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Investigation of the strength of carbon-sand mixture

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Abstract

The greatest stress that a composite soil can sustain is a critical value when dealing with slope stability, bearing capacity and lateral earth pressure. Cohesion and internal friction of soil composite particles will create tension and retain any stresses which are applied to the composite material. The soil composite will remain secure unless the applied external stress reaches its shear capacity. This research examined composite materials consisting of sand and various percentages of carbon. The sand used in this experiment was yellow sand which is available in Western Australia. For the purpose of testing strength, three different percentages of carbon (5, 10 and 15) were added and mixed homogeneously with the sand. The strength of the composite material was tested using a small direct shear machine, in order to determine the effect of the presence of carbon on the soil strength. The experiment results provided evidences that the presence of carbon influenced the shear performance of the sand, with the shear strength of the sand-carbon composite being significantly lower than that of pure sand. The more carbon that was added to the mixture, the lower the shear strength. Carbon also takes up initial moisture content in the sand during the mixing process. The results of this research are potentially very useful in the geotechnical field, particularly with regard to construction sites containing carbon.

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1. Introduction

Structures can collapse for many reasons. One of them is settlement, which may be due to the extraction of water [1], and another is a loss of strength. Stabilization of soil has therefore always been an issue for the researcher. If soil fails, the consequences may be significant, such as major damage to civil engineering projects. Soil shear strength parameters are required to analyze soil bearing capacity, slope stability and retaining walls [2]. The capability of the soil to support any structure relies mainly on the soil's shear strength. The shear strength of soil can be represented by its cohesion (C) and internal friction angle (θ) [3].

In Western Australia, sand or coarse-grained soil is the type of soil often used as a basic foundation in civil engineering work. The disadvantage of sandy soil is that there is no holding capacity between the particles and it can therefore be classified as a non-cohesive (cohesionless) soil [4]. Non-cohesive soils display intergranular looseness, which is indicated by the separation of the soil particles in dry conditions and the fact that the particles only adhere to each other when wet, as a result of surface tension forces [5].

The shear strength performance of sand is also influenced by the purity and particle uniformity of the sand [3, 6]. Some other components may be found in sand, such as carbon, which may affect the purity of the sand. The percentage of carbon in the sand varies from one area to another, and it may have some influence on the shear performance [7]. Therefore, this project examine of carbon content in the sand upon the shear strength performance of the sand and look for any potential uses of carbon as a soil stabilization material.

2. Materials

The composite that was studied included the following components:

2.1. Sand

Yellow sand or Baldvis sand was selected for this experiment due to its availability in Perth, Australia. Baldvis sand can be classified as a poorly-graded sand and has a specific gravity of 2.65.

2.2. Carbon

This experiment used granular activated carbon (GAC) obtained from a local supplier. The adsorption surface area of the GAC was about 650 to 1000 m²/gram. This type of carbon was produced from a carbon source (wood, lignite, nutshells or coal) in the absence of air. This type of carbon is generally used in water treatment processes or the filtration of any other liquid to remove contaminants [8].

2.3. Experiment procedure

At least four sets of direct shear tests were conducted for four different types of sample, consisting of pure sand and sand containing 5%, 10% and 15% carbon. The sand was prepared by sieving to achieve particle uniformity and drying to remove the initial moisture content. For the preparation of the sand-carbon mixture, the percentage of carbon was calculated based on the dry weight of the sand. The direct shear test itself was run according to the procedure given by AS 1289.6.1.1-1998 [9]. Each sample was poured and compacted into the shear box prior to direct shear testing. Once the sample was ready, water was added to the shear box and the first 50 kPa of normal stress was introduced to the sample. The sample was then allowed to become fully consolidated before the shear stress was applied. Since the direct shear testing was performed using the automated direct shear machine, the results were logged and saved automatically by the software installed in the computer. After completion of the tests, the results were transferred to a spreadsheet in order to perform the calculation. The same procedure was carried out a normal stress of 150 kPa and 250 kPa and continued for each sample. The failure stresses were treated as being of high importance in order to discover the friction angle and cohesion.

