Effect of fibre inclusion on cemented soil

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ABSTRACT
Brittle behaviour of cemented soil has been an issue in recent years due to increasing in stiffness of composite because of cement usage. Fibre inclusion in cemented soil has been an interest for researchers recently as a solution. The prospects of using fibre reinforcement in soil-cement composite were investigated in this paper. A series of unconfined compression tests were conducted. In this investigation two types of clay soil were used. The strength properties of cemented soil were obtained for different cement percentage (i.e. 0.5%, 1%). The fibre percentage also varied from 0% for unreinforced sample to 3% (by dry weight). The tests were conducted in different fibre lengths (i.e. 10mm and 25 mm).The results showed that fibre inclusion in the cemented soil composite increased Unconfined Compression Strength (UCS). Moreover, using of fibre caused increase in ductility of composite samples. Therefore fibre inclusion in cemented soil can be a practical method to increase usage of cemented soil in civil engineering projects.

RÉSUMÉ
Le comportement cassant de sol cimenté a été une édition au cours des dernières années en raison de l'augmentation dans la raideur de composite à cause de l'usage de ciment. L'inclusion de fibre dans le sol cimenté a été un intérêt pour les chercheurs récemment comme une solution. Les perspectives d'utiliser le renforcement de fibre dans le composite de ciment de sol ont été enquêtées dans ce papier. Une série d'épreuves de compression ouvertes a été accomplie. Dans cette enquête deux types de sol de glaise ont été utilisés. Les propriétés de force de sol cimenté ont été obtenues pour le différent pourcentage de ciment (c'est-à-dire 0.5 %, 1 %).Le pourcentage de fibre a aussi varié de 0 % pour l'échantillon non renforcé à 3 % (par le poids sec). Les épreuves ont été accomplies dans de différentes longueurs de fibre (c'est-à-dire 10 millimètres et 25 millimètres) .The les résultats a montré que l'inclusion de fibre dans le composite de sol cimenté a augmenté la Force de Compression Ouverte (UCS). De plus, l'utilisation de fibre a provoqué l'augmentation dans la ductilité d'échantillons composites. Donc l'inclusion de fibre dans le sol cimenté peut être une méthode pratique d'augmenter l'usage de sol cimenté dans les projets de travaux publics.

1 INTRODUCTION

The paper presents the effect of fiber inclusion on unconfined compressive strength of clay composite. Applications of soil strengthening or stabilization range from the mitigation of complex slope hazards to enhancing the subgrade stability. Together with the many applications for improving soil, there are several widely varied methods. Chemical stabilization by cement or lime is a proven technique for improving the performance (strength and stabilization) of soil (Ismail et al., 2002; Aiban, 1994; Huang and Airey, 1998; Basha et al., 2005; Kolias et al., 2005; Sherwood, 1993; Al-Rawas, 2002; Tremblay et al., 2002; Lima et al., 1996; Thome, 1999). However, these chemical additives usually result in a high stiffness and brittle behavior (Wang et al., 2003; Basha et al., 2005). The mixing of randomly oriented fibers to a soil sample may be considered same as other admixtures used to stabilize soil. Materials which are used to make fibers for reinforcement may be obtained from paper, metal, nylon, polyester and other materials having widely varied physical properties. There have been numerous past papers published on the topic of fiber strengthening of soils. Examples include Lee et al., 1973, Hoare,1979, Andersland and Khattac,1979, Freitag,1986, Gray and Ohashi, 1983, Gray and Rafeai, 1986, Maher and Gray 1990, Maher and Ho, 1994, Michalowski and Zhao 2002, Ranjan et al. 1996, Kaniraj and Havanagi 2001, Consoli et al. 2009. All of the papers listed above indicated that; strength of the soil was improved by fiber reinforcement. The investigation on clay composite is very limited. The purpose of this survey is to evaluate normal clay and cemented clay behaviour induced by fiber inclusion.

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2 MATERIAL

Composite soils consist of two parts. The first part is soil part which can be dealt as normal soil. The second part is reinforcement part which can be made up of any material which helps soil to have better performance.

