



## EFFECT OF NANOMATERIAL TREATMENT ON GEOTECHNICAL PROPERTIES OF A PENANG SOFT SOIL

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### ABSTRACT

*This study aims to investigate the effect of addition of different nanomaterials, including nano Cu, nano MgO, and nano clay, on the geotechnical properties of soft soil samples from Penang State. Various amounts of nanomaterials (0.05% to 1%) were added to the soil to study their effect on the soil's compaction characteristics, consistency limits, and compressive strength. Improvements in these geotechnical properties depended on the type of nanomaterials added, and increasing the percentage of each of the added nanomaterials increased the maximum dry density of the soil. The linear shrinkage and plasticity index decreased with increasing nanomaterial content. The unconfined compressive strength increased as the nanomaterial content increased up to a certain percentage in the soil and then decreased afterwards.*

**Key Words:** Soil stabilization, Nanomaterials, Consistency limit, Unconfined compressive strength.

### INTRODUCTION

Generally, soft soil includes large fractions of fine silt, peat, and loose sand deposits below the ground water table (Nagaraj, 2001). Among the soils, soft soil has the smallest particle size, usually less than 2  $\mu\text{m}$ . It is produced from weathering processes, hydrothermal activities, or sediment deposits. The Unified Soil Classification System (USCS) classifies soft soil as a small-particle soil of which 50% passes through Sieve No. 200 (US Specification, 0.075 mm). Soft soils (Taha, 2009) possess high moisture contents of up to over 85% and high compressibility and sensitivity; they can also be easily interrupted by activities on its surface. Structures constructed on soft soil can encounter engineering problems, especially during settlement and stabilization. Soft soil is found in coastal and lowland areas with high compressibility and low shear strength. Thus, enhancing such properties is of great interest for researchers (Mirlohi, 2011).

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In the 1970s and 1980s, soil stabilization by admixture was developed in Japan. Soil treated in such a manner was better than the original soil in terms of strength, reduced compressibility, and hydraulic conductivity (Kazemian, 2010). Different soil improvement methodologies are also currently in practice to ensure optimum geotechnical properties, for example, the improvement of soft soil grounds before building upper constructions (Xie, 2011). Some of these soil improvement methods include compacting grouting, permeation grouting, hydraulic fracture grouting, jet grouting, and deep mixing (Navin, 2006). This paper investigates the effect of addition of different nanomaterials, including nano Cu, nano MgO, and nano clay, on the geotechnical properties of a Penang soft soil.

