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Influence of Nano-Soil Particles in Soft Soil Stabilization

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ABSTRACT

This paper intends to present the influence of using nano-soil particles in soft soil stabilization. This experimental based on laboratories study was conducted to evaluate the effectiveness on the geotechnical properties of soft soil stabilized using nano-soil particles. The soft soil sample was collected from Banting, Malaysia. Meanwhile, the nano-soil sample was produced from pulverization process of soil samples through high energy milling process into nanoparticle size. Therefore, only 2%, 3% and 4% nano-soil samples were used in this study due to the limited amount produced from the milling process. The 2%, 3% and 4% nano-soil were mixed to the soft soil based on optimum moisture content at maximum dry density of soil. The first objective of this study is to determine the effective shear strength of soft soil stabilized with nano-soil. Meanwhile the second objective is to determine the compressive strength of soft soil stabilized with nano-soil. The third objective is to determine the Atterberg limit parameters such as liquid limit (LL), plastic limit (PL), and plasticity index (PI) of soft soil stabilized using nano-soil. This study involved three main laboratories testing such as unconfined compression strength to determine the compressive strength and consolidated drained test to determine the effective shear strength. Meanwhile, the Atterberg limit test were conduct to determine the liquid limit (LL) and plastic limit (PL). The laboratories result showed, the addition of 2%, 3% and 4% nano-soil into soft soil was improved the soil strength and effectiveness shear strength of stabilized soft soil. Meanwhile the plasticity value showed decreasing after addition of 2%, 3% and 4% nano-soil and indicating of soil improvement process. The results showed the small amount of nano-soil has a significant to improve and enhanced the geotechnical properties of soft soils.

KEYWORDS: Soft soil, soil stabilization, nano-soil particles

INTRODUCTION

Soft soil has the smallest particle sizes usually less than 2mm, possess up 85% for moisture content that have high moisture content, approaching that of liquid limit and has a shear strength less than 25kPa (Taha, 2009). Instead, soft soils are identified as problems soil due to their low shear strength, high compressibility, low permeability, high of swell and shrink potential. Soft soil considered undesirable engineering properties and unpredictable behavior in construction (Abdullah and Abadi 2005). Nowadays, the nanomaterial and nanoparticles were growing of interest to researcher in engineering application especially in civil engineering. The nano particle size usually in range of 1-100nm and often crystalline that is referred as nanocrystals. Holister et al. (2003) stated there are a number of changes in physical properties due to the increment ratio of surface area and volume changes alteration from micro particles to nano particles. Nanoparticle size becomes more reactive than original size and able to produce materials with new applications due to increase in the total size of the surface over large and acting as good catalyst. Instead, Nanoparticle has a large surface area that will increase a lot of interaction among intermixed materials such as nano-composites in increase in strength of the materials. Therefore it becomes more reactive and potentially suitable for improving the properties of soil for various applications. (Taha, 2009). Meanwhile Norazlan et al. (2014) was stated by using small percentage of nano particle of kaolin showed dramatically influenced to the basic properties and engineering of kaolin. There are increments of research and development in nanoparticles that have been used as filler or additives for various desired effect (Faheem, 2008). This paper deals with an experimental study to evaluate the effectiveness using nanoparticles size of nano-soil in soil improvement to improve the Atterberg limit parameter, shear strength and effective strength. The experimental results showed that the application of small amount of nano-soil was significant slight improved the geotechnical properties of soft soil.

MATERIALS

Soft soil samples

The soft soil samples were collected from Banting, Selangor, Malaysia was in grey colour were sealed and wrapped with plastic after collection to maintain the original moisture contents and stored at room temperature in the laboratory. The tests were conducted on soft soil samples for physical and engineering properties in accordance to BS 1377: Part 2: 1990 and the summary result shown in Table 1. The result showed the soil samples containing higher of moisture content about 128%. Based on the physical properties result, the soft soil samples classified as slightly sandy SILT of Intermediate Plasticity.