3. Results and discussion

The first stage of the direct shear test was conducted for the sand sample without any carbon content. Three different normal stresses were applied to the sample (i.e 50, 150, and 250 kPa). The first load applied was 50 kPa and the maximum shear stress at failure was 35.87 kPa. The second normal stress applied was 150 kPa which produced a highest recorded shear stress failure of 98.86 kPa. Finally, 250 kPa of normal stress was applied to the sample, resulting in 172.36 kPa of shear stress failure. These results gave a cohesion value of 0 and an internal friction angle of 34.3° (Fig. 1).

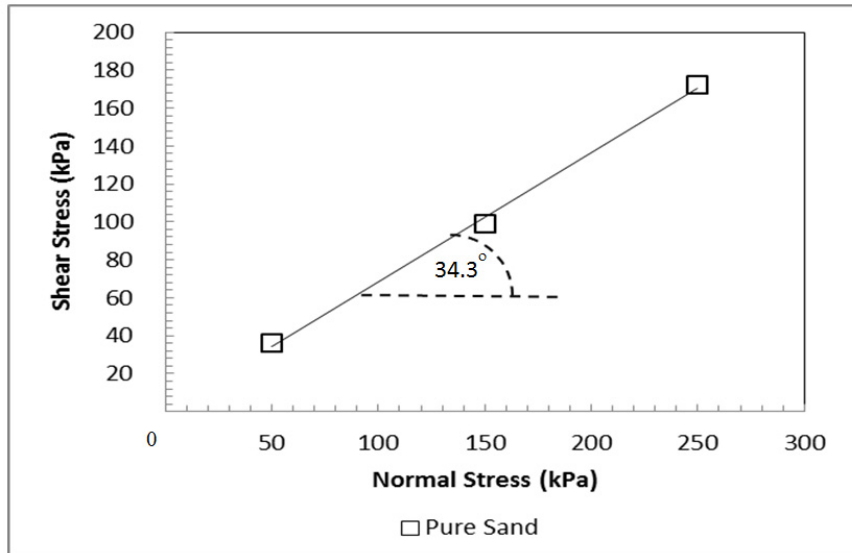


Fig. 1. Shear stress of sand under different normal stresses

Following the direct shear test on the pure sand, the next experiment aimed to investigate whether any change occurred in shear strength due to the presence of carbon in the soil sample. First, the sand sample with 5% of carbon content was tested at three different normal stresses (50, 150 and 250 kPa). The results showed that when 50 kPa of the normal stress was applied, the maximum shear stress failure recorded was 35.1 kPa. At 150 kPa of normal stress, the highest shear stress failure recorded was 84.1 kPa, and a maximum shear stress failure of 145.9 kPa was recorded after application of 250 kPa of normal stress. As seen in Fig. 2., the internal friction angle of the sand sample containing 5% carbon is 29° .