**EXPERIMENTAL PROCEDURE**

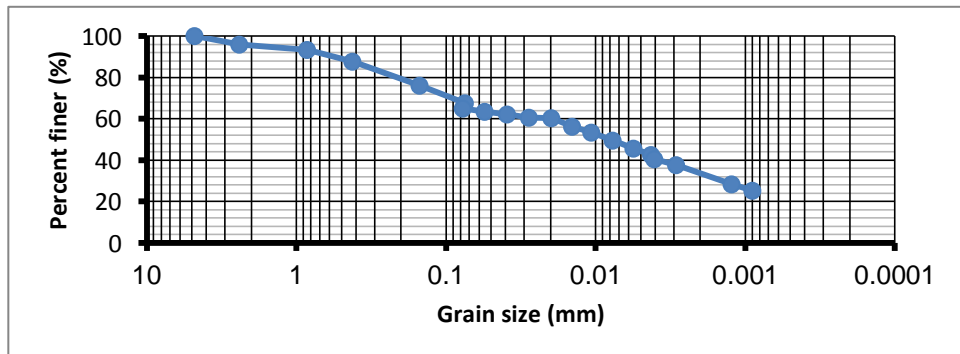
**Materials**

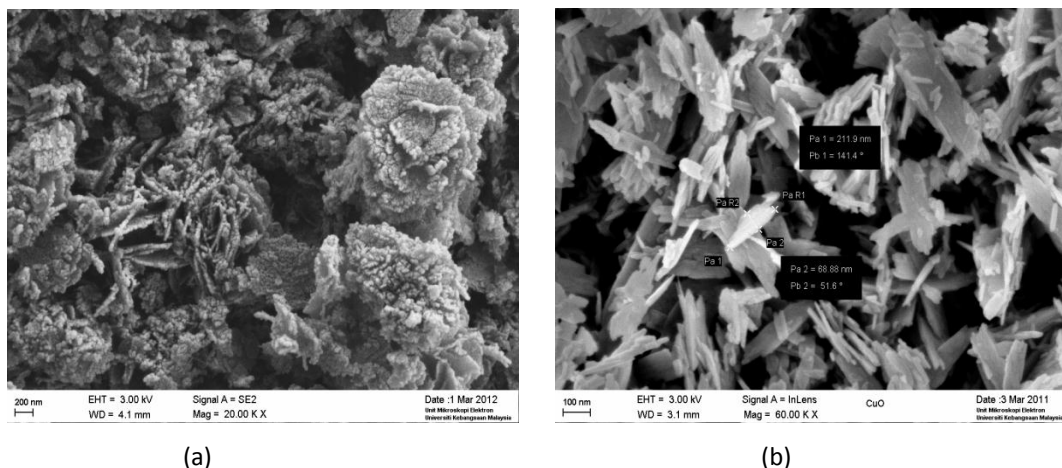
Soil from the Universiti Sains Malaysia (USM) Engineering campus in the State of Penang was used in the study. The USM Engineering campus is located in Transkrian, Nibong Tebal, Seberang Perai Selatan, Penang (GPS coordinate: N5 08.604 E100 29.415). The grain size distribution of the fine-grained soil is shown in Figure 1. Table 1 presents a summary of the geotechnical properties of the soil.

**Table-1.** Properties of the Soil Used in this Study

Property	Value
Organic Content	12.17 %
pH	3.5
Liquid limit	47 %
Plastic limit	28 %
Plasticity index	19 %
Linear Shrinkage	11.07 %
Specific gravity	2.42
Clay fraction	29.8 %
Silt fraction	31.3 %
Sand fraction	38.9 %
Classification (USCS)	OL
Max dry Density	14.44
Optimum Water Content	kN/m <sup>3</sup> 21.6 %

**Figure-1.** The Grain Size Disruption of the Soil.



**Figure-2.** The Nanomaterials used in the study under SEM :(a) nano MgO (b) nano CuO.

### Sample Preparation

Soil samples were compacted at maximum dry and optimum moisture content using the standard compaction test method before and after nanomaterial (i.e., nano CuO, nano MgO, and nano clay) addition.