Table 1: The properties of soft soil sample

Properties	Values
Specific Gravity, (Gs)	2.60
Natural moisture content (%)	128
Liquid Limit, LL (%)	45.7
Plastic Limit, PL (%)	22.9
Plasticity Index, PI (%)	22.8
Sand (%)	8.2
Silt (%)	85.1
Clay (%)	6.7
Optimum water content (%)	23.6
Maximum dry density (Mg/m^3)	1.43
Soil Classification	Slightly sandy SILT of Intermediate Plasticity

Nano-soil samples

The nano-soil samples were produced from pulverised technique process using high energy ball milling of Fritsch Pulverisette machine from original soft soil samples into nano sizes ranging of (1-100nm). This milling technique considered low cost to produce nanomaterial in laboratory. However the right selection of duration of milling and speed are important to optimize the end product due to the size of nanoparticle produced are not uniform from the milling process. Meanwhile, the nano-soil sample was analyzed using Zeta Potential Particle Analyzer after milling process to determine the potential sizes of nanoparticles. Figure 1 present the distribution graph of nano-soil samples produced from milling process. It shows, almost 91% of nano-soil particles diameter within range of 32d.nm to 92d.nm in 1 g of soft soil after milling process. That proportion is adequate to be classified as nano-soil and fully used to modified soil.

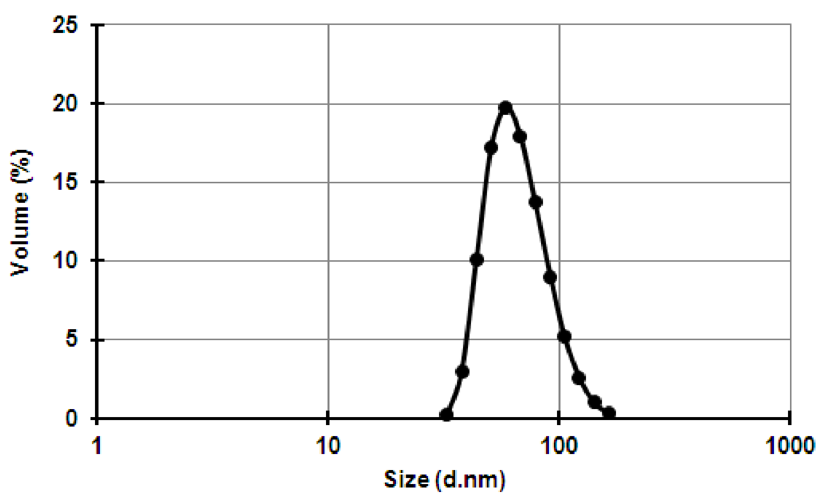

Figure 1: Particle size distribution of nano-soil

EXPERIMENTAL PROGRAM

The soft soil samples were prepared by mixed with series percentage of nano-soil to the weight of soft soil samples that shown in Table 2. All the samples mixed based on optimum moisture content at maximum dry density of soft soil samples. The small percentage series of nano-soil was used due to the very limited amount to produce the nano-soil samples from milling process. The entire mixed samples were cured in room temperature for 24hours for reaction before compressive strength testing and consolidated drained test.

Table 2: Details of samples

Sample	Nano-soil (%)
Soft soil	-
Soft soil + 2% nano-soil	2
Soft soil + 3% nano-soil	3
Soft soil + 4% nano-soil	4

The consistency limit experiments for Atterberg limit (liquid limit, plastic limit and plastic index) were conducted using cone penetration method describe in BS 1377:1990 Part 2. Meanwhile the compressive strength of mixed soft soil with nano-soil was evaluated using unconfined compressive test (UCT) and the effective strength of mixed soft soil with nano-soil was evaluated consolidated drained (CD) test. All the entire strength testing based on BS 1377:1990. The specimen samples for UCT and CD test wrapped and placed at room temperature condition to protect from loss of moisture content for 24hours before tested allow the reaction between soil and nano-soils.

RESULTS AND DISCUSSION

Table 3 summarized the result Atterberg limit parameters (liquid limit, plastic limit, plasticity index) and classification samples from plasticity chart for soft soil and soft soil stabilized with nano-soil. Meanwhile, Figure 2 illustrated the graph on the effect of addition 2%, 3% and 4% nano-soil to stabilize the soft soil on the Atterberg limit properties. The result from this study show that the liquid limit and plastic limit result slightly increase as the nano-soil content increase. Otherwise, the plasticity index showed decrement as the nano-soil content increase. Based on the classification from plasticity chart, the soft soil stabilized with nano-soil classified as silt of high plasticity as the increment percentage of nano-soil compared to unstabilized soft soil that classified as clay of intermediate plasticity. Taha (2009) mentioned that there are indicators of soil stabilization and enhancement of soil properties in reduction of plasticity index.

