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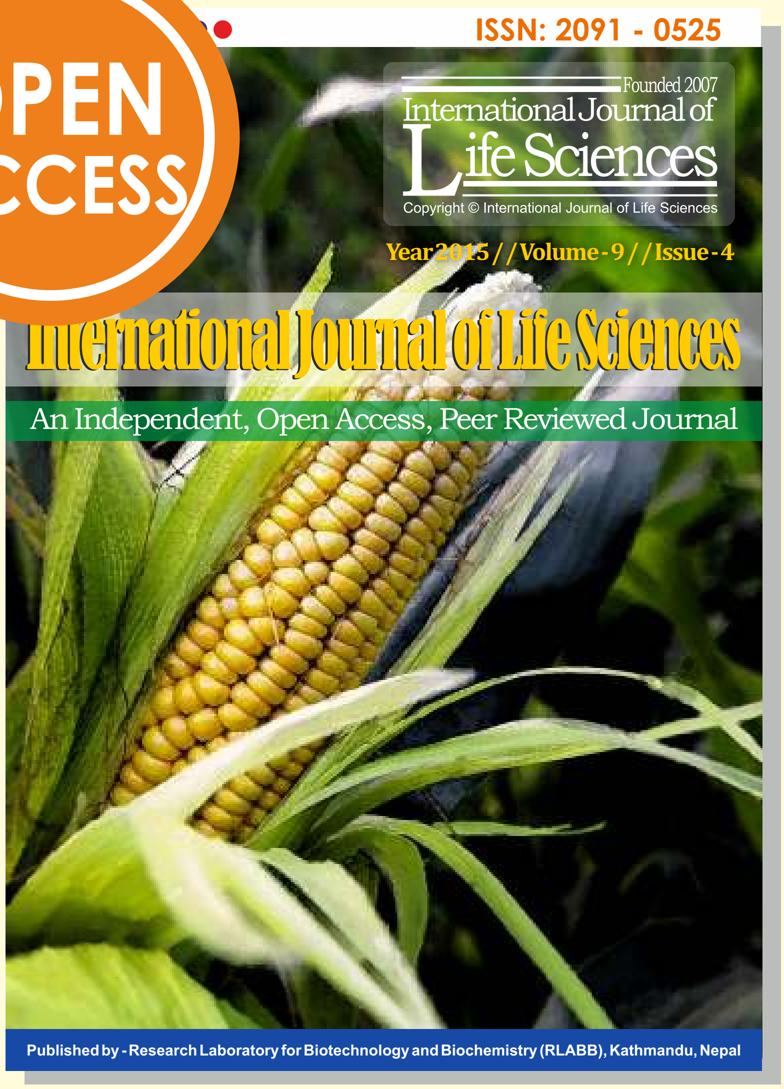

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Research Article

The Effect of Nanoparticles on Geotechnical Properties of Clay

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Article Information

Key words:
Nanoparticles;
Soil; nanoclay;
CBR tests

ABSTRACT

Nanoparticles are one of the newest materials that can be used in soil stabilization. The effect of Na + modified montmorillonite nanoclay on clay engineering properties has been examined in this study. At first, it is used for dispersing nanoparticles into soil and preparing samples. Used nanoclay content by dry weight percentage of soil is 0.5, 1, 1.5 and 2%. Variations caused by increasing nanoclay content were studied. Soil compaction test was performed in order to achieve maximum specific weight and optimum moisture content. Tests were conducted using nanoclay and then without it. The obtained results show that liquid and plastic limits rise with increasing nanoclay content. In the uniaxial and CBR tests, the highest soil resistivity can be seen by adding 1.5% of nanoclay. Low percentage of nanoclay generally improves the soil properties.