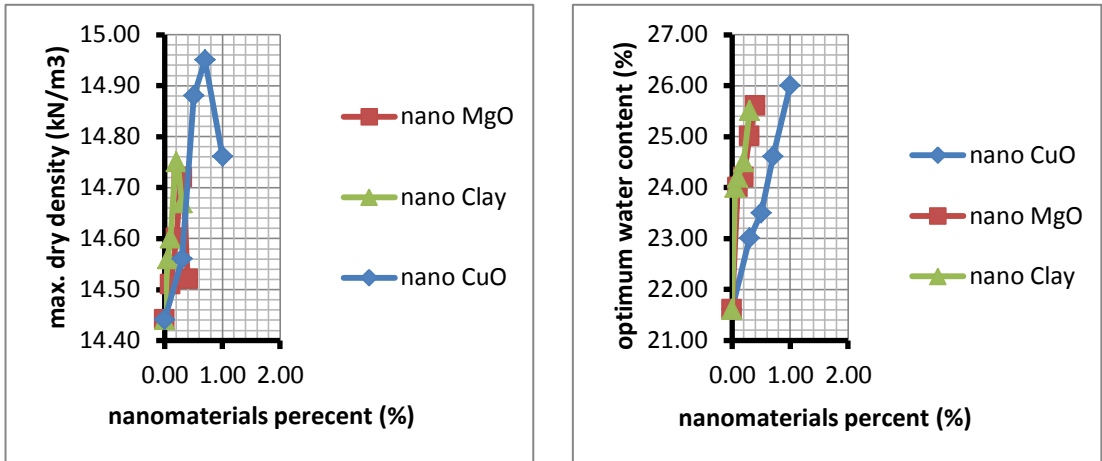
### Laboratory Tests

The standard proctor compaction test was carried out to determine the moisture content-dry density relationship according to American Society for Testing and Materials specifications (ASTM D 698). The liquid limit test was conducted using the cone penetrometer method apparatus according to British Standards (BS, 1377-part 2-90). The plastic limit test was conducted according to BS (1377-part 2-90). These tests were carried out to investigate the effects of nanomaterial addition on consistency limits. Compacted specimens were obtained by inserting tubes with a diameter of 38 mm into the soil using a compression machine. Specimens were extracted from these tubes by an extruder, and then cut into 89 mm long specimens. All specimens were tested immediately after preparation using a test conducted according to ASTM (D2166-65).

### Result and Discussion

The relationships between the maximum dry density and optimum water content of different nanomaterials (i.e., nano CuO, nano MgO, and nano clay) are shown in Figure 3. The addition of nanomaterials to the soil increased both the maximum dry density and the optimum moisture content. An increase in the maximum dry density generally indicates soil improvement. Das (2010) listed the factors that affect compaction, including the particle size and specific gravity of the soil and the stabilizer. The increase in optimum moisture content is attributed to the additional water held within the flocculent soil structure due to the excess water absorbed resulting from the porous property of the soil; this water is believed to contain organic materials (Lancaster et al., 1996).