Table 3: Result and classification of liquid limit, plastic limit and plasticity index on different percentage of nano-soil stabilized soft soil

Samples	Liquid Limit (LL)	Plastic Limit (PL)	Plastic Index (PI)	Classification from plasticity chart
Soft soil (control)	45.7	22.9	22.8	Clay of Intermediate plasticity (CI)
Soft soil + 2% nano-soil	48.1	27.2	20.9	Clay of Intermediate plasticity (CI)
Soft soil + 3% nano-soil	51.8	32.9	18.9	Silt of high plasticity (MH)
Soft soil + 4% nano-soil	53.3	36.1	17.2	Silt of high plasticity (MH)

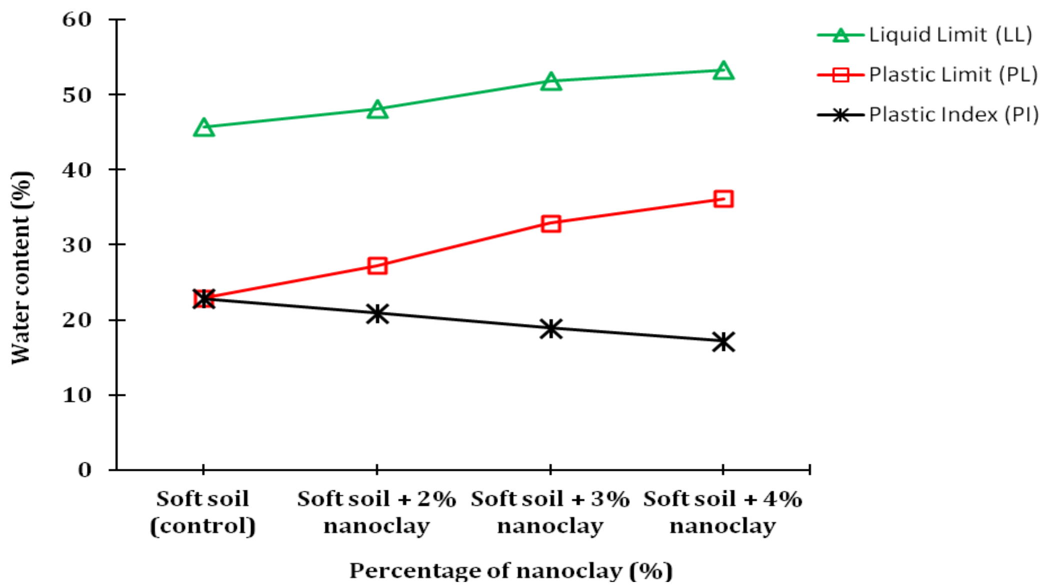

Figure 2: Effect of different percentage nano-soil on water content to the Atterberg limit

Figure 3 shows the graph of axial strain versus deviator stress between soft soils and various percentage of nano-soil mixed to the soft soil. From the laboratories result, it shown the maximum shear strength increased together with the decrement of axial strain for soft soil mixed with nano-soil. Meanwhile Figure 4 summarized the compressive strength value result for soft soil and soft soil mixed with nano-soil accordingly to the graph shown in Figure 3. The result shown that the influence of small amount percentage nano-soil mixed to the soft soil has a significant in increment of compressive strength. It shows the compressive strength increase with increment percentage of nano-soil from 2% to 4% nano-soil. It indicates that, the using of nano-soil was resulting the compressive strength result due to the interaction and bonding developed between of nanoparticles with clay soil matrix.