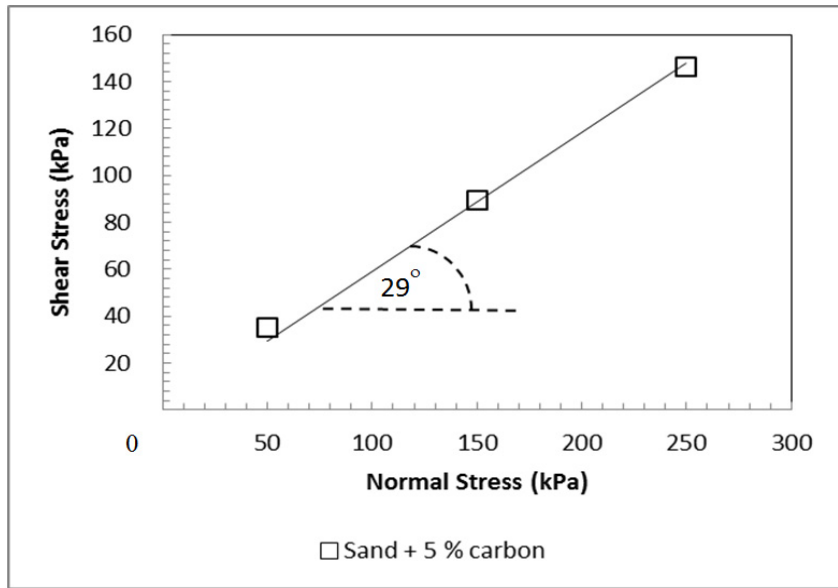


Fig. 2. Shear stress of sand containing 5% carbon with various normal stresses

Fig. 3 illustrates the results obtained from applying three different normal stresses to the sand samples with 10% carbon. The application of 50 kPa of normal stress resulted in a shear stress failure of 31.1 kPa. In the meantime, the application of 150 kPa and 250 kPa of normal stress resulted in a shear stress failure of 84.1 kPa and 140.2 kPa respectively. The results show an internal friction angle of 28.6° for the sand sample containing 10% carbon.

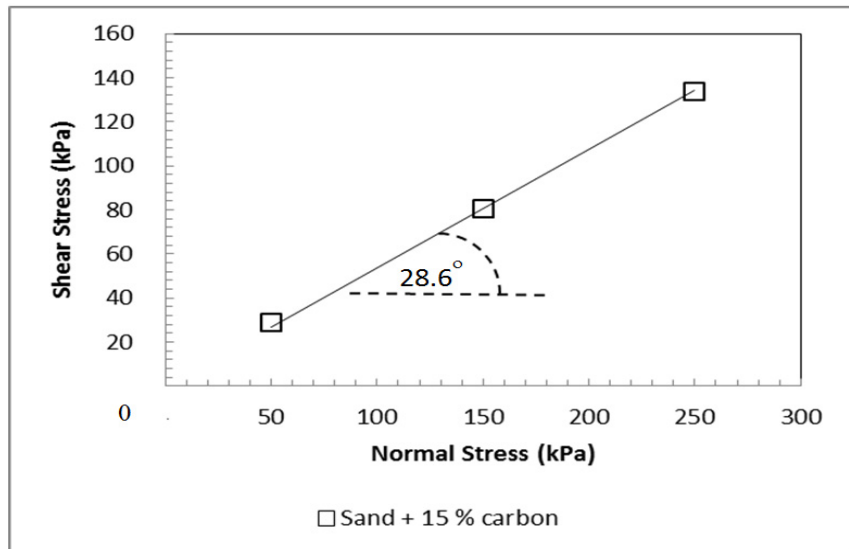


Fig. 3. Shear stress of sand containing 10% carbon under a series of normal stresses

Fig. 4 shows the result of the shear strength test on the sand sample containing 15% carbon. The application of normal stress of 50 kPa resulted in maximum shear stress values of 28.8, normal stress of 150 kPa concluded 80.4

kPa of shear stress and respectively 133.6 kPa under 250kPa. Those results yielded an internal friction angle of 27.6°, which was the lowest compared to other sand-carbon mixtures.