**Figure-3.** Effect of Different nanomaterials Percentage and: (a) Max. Dry Density (b) Optimum Water Content

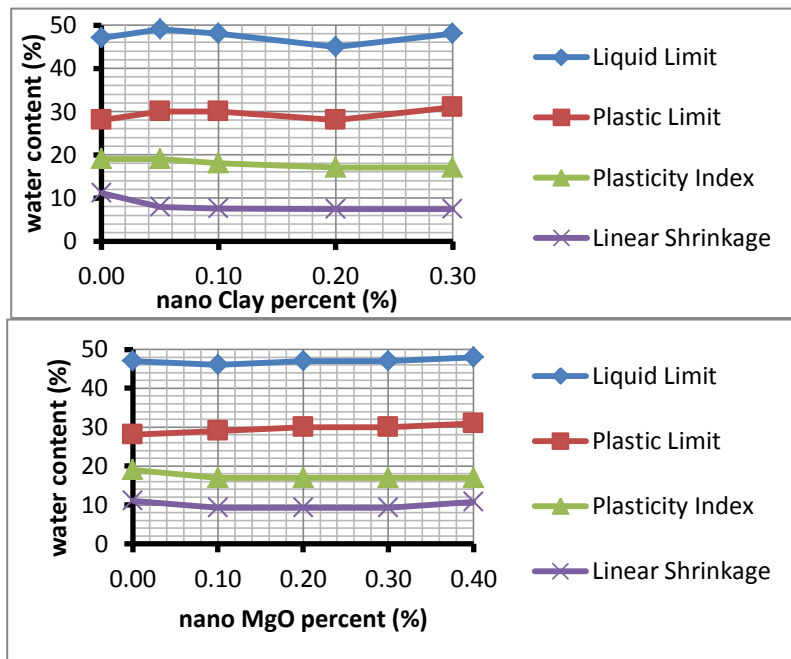


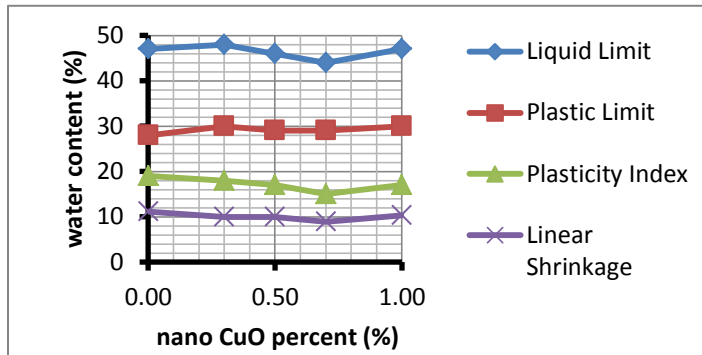
(a)

(b)

Figure 4 shows the effect of nanomaterial contents on the Atterberg limits. The liquid limit, plastic limit, plasticity index, and linear shrinkage decreased as the nanomaterial content increased. Reductions in the plasticity indices are indicators of soil improvement. Thus, addition of fine particles, such as nanomaterials, to soil, even at low doses, can enhance its properties (Taha, 2009).

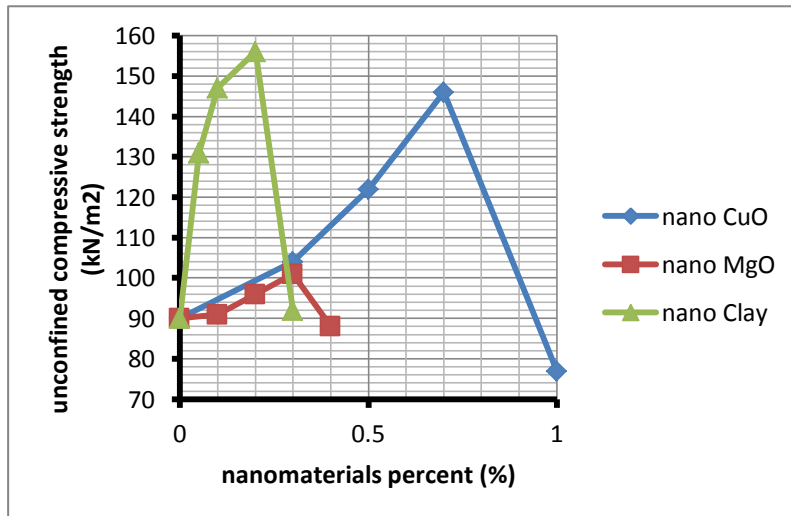
**Figure-4.** Effect of Different nanomaterials Percentage and Moisture Content on Engineering Properties of the Soil.





The unconfined compressive strength of specimens with different percentages of nanomaterials is shown in Figure 5. Increasing the amounts of nanomaterials led's to an increase in the unconfined compressive strength. The increase of nanomaterial more than the optimum limit may possibly result from agglomeration in nanomaterial particles which in turn cause an increase in the void ratio then decrease in density and increase in water content. The results indicate that the maximum shear strength it's obtained from soil treated with nano clay. Soil to which nano clay had been added showed hardening and improved strength compared with soil specimens that contained other nanomaterial additives.

Figure-5. Effect of Different nanomaterials Percentage and Unconfined Compressive Strength.



## CONCLUSION

This investigation was conducted to study the effect of addition of three nanomaterials (i.e., nano CuO, nano MgO, and nano clay) on the geotechnical properties of a Penang soft soil. The liquid limit, plastic limit, linear shrinkage, dry unit weight, moisture content, and shear strength of the soil

were determined. Addition of each of the nanomaterials decreased the liquid limit, plastic limit, plasticity index, and linear shrinkage of the soil. The dry density and optimum moisture content increased with increasing nanomaterial percentage. As well, the compressive strength of the soil increased with nanomaterial addition. These results can help researchers further improve soil strength and other soil properties.

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