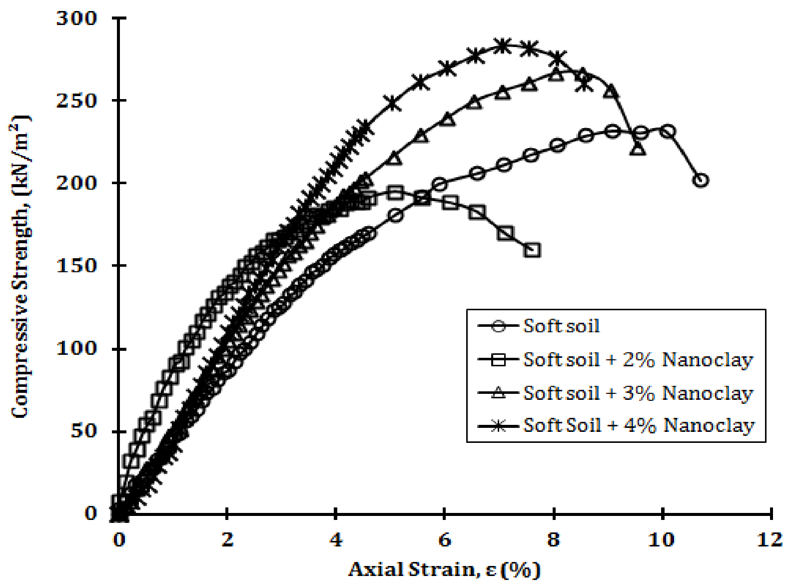

Figure 3: Graph stress strain curve of unconfined compression test

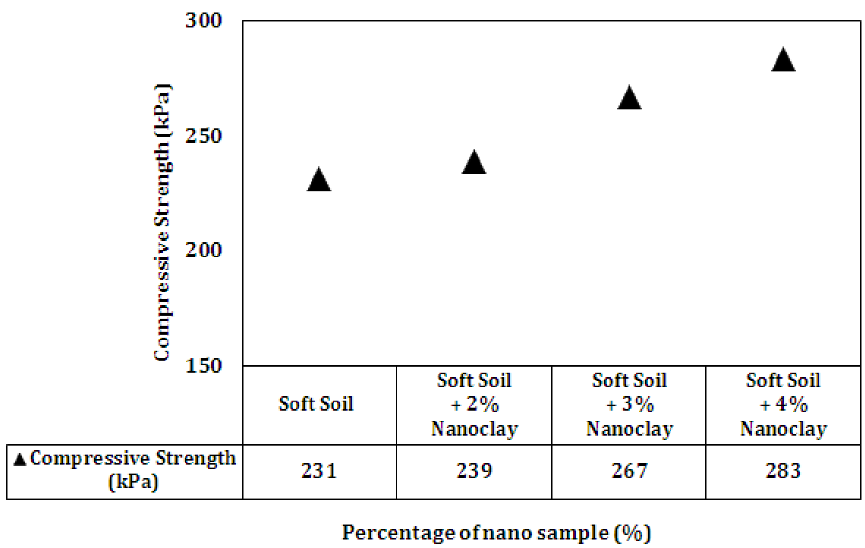

Figure 4: Summarized result of compressive strength for soft soil stabilized with different percentage of nano-soil

The Mohr circle graphs of effective stress for soft soil and soft soil stabilized with 2%, 3% and 4% of nano-soil are shown in Figure 5. The failure envelope was drawn to the best fit tangent line. Meanwhile Figure 6 summarized the values of effective cohesion (c′) and effective friction angle (φ′) getting from the Mohr-Circle graph. The result shows the increment of effective internal friction angle as the increment of addition nano-soil percentage. It indicate that the addition of small amount percentage of nano-soil showed the best result of effective strength and hence having the high internal particle bonding between the soil particles and produced the greater of effective shear strength.

