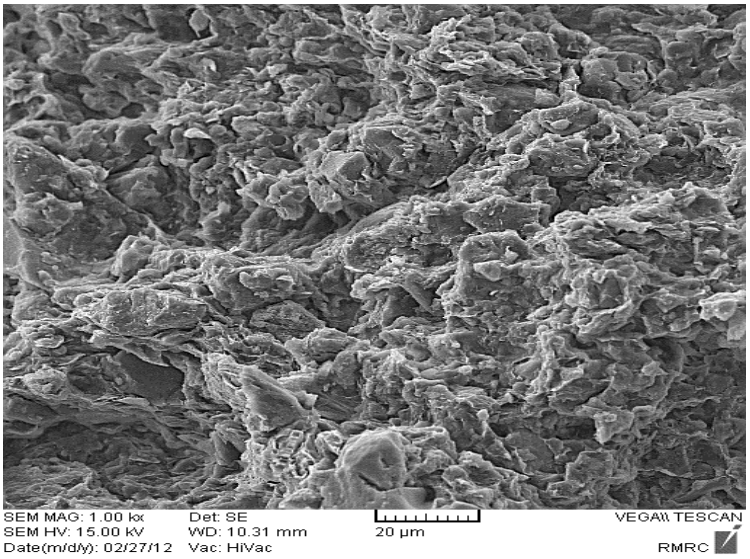

Figure 6: picture SEM from sample containing 2% Nano-clay

The result of unconfined compression test is shown in figure 7. As we can understand from this diagram, increasing Nano-clay up to 0.5% dose not influence in soil strength. As Nano-clay percent increase the final strength of soil enhance, and when the percent

of Nano-clay reaches to 1.5 %, the soil shows the maximum strength. And when Nano percent increase from 1.5% to 2% ; the final strength in specimen reduce.

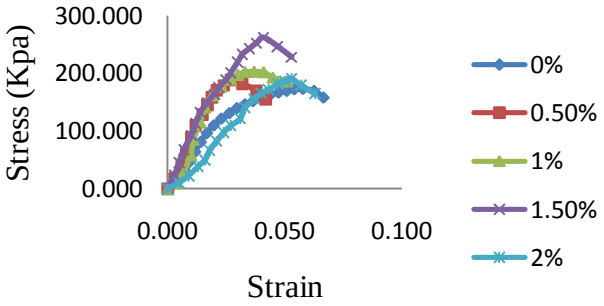

Figure 7:unconfined compression test for samples containing Nano-clay

The result of CBR test is shown in figure 8. As we can understand from this diagram, increasing Nano-clay up to 0.5% dose not influence in soil strength. As Nano-clay percent increase the final strength of soil enhance, and when the percent of Nano-clay reaches to 1.5 %, the soil shows the maximum strength. And when Nano percent increase from 1.5% to 2% ; the final strength in specimen reduce. By comparing the result of CBR test and unconfined compression test it can be find that CBR test, soil strength is increased at the same percent of Nano-clay.

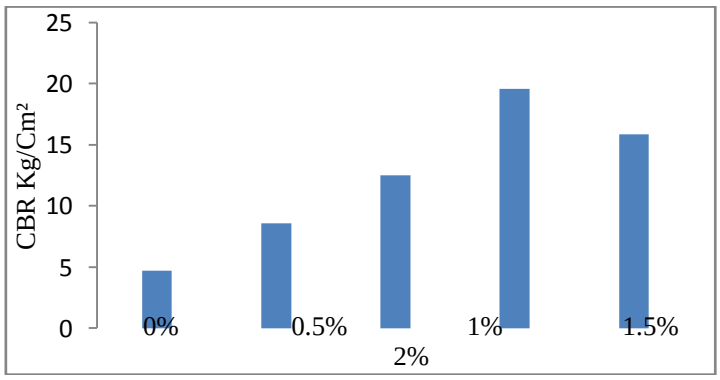

Figure 7:CBR test for samples containing Nano-clay

IDFix analysis are taken on soil specimen with 1% and 2% Nano-clay. Their result are shown in diagram of figure 9 and 10. This analyze is made by radiating ray on micro and determining existing elements in soil in. we can realize from diagrams that percent of elements that exist in Nano-clay combination increase by enhancing the Nano-clay percent in soil. For example percent of O and SI elements in sample increase as Nano-clay enhanced.

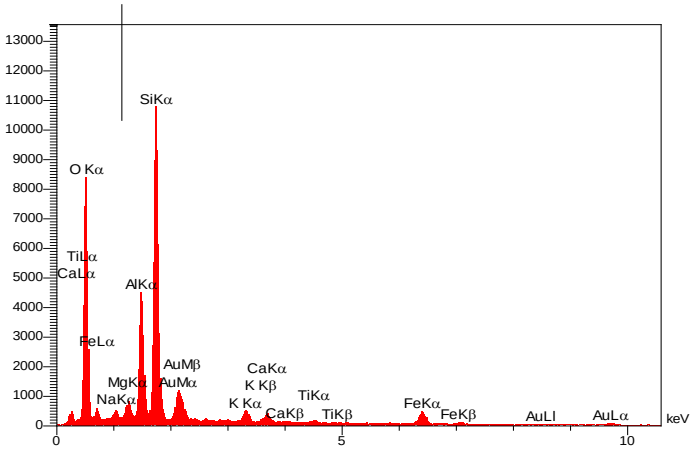

Figure 9: diagram of IDFix analysis with 1% Nano-clay

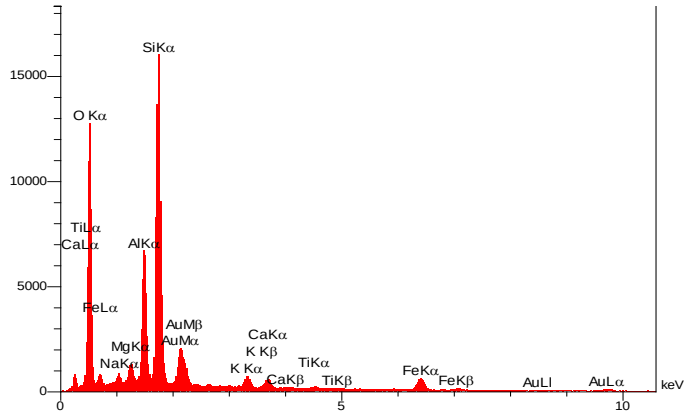

Figure 10: diagram of IDFix analysis with 1.5% Nano-clay

CONCLUSIONS

The most common method for soil improvement is stabilization by using additive. Improving soil properties accompanied with Nano-material can be used to solve geotechnical problems. According to implemented tests, adding Nano-clay to soil causes to increase liquid limit and plastic limit of soil but plastic index reduce(PI=LL-PL) in soil. The effect of Nano-material in soil properties are created by area of very large specific surface and superficial loading, Nano-porosity of intra-particle and micro structure of mass and compacted form. By adding Nano-clay soil shear strength of soil increase and that is because of cohesion enhance; this keeps increasingly to 1.5% and then no change happen. Final strength increase by increasing Nano-clay in unconfined compression test and CBR test. When Nano-clay percent in soil reaches to 1.5% percent , soil has maximum final strength. As Nano-clay increase to 2% the final strength of specimen reduce. 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. Moreover this material can be used with another additive like lime, cement, fly ash and so on to see the combination effect of this material on soil.

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