INTRODUCTION

Soil is the basic component of any structure that effectively distributes loads. Soil Strength and stability play a major role in preventing structural subsidence, cracks and fissures. Soil stabilization is one way to overcome the weak soil. Increased bearing capacity, controlled deformation and increased strengthening speed, leakage control, reduced permeability and more are the main goals of improving and stabilizing the soil. Soil modification using additives such as cement, lime, asphalt, polymeric materials, etc. improves its properties. Investigators have been long using them for their researches (Munfakh, 1997; Haussmann, 1990; Indraratna et al., 2005; Wardani and LO, 2009). Nanoparticles along with these materials have unique features that are used less. Nanoparticle is to have at least one dimension in the nanoscale. Nanosized particles show different behavior with enhanced properties compared to larger particles. According to the characteristics such as high specific surface, engineering properties and physical and chemical behavior of the soil may be influenced by surface loads (Zhang, 2007). Soils having nanoparticles with intraparticle porosity typically show more plastic and liquid limits (Zhang et al., 2004). Increased shear strength of the soil due to nanoparticles intensifies soil thixotropic. In cases such as leakage control, the impact of clay plasticity detects its importance. Extensive research has done on nano-particles. Zhang *et al.* (2004) stated that soil nano-structure increase resulted in Atterberg limits. Noll *et al.* (1992) studied the effect of silica nanoparticles on soil permeability. In 2005, these particles were used to increase adhesion and decrease viscosity. Finally, it was found that the adhesion is correlated to nanosilica content (Gallagher and Lin, 2005). Yonekura and Miwa (1992) made use of nanoparticles to increase the compressive strength of soil. Geotechnical properties and variations of clay using nanoparticles have been evaluated here.

MATERIALS AND METHODS

The soil used in this research was obtained from dredging Karun River. The soil aggregation diagram is shown in Figure 1. Aggregation in the hydrometer test was performed using ASTM D 422 standard (ASTM, 2006). Atterberg limit testing was conducted by ASTM D 4318 standard. The results are shown in Table 1. The clay has been characterized low liquid limit (CL) based on these two tests. White commercially purchased powder, Na + modified montmorillonite, is used as nanoclay in this study. Chemical compounds and physical properties of nanoclay are shown in Tables 2 and 3.

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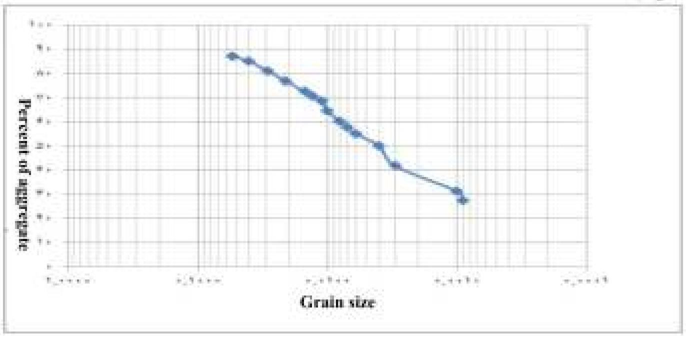

Figure 1. Diagram fine grained soil (hydrometer test)

Table 1: Atterberg Limits

Soil	Plastic Limit P I	Liquid Limit L L	Plasticity Index PI
Clay	25	42	17

Table 2: Chemical composition of nanoclay

Chemical formula	(Na,Ca)0,3(Al,Mg)2Si4O10(OH)2•n(H2O)
Chemical compounds	Percent
Na_2O	1.13
CaO	1.02
Al_2O_3	18.57
SiO_2	43.77
H_2O	36.09

Table 3: Physical properties of nanoclay

Specific surface area	750m /g
Particle size	10mm
Density	2.35g/cm3

After selecting soil and nanoclay, unconfined compressive strength test to measure unrestricted shear strength of cohesive soil is performed according to ASTM 2166-87 standard. This is a triaxial unstabilized - undrained (UU) test with whole zero pressure. Undrained adhesion (Cu) can be calculated from the results.

$$Cu=qu/2 \quad (1)$$

qu=Simple compressive strength (uniaxial). Compaction test is essential to obtain optimum percentage for test samples preparation since soil resistivity tests including uniaxial compressive strength and CBR soil samples are performed at optimum moisture content. Standard proctor test was conducted according to ASTM D 698 under various conditions and optimum moisture content was obtained.