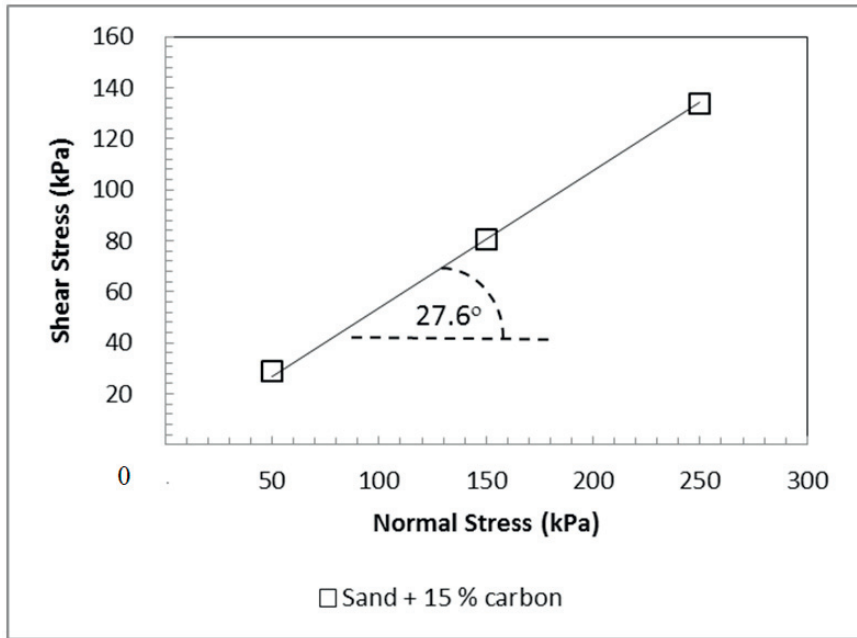


Fig. 4. Shear stress of sand containing 15% carbon under different variation of normal stresses

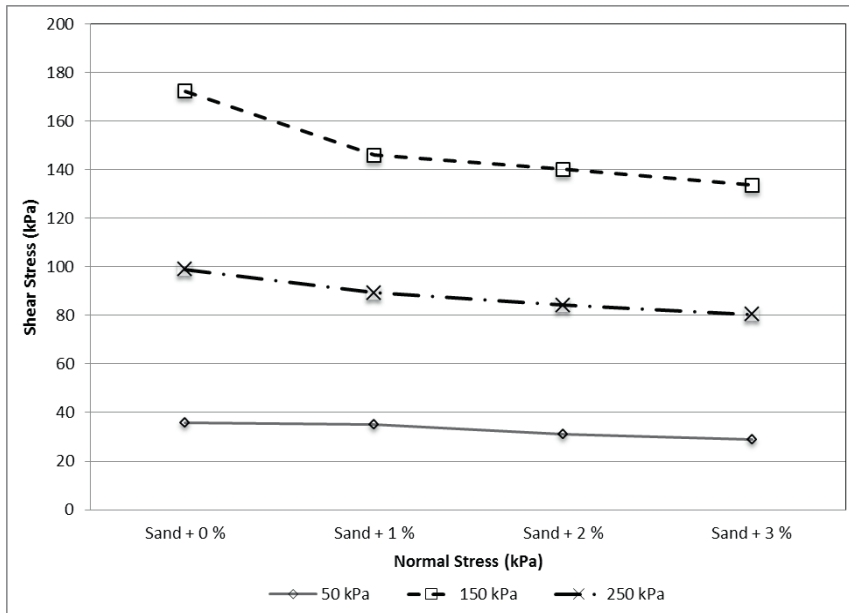


Fig. 5 The comparison of shear stress of sand containing 0%, 5%, 10% and 15% carbon under a set of normal stresses

Under the application of a series of normal stresses, the shear strength of the sand-carbon mixture tended to decrease with an increase in the percentage of added carbon. Under 50 kPa of normal stress, the presence of 5% carbon tended to reduce the shear strength of sand by 2.1%, while 10% and 15% carbon led to a reduction of shear strength by 13.3% and 19.6% respectively. Under 150 kPa of normal stress, the presence of 5% carbon tended to reduce the shear strength of sand by 9.7% while the 10% and 15% carbon resulted in 14.9% and 18.7% respectively. Under 250 kPa of normal stress, the presence of 15% carbon tended to reduce the shear strength of sand by 15.3% while 10% and 15% carbon led to a reduction of 18.6% and 22.5% respectively, compared to the shear strength of pure sand.

4. Conclusion

This study focuses on the effect of stabilization material in soil. A series of direct shear tests was performed using an automated direct shear machine to examine the effect of the presence of carbon in sandy soil. The sandy soil used in this experiment was yellow sand (Baldvis sand) which is widely available in Perth, Australia. The sand had a cohesion value of 0 and an internal friction angle of 35°. The presence of carbon seemed to change the internal friction angle of the sand, with a carbon content of 5%, 10% and 15% changing the internal friction angle to 30°, 29° and 18° respectively. However, the cohesion value was not affected by the presence of carbon. The maximum shear stress under different normal stresses decreased by 10% to 19% for sand containing 5% to 15% carbon. These results show that carbon tends to reduce the shear strength of the sand, and it is therefore not recommended for soil stabilization purposes.

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