Modern Environmental Science and Engineering (ISSN 2333-2581)
May 2022, Volume 8, No. 5, pp. 263-266
Doi: 10.15341/mese(2333-2581)/05.08.2022/002
Academic Star Publishing Company, 2022
www.academicstar.us

Applying Multiwall Carbon Nanotube for Increasing Soil Bearing Capacity

Daniel Hartanto, and A. Seputra Sudianto
Civil Engineering Study Program, Soegijapranata Catholic University, Semarang, Indonesia

Abstract: Nanotechnology is an alternative in soil improvement methods. The size of the nanoparticles is very small, ranging from 1 to 100 nm. Multiwall Nanotube is one of the nano materials in increasing the bearing capacity of the soil. According to Arabania et al. (2012), the strength of clayey sand increased by 120% by adding 3% Multiwall Carbon Nanotube. Meanwhile, according to Taha (2012), the recommended addition of Multiwall Nanotube Carbon is 0.1-0.5%. This research uses Unconfined Compression Test to determine the unconfined compressive strength (q_u) and undrained shear strength (c_u) of the land.

Key words: nano, multiwall nanotube, multiwall nanotube carbon, unconfined compression test, undrained

1. Introduction

Soil improvement generally uses materials mixed in the soil, including: cement with a certain composition. According to Kitazume and Terashi (2013), under certain conditions, the soil requires quite a lot of cement to be mixed in order to improve its mechanical behavior.

In recent development, sustainable soil improvement is the primary challenge of soil improvement methods. The materials commonly used for soil improvement such as: lime, silicate, acrylate and epoxy have limited maintenance. In addition to chemicals, *geotextiles* which are usually used in highway construction, require compaction and heavy equipment.

According to *the National Nanotechnology Initiative of the United States* 92007, nanotechnology can be defined as the materials manipulation with one dimension ranging from 1 to 100 nm. Nanotechnology also includes the science of atomic movement and the transformation of atoms.

Nanotechnology can also be applied in many fields of Civil Engineering such as: improving the properties of a material, reducing the energy consumption of a material, for example: using copper nanoparticles to increase the weldability of corrosion-resistant steel surfaces (Hanus, Haris, 2013).

One of the nanomaterials which can be used in soil improvement is *multiwall carbon nanotube* (MWCNT) which has properties such as melting strength and has a very high modulus of elasticity (Makar, 2011)

1.1 Multiwall Carbon Nanotube (MWCNT)

According to Chong (2003), multiwall carbon nanotubes (MWCNTs) are made of Graphene. Graphene is a super-thin sheet of carbon atoms. MWCNT is made of 90% pure carbon with some metal oxides at 10% (Nanocyl, 2019). The sizes of MWCNT are as follows: with a diameter of 10-15 nm, length 10-15 microns and an average density of 50-150 kg/m, and also the specific surface is about 1,000 times higher than cement particles. The specific surface area is the surface area per unit volume or surface area per unit weight. In the manufacturing of MWCNT rolled into tubes, graphene that has been formed into MWCNT

Corresponding author: Daniel Hartanto, ST., MT., research areas: geotechnical engineering. E-mail: daniel@unika.ac.id.

can produce a strength one hundred times stronger and six times lighter than steel. Due to its very high elasticity and strength, MWCNT has been used as filler and metal reinforcement (Sathurusighe, 2012). If MWCNT is used as a filler for cement granules, it will become a dense and hard composite material (Fakhim, 2013). Besides, multiwall carbon nanotubes were chosen because of their lower cost than *single-wall carbon nanotubes*.

Arabania (2017) mixed clay sand with a composition of 0.05-3% MWCNT based on soil weight, and producing maximum soil bearing capacity at a mixture of 3% MWCNT resulted in an increase more than 120% stronger than the original soil.

There are several problems that arise with the use of nanoparticles for soil improvement, including: cost and environmental impact. Firstly we will rule out the costs factor because the environmental impact on the organisms and animals around them is the main focus. The percentage amount of MWCNTs mixture suggested by Taha (2012) is 0.1-0.5% of the weight of the soil so that the environment is not damaged. However, the environmental impact on toxicity effects can be minimized with a right composition. Experts agree that the effects on humans are still widely questionable, but for use with the right composition it can minimize risks to humans and the environment. Nanoparticles have become a mixture of many items that are often used such as lotions. It provides some evidence to support the use of nanoparticles for their toxicity, but if the ingredients are still controlled, the level of toxicity to humans can be minimized (Taha, 2012).

