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Effect of Ultrasonic Energy and Multiwall Carbon-nanotube on the Shear Strength of Problematic Soils

A. R. Negahdar*, B. Zareei

Department of Civil Engineering, University of Mohaghegh Ardabili, Ardabil, Iran

ABSTRACT: Problematic soils are those that make the construction of foundations extremely difficult. These soil should be replaced or modified. These types of soils are problematic, such as swelling soil, dispersive soil and the soils that loss their strength at saturated conditions. As silty soil and quicksands have low strength at saturated condition, it seems that stabilization of these soils is necessary. In literature, stabilizing these soils by cement is more effective. On the other hand, by developments in nanotechnology within last three decades, researchers discovered a material with unique properties, named as carbon nanotube. The carbon nanotube has very high strength even higher than steel, high elastic module and toughness and other unique properties. Within last three decades, many studies are concerned in applying this material in cement composites, but only we can find a few works related to use of this material in soil stabilization. Since carbon nanotube attract each other, we should separate nanotube particles. In this study, different values of ultrasonic energy (as mechanical agent) and polycarboxilate based super plasticizer solution (as chemical agent) was used to overcome carbon nanotubes agglomeration problem. As it is not possible to use carbon nanotubes in dry state, to investigating the effect of carbon nanotubes on the soils, the aqueous solution of carbon nanotube was added to the soil, using wet mix method. The samples were cured in water for 7 days. After performing direct shear test the shear strength and its parameters were evaluated. The results show using 0.125 % carbon nanotube and applying different ultrasonic energy to the carbon nanotubes solution the highest benefit of ultrasonic energy achieved when it used as 500j/ml. Comparing to the samples that threated by defective ultrasonic energy, it is observed that the shear strength of silty and sandy soil was improved as 19.7% and 21%, respectively.

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1- Introduction

Many soils can prove problematic in geotechnical engineering [1]. Problematic soils are those that make the construction of foundations extremely difficult [2]. These types of soil make the foundations extremely difficulties and stabilization of these soils is necessary. In literature, good results in stabilization of problematic silty and sandy soil by cement are reported. Also cement stabilization of silty soils provides perhaps the most dramatic improvement of any soil type [3].

Carbon Nanotubes (CNTs) are one of the lightest, strongest, stiffest, electrically and thermally conductive engineering fibres. Main difficulties in using carbon nanotube is related to its tendency to be agglomerated that reduces its effect. For this purpose, applying ultrasonic energy to carbon nanotube solution is preferred. Many studies are focused on applying of carbon nanotubes (CNTs) for reinforcing cement pastes, mortars and concrete [4-9]. Nonetheless, we can find only a few studies about improvement of soils mechanical properties using CNT-cement mixture, for soil stabilization programs. In this paper we attempt to determine the optimum ultrasonic energy, and investigating the effect of different content of multiwall carbon nanotube on shear strength and shear strength parameters of silty and sandy soil.

Corresponding author, E-mail: negahdar@uma.ac.ir

2- Methodology

The steps of Preparing stabilized samples is divided into two main part; preparing carbon nanotube solution and mixing soil by cement and prepared carbon nanotube solution.

To prepare aqueous solution, 0.3, 0.15 and 0 gram of MWCNTs was mixed by polycarboxilate based super plasticizer (SP) at different amount (as 2.4, 3.6, 6 grams) in 120 gram of distilled water. Using MidPIP PIT300 magnetic stirrer, the prepared solution was mixed for 30 min. All sonication processes were carried out with a probe sonicator (TopsonicUP400). The amount of energy is expressed based on the j/ml unit [10]. The multiwall carbon nanotube aqueous solution was mixed by cement. The prepared grout was mixed by 1200 grams of silty soil and same amount of sandy soil. The cement content for each soil are adopted based on typical cement requirements for various soil type [11]. Then the soil and reinforced cement slurry is mixed into a bowl using rotary mixing tools as it is recommended in wet mix method. Then, prepared soil was placed in a cubical mould. The specimens were extracted from the moulds after 24hrs. All of the soil samples were cured for 7 days at room temperature (approximately 25◦C). By erforming direct shear tests on the soil samples, we study the changes in cohesion and internal friction angle of stabilized soils. To increase accuracy, in order to drawing mohr-colomb envelop, 3 samples were tested at each normal stress as 9 sample were tested for drawing each line. In other word, to investigating shear parameters of stabilized soil each point earned from 9 direct shear tests.