Strength test (CBR) was done on the soil containing nanoclay nanoparticles using ASTM D 1883 standard. CBR is the ratio of required force for inserting a piston with a given form, speed and depth in respective soil to that for inserting the same piston into standard materials. Shear strength testing for specific weight and optimum moisture determined by this test is not constant and depends on soil compaction and moisture. In road construction will be all the layers bearing capacity of pavement layers and their initial thickness can be obtained from CBR. Atterberg limit test was performed for clay and nanoclay. Plastic and liquid limits were quantified by ASTM D 4318 standard. They were calculated and compared before and after adding 1 and 2% of nanoclay. Ball mill is applied to disperse nanoparticles into soil. In order to ensure adequate nanoparticles dispersion, mixture samples levels were investigated by scanning electron microscope.

RESULTS AND DISCUSSION

Figure 2 shows the results of Atterberg limits test before and after adding nanoclay. As seen in the Figure, nanoclay increases liquid and plastic limits. Plasticity is influenced much more. These changes may reduce plasticity index (PI). The more nanoclay content, the greater variations will be.

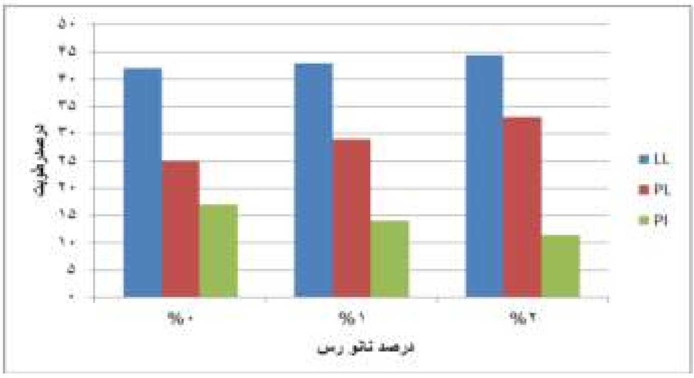

Figure 2- Atterberg limits comparison at 0, 1 and 2% of nanoclay

Clay nanoparticles can affect the plastic characteristics of the soil by the following methods:

• Intraparticle nanoporosity. The water usually enters intraparticle pores through the absorption or hydration during the minerals formation process. Existing water disappears only through kiln drying and cannot fully participate in particles surface reaction. So porous nanoparticles show high limits [5].

• Surface loads and large specific surface area. Surface loads are normally linked to hydrated cations or double water layers and increase the thickness of these layers, resulting in more soil moisture absorption [5].

• Bulk microstructure. Nanoparticles may not become scattered and disappeared during soil paste preparation to measure Atterberg limits in a stronger mass having intergranular pores filled with water. The water trapped in intramass pores is involved in raising Atterberg limits too [6].

To obtain the optimum moisture content and maximum specific dry weight, soil compaction test was conducted based on ASTM D 698 standard. The results show 3% and 1.57 gr/cm3 values for optimum moisture content and maximum specific dry weight, respectively (Figure 3).

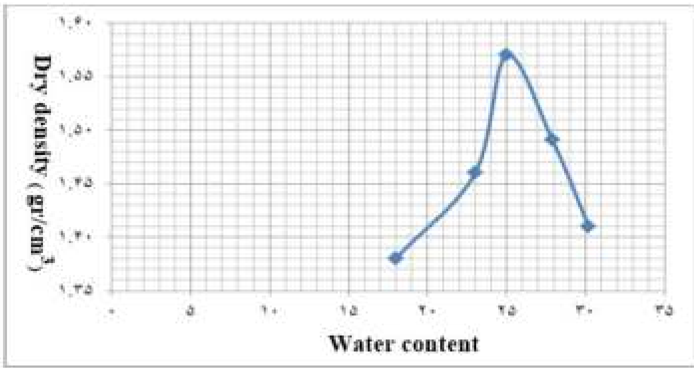

Figure 3- The initial soil compaction test on samples containing 0, 0.5, 1, 1.5 and 2% of nanoclay