In Fig. 1, you can see several layers and they are tubular because in the manufacturing process the carbon atoms are rolled up and made into many layers.

2. Method

This research was carried out by mixing cement, MWCNT particles and water with a certain composition so it is hoped that it will find the right mixture of materials to improve the soil that has less bearing capacity.

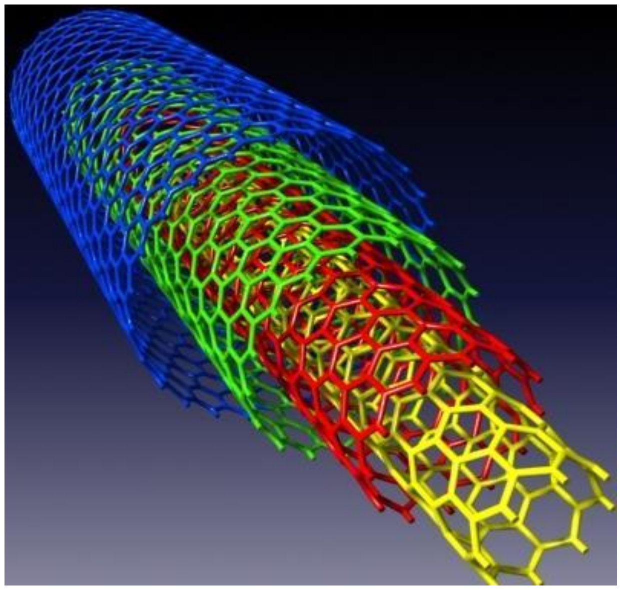

Fig. 1 Multiwall carbon nanotube.

2.1 Research Flowchart

Fig. 2 shows a flow chart of the research method to be implemented.

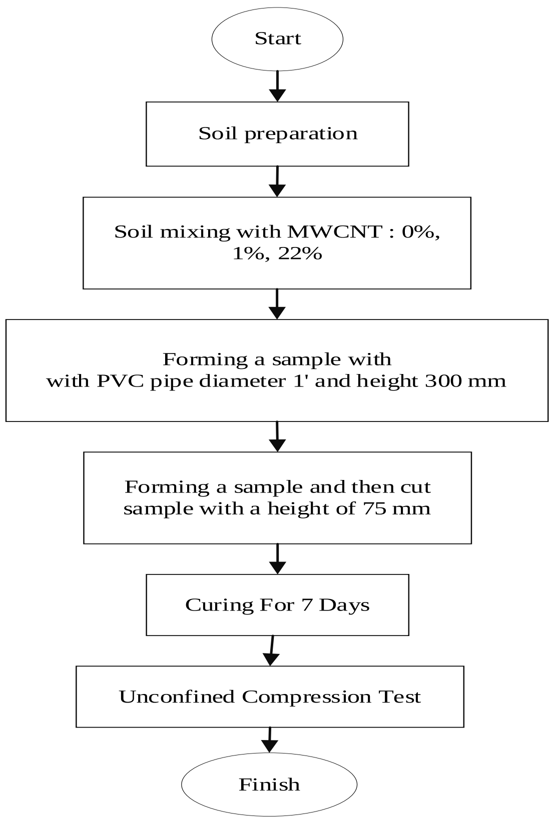

Fig. 2 Flowchart of the research.

2.2 Soil Preparation

Air-dried soil was filtered through filter no. 4. After being filtered, the soil that passed the filtering process weighed 5 kg. Prepare 3 soil samples each 5 kg. Each sample received a different treatment while mixing the soil.

2.3 Mixing Soil With MWCNT

40 grams of portland cement was mixed in a mixing bowl. Add 150 ml of water with the percentage of MWCNT as much as: 0% of the weight of the soil. All materials were mixed with a mechanical mixer at 136 Rpm for 3 minutes. When it is finished, take a little sample to find the water content. Then immediately put the soil in the mold with a maximum time of 30 minutes after mixing.

Put the soil that has been mixed with MWCNT in a PVC mold. Previously, the inside of the PVC wall was given a vaseline lubricant so the removal process becomes easier. The bottom of the mold was given a base so the soil does not come out of the mold. The mold base is a geotextile filter. The soil sample was inserted into a mold with 6 layers. Each layer compacted with a circular plate and vibrated with a hand drill. The purpose of vibrating the mold is to remove air bubbles in the soil sample. Repeat the mixing steps for the MWCNT content of 1% and 2%.

2.4 Curing

After the soil sample is removed from the mold, the curing process is carried out. Soil samples were put into a water bath with 20°C temperature and given a vertical pressure of 24 kPa at the top of each soil sample. The purpose of applying vertical pressure is to simulate the effective vertical stress in the field at a depth of 5m (Correia 2011). The cure time is 7 days.

