EFFECTS OF CARBON NANOTUBE ON KAOLINITE: BASIC GEOTECHNICAL BEHAVIOR

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Introduction

Fundamental experiments in which kaolinite (representing a soil) was mixed with carbon nanotubes (CNT) was conducted for the first time to study the changes in its basic geotechnical properties. Taha et al. [1] presented a study in which a Malaysian natural residual soil (UKM soil) was mixed with nanosoil derived by ball milling the soil itself. They showed that significant improvement can be obtained in the geotechnical properties of the parent material with cement mix by adding only 2% by weight of the nanosoil (Fig. 1). Such observations are important in geotechnical engineering for soil improvement as other materials including nanomaterials are continuously sought to study its performance in enhancing the properties of soil.

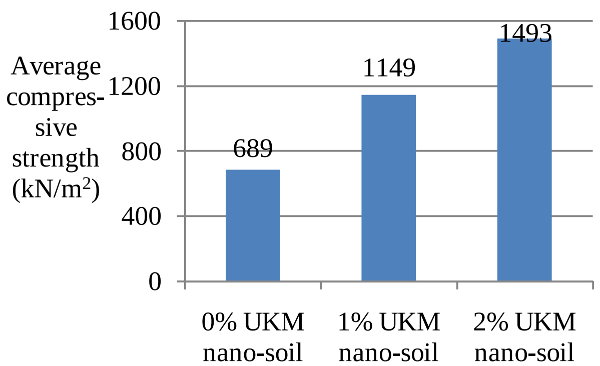

Fig.1 Compressive strength of soil - cement-nanosoil mixtures [2]

CNT can now be considered as the "king" of nanomaterials as it is being used in many applications i.e medicine, electronics, energy and environment, etc. Its exceptional strength have made it as one of the candidates for stiff and robust structures [3]. In-line with this, as the prices of the CNT continue to drop (this is important since geotechnical engineering use materials in bulk), its applications in geotechnical engineering is envisaged.

In this study, the basic properties that will be discussed include Atterberg's limits and consolidation. The Atterberg limits are important as it gives early indication of the behavior of soil upon mixing with water. It is used extensively for identification, description, and classification of soils (especially cohesive soils) as a basis of its mechanical behavior [4]. Consolidation provides knowledge of its settlement behavior under given load.

Experimental Work

Materials

The kaolinite used was supplied by Kaolin (M)alaysia Sdn Bhd Malaysia. It appeared as a white powder which is chemically a hydrated aluminium silicate.

The CNT is a multi-walled nanotube (MWNT) and was purchased from Arkema, France under product name Graphistrength C100. It is a black powder with a bulk density ranging between 50-400 kg/m^3.

Methods

All soil/geotechnical tests were conducted based on the British Standard BS 1377:Part 2:1990. These include specific gravity (G_s), Atterberg limits (liquid limit (LL) & plastic limit (PL), and consolidation tests. Most basic tests for soil-CNT mixtures have a maximum range of 0.5% - 1% CNT by weight to limit the use of CNT. These test uses comparatively higher amounts of soil and repeated a number of times. Thus, the use of CNT is also high rendering issues with regard to disposal of waste materials to be also a major consideration.

Results

The result for basic characteristics of soil and soil-CNT mixtures are given in Table 1. It is shown that even with small amount of CNT, the changes in basic charateristics are measurable. Increase in CNT led to increase in LL, PL and plasticity index (PI=LL-PL). The specific surface of the soil increase as the LL increases as first obtained by Farrar and Coleman [5]. In these tests, the addition of the fine CNT particles certainly increases the overall specific surface of the mixture as indirectly shown by an increase in LL. The values of G_s, in general, decreases upon addition of CNT due to the low density of CNT (1.3-1.4 g/cm^3).

In terms of mechanical properties, increase in LL (and increase in surface area) means the soil will have higher capacity for water thus decreasing its strength and increasing its consolidation/compressibility (settlement). However, increase in PI will generally mean a decrease in its hydraulic conductivity. For geotechnical structures (such as foundations and retaining walls) in which strength and compressibility are the main criteria, the use of CNT may not be advantageous. In the case of landfill liners and caps, in which low hydraulic conductivity is very important, its use may thus be considered. Although this study have explored to some detail on the effects of CNT on kaolinite, much more studies are still required to further ascertain some of the aforementioned facts.

Table 1 Basic parameters of soil-CNT mixtures

Properties	%CNT					
	0	0.1	0.2	0.3	0.4	0.5
LL	37.50	37.11	38.27	38.85	38.95	40.02
PL	27.91	27.34	28.44	28.95	28.45	29.38
PI	9.59	9.77	9.83	9.90	10.50	10.64
G_s	2.70	2.72	2.69	2.68	2.66	2.66

The results of the 1-D consolidation tests are shown in Fig. 2. The behaviour of soil-CNT mixtures at less than 0.5% CNT seemed to be almost similar with the higher percentage CNT showing greater compressibility. This general observation was also concluded from the Atterberg limit tests. At 1% CNT the plot significantly deviate from the others. This show that at 1% CNT the void ratio markedly increases. However, the amount of compression remains the same indicating possibly that only the soil compresses but not the CNT.
In Table 2, the parameters derived from the consolidation tests show that the compression and swelling index increases, as expected, with the amount of CNT.

Table 2 Compression and swelling index from consolidation tests

Index	%CNT			
	0	0.25	0.5	1.0
Compression	0.159	0.184	0.1939	0.2102
Swelling	0.0174	0.0187	0.0186	0.0193

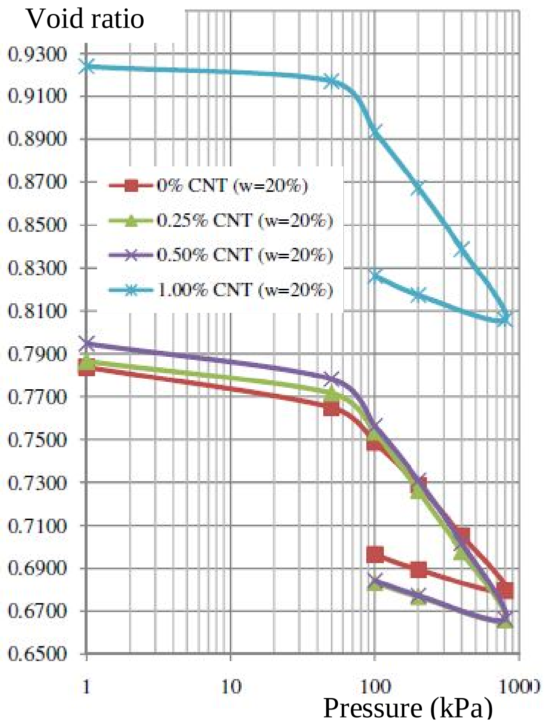

Fig. 2 Consolidation test results at water content (w) 20% for various CNT %

Conclusion

A study was conducted to evaluate the effects of adding CNT to kaolinite (soil). The liquid limit, plastic limit, and of the mixtures increases with the amount of CNT in the mixture. This indicate that the mixture will have a lower soil strength, higher compressibility and reduced hydraulic conductivity. Consolidation tests results showed that the observation on compressibility to be true.

References

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