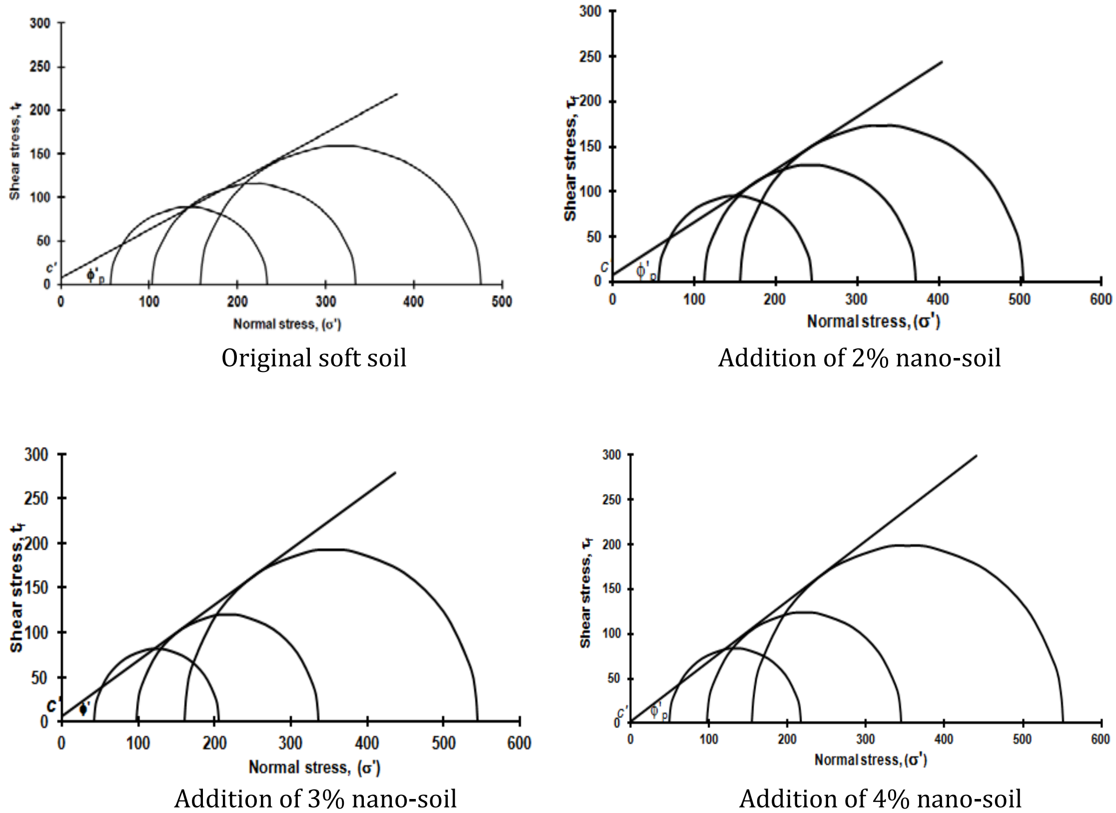

Figure 5: Mohr-Coulomb failure envelope for addition of 2%, 3% and 4% nano-soil

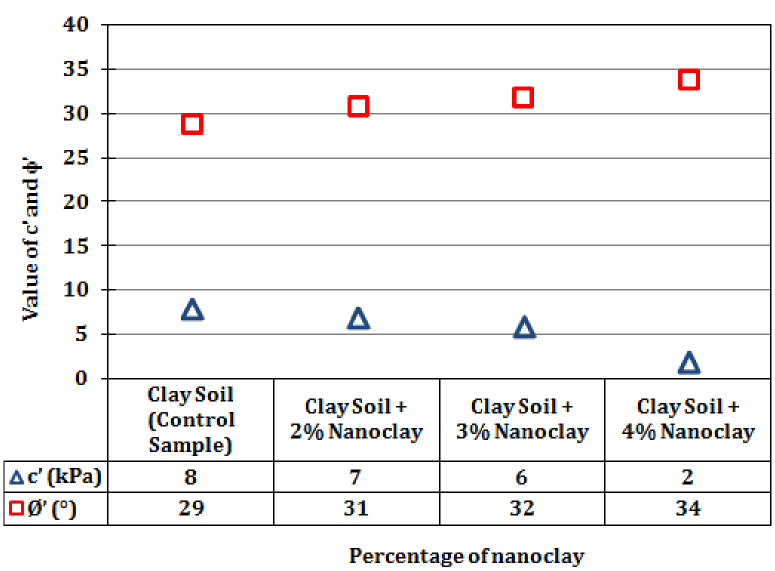

Figure 6: Summarized result for effective strength of soft soil stabilized with various percentage of nano-soil

CONCLUSION

From the experimental studies on effective of using nano-soil in soft soil stabilization, it can be concluded that soft soil of slightly sandy CLAY of intermediate plasticity soils can be stabilized using small amount percentage of nano-soil. It can be seen from the result of this study, that the addition of 2% to 4% nanocaly was increased the compressive strength of soft soil about 3% to 22% from the original soft soil. Instead, noticed that the addition 2% to 4% of nano-soil also was improved the internal friction (ϕ') from effective shear strength from 7% to 17%. Meanwhile the Atterberg limit parameter for liquid limit (LL) and plastic limit (PL) show the slightly higher compared to original soft soil. However the plastic index (PI) values indicate a decrement about 8% to 25% for the addition of 2% to 4% of nano-soil. The decrements of plasticity indices are indicators of soil improvement. Based on the study it shown, by using small amount percentage of nano-soil were giving significant in soft soil stabilization to improve the geotechnical properties of soft soil.

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