3.5 Cutting the Sample

Cut the sample by using a hydraulic extractor. The sample was cut to a size of 75 mm and given the identity of the sample. The identity of the sample and the method of cutting can be seen in Fig. 3 below.

From Fig. 3, it can be seen that from the 3 samples that were inserted into the tube, they were further divided into 4 parts and given a name for each part. In sample 1, it is an addition of 0% MWCNT, in sample 2 it is an addition of 1% MWCNT, and in sample 3, it is an addition of 2% MWCNT. These several parts are done to reduce the risk if there is damage to one sample there is still a reserve to replace it. However, if there is no damage to sample the samples tested and the highest compressive strength is selected.

3.6 Unconfined Compression Test (UCT)

Soil samples that have been cut and then removed from the mold and placed in the UCT tool, give a shear speed of 1% per minute.

3.7 Test the Results

The following bar chart is the results of testing samples with MWCNT levels added to the samples as much as 0%, 1%, and 2%.

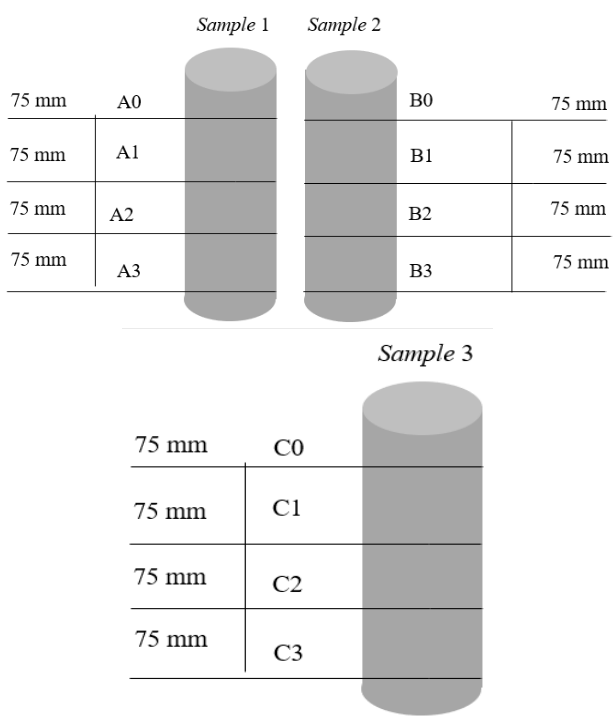

Fig. 3 Cutting samples, and naming.

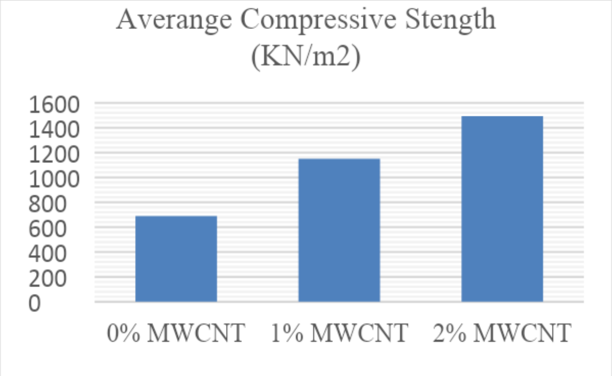

Fig. 4 Test results with 0%, 1%, and 2%.

Fig. 4 shows, in the first bar, when the samples are mixed with 0% MWCNT, the average of compressive strength is 689 KN/m^2. When the samples are added with 1% MWCNT, the average compressive strength becomes 1149 KN/m^2, and for samples that are given MWCNT as much as 2% the average compressive strength becomes 1493 KN/m^2.

4. Conclusion

The application of nanotechnology, especially the use of Multiwall Carbon Nanotubes (MWCNT) can be used as an additional material for soil improvement, as in the results of the tests can be concluded that MWCNT as much as 2% is able to produce maximum compressive strength. This can be used for the latest innovations for improving soil's quality because the process is quite easy.

However, there are still limitations in this study, such as:

1) In this study, it was only tested up to the addition of 2% MWCNT, and in that addition the soil bearing capacity could increase to more than 2x the initial carrying capacity, namely the addition of 0% MWCNT. In this study, it has not been proven for the addition of MWCNT more than 2% whether the carrying capacity could increase or decrease.
2) This study did not include the effect of adding MWCNT for soil improvement to the environment, organisms and animals in the vicinity.

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