Uniaxial test is usually applied to quickly determine untrained shear strength of cohesive soils. Nanoclay shows adhesion properties only beside the humidity, thus it is expected to have a significant impact on soil resistivity. According to the Figure 4, nanoclay content rising by 0.5% does not affect soil resistivity. The ultimate soil strength becomes more as the clay content increases. If nanoclay content is between 1.5 to 2%, the ultimate strength decreases.

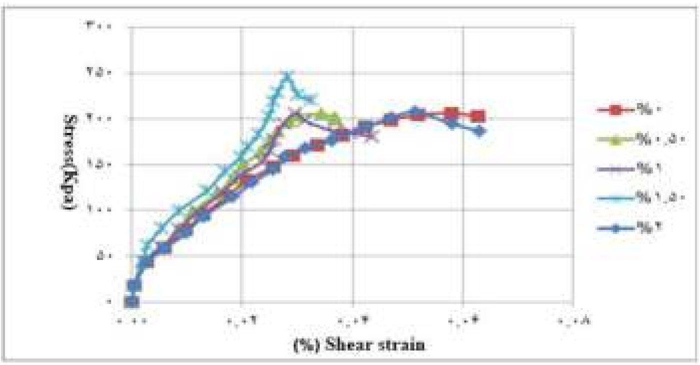

Figure 4- uniaxial test results on samples containing 0, 0.5, 1, 1.5 and 2% nanoclay

CBR test results are shown in Figure 5. As seen in the diagram, there is no effect on soil resistivity as nanoclay content increases by 0.5%. The ultimate strength increases by raising nanoclay content. The ultimate strength reduces if nanoclay content is between 1.5 to 2%. Comparing the unconfined compressive strength and CBR tests can be concluded that soil resistivity increases same the percentage as nanoclay.

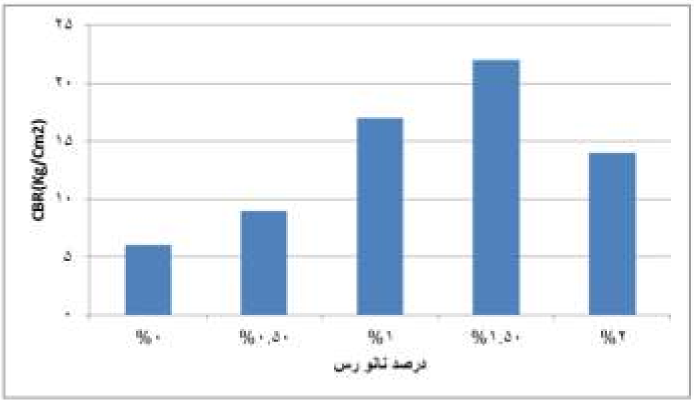

Figure 5- CBR test results on samples containing 0, 0.5, 1, 1.5 and 2 percentage of nanoclay

CONCLUSIONS

This study has experimentally evaluated the effect of Na + modified montmorillonite nanoclay on engineering properties of clay. The results of Atterberg limits test suggests that plastic and liquid limits can be increased by adding nanoclay into the soil. This variation is greater in plastic one. Given the results of unconfined compressive strength on nanoclay samples, the soil containing 1.5% of nanoclay has the greatest resistivity. Increasing nanoclay content from 1.5 to 2% reduces the ultimate compressive strength. CBR test results showed that the sample containing 1.5% of nanoclay had the highest CBR value. Nanoclay content rising by 2% decreases CBR. Despite this reduction, it is more than CBR value of sample without nanoclay. It is concluded that nanoclay due to high specific surface area makes a major impact on soil engineering properties and so little percentage of this material can be used to achieve better results.

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