3- Discussion and Results

Figure 1 and Figure 2 shows the effect of varied amount of multiwall carbon nanotube on shear strength parameters of sandy and silty soil, respectively. Both silty and sandy soil is stabilized by carbon nanotube in varied amounts, as 0, 1.5 and 3 grams of multiwall carbon nanotubes. As it is observed, carbon nanotube increases the shear strength of both silty and sandy soil by increase in cohesion term of stabilized soil. On the other hand, the internal friction angle term of shear strength of stabilized soils did not change significantly when carbon nanotube content was increased. This could be attributed to the fact that the individual fiber inclusions had no discernible effect on the microstructure of soil.

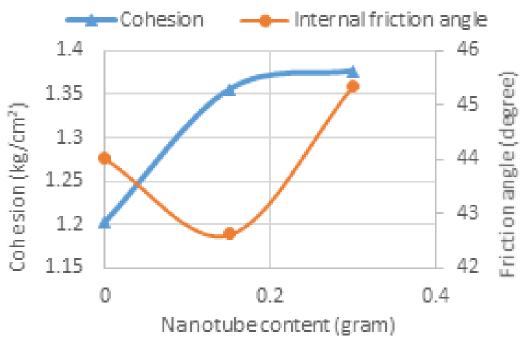

Figure 1. Effect of nanotube content on shear strength parameters of stabilized sandy soil

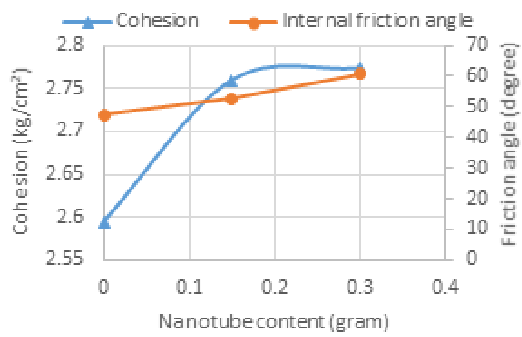

Figure 2. Effect of nanotube content on shear strength parameters of stabilized silty soil

The cohesion of the sandy soil increases from 1.2 to approximately 1.37 kg/cm^2. This shows 0.17 kg/cm^2 improve in cohesion of sandy soil. This improve for silty soil is 0.11 kg/ cm^2. We can observe that carbon nanotube is most effective for improving cohesion term of sandy soil rather than silty soil.

Also the result of applying different ultrasonic energy to dispersing CNTs on the shear strength of CNT-Cement stabilized soil shows that the maximum shear strength of soil achieved when it used as 500j/ml, both types of soil achieve their maximum shear strength comparing with other ultrasonic energies. Compared with lowest ultrasonic energy, it is observed that using ultrasonic energy as 500j/ml the shear strength of silty and sandy soil was improved as 19.7% and 21%, respectively.

4- Conclusions

By performing direct shear test on stabilized soil by cement and carbon nanotube the following conclusions may be drawn:

1. In order to dispersing used carbon nanotubes in the solution, ultrasonic energy has an optimum value and it is 60kj energy for 120ml of carbon nanotube suspension and it is independent of normal stress and soil type.
2. Optimum surfactant content isn't same for sandy and silty soil. It is 1% (of cement) for sandy soil and 1.5% for silty soil.
3. Carbon nanotubes increases the shear strength of soil mainly by increase in cohesion term of shear strength.

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