2.1 Soil Type

The soil type in this study was Western Australian clay. The properties of clay are presented in table 1.

Table1. Clay properties

No.	Type	
1	Soil type	Clay
2	Liquid Limit	49
3	Plastic Limit	23
4	Pl. Index	26

2.2 Fiber Type

The natural fiber and plastic fibre has been used for this investigation. Figure2 and figure 3 shows the used fiber. The used fiber has good potential to absorb energy and good adhesion with soil particle.

Figure. 2 Plastic fibre

2.1 Cement Type

Portland cement type IV was used in this study. Type IV Portland cement is generally known for its low heat of hydration. Its normal compound composition is:
28% (C3S), 49% (C2S), 4% (C3A), 12% (C4AF), 1.8% MgO, 1.9% (SO3), 0.9% Ignition loss, and 0.8% free CaO.The percentages of (C2S) and (C4AF) are relatively high and (C3S) and (C3A) are relatively low. A limitation on this type is that the maximum percentage of (C3A) is seven, and the maximum percentage of (C3S) is thirty-five. This causes the heat given off by the hydration reaction to expand at a slower rate. However, as a result the strength of the concrete develops slowly. After one or two years the strength is more than the other types after full curing. This cement is used for very large concrete structures, such as dams, which have a low surface to volume ratio. This kind of cement is generally not stocked by manufacturers but some might consider a large special order. This type of cement has not been made for many years, because Portland-pozzolan cements and ground granulated blast furnace slag addition offer a cheaper and more reliable option.

3 TEST PROGRAM

A series of unconfined compression have been performed on reinforced clay composite.

3.1 Unconfined Compression Test

The unconfined compression test applies uniaxial stress conditions on a sample of soil, and is therefore a special case of the trixial test with no confining stress. The unconfined compression test has a considerable cost advantage over triaxial test due to the simpler testing requirement. The limitation of this test can be named as: preparing stable sample for cohessionless material and undrained estimation due to quick test.

3.2 Main Equipments

To run the test, tools are needed as:

- Unconfined compression testing machine (Triaxial Machine)
- Specimen preparation equipment
- Sample extruder
- Fiber
- Balance

Figure 2 shows the triaxial base which was used to run the UCS test. The device is fully automated so the results easily transferred without any user interference. Figure 3 shows the mechanism of CBR test machine.

Figure. 2 Trixial Base

4 SAMPLE PREPARATION

The samples were provided by mixing clay and three percentage of fiber. Specimen preparation procedure was the standard compaction method, which was used in an ongoing experimental research on fiber-reinforced clay at Curtin University. The soils were first oven-dried. The dry soils were then crushed using a hammer. A mixer was used to thoroughly mix the soils with water to obtain the desired water moisture content for compaction. The mixing of soil with fibers was performed mostly by hand rather than using the mixer because the mixer caused the fibers to tangle or break. The fiber-soil mixture was placed in a closed container for 24 hours after mixing was completed. A split mould and a specific hammer were used to compact the specimen. The specimens were prepared in different fiber content (i.e. 1%, 2%, and 3 %) and different fiber length (aspect ratio) which were 10mm, 25mm. For the cemented samples, 0.5% and 1% cement were used.

5 TEST METHODOLOGY AND PROCEDURE

The test procedure can be listed as:

- The specimens were prepared in the laboratory with 90% compaction effort, special care was taken during this process
- The size of samples were checked to be suitable for the test purpose
- The samples were put for 24 hours in geotextile and packed
- Special attention was applied for preventing any moisture loose
- The samples were placed in trixial base without any confinement pressure
- According to ASTM 1.27 mm/min were applied through the tests
- The data was collected automatically

The stress-strain curve plot used for strength behavior investigation

6 RESULTS AND DISCUSSIONS

The unconfined compression tests were conducted in order to determine effect of fiber inclusion on Unconfined Compressive Strength (UCS). The tests were included two parts. First part was to consider the effect of fiber inclusion on normal kaolin clay. The second part was related to effect of fiber inclusion on cemented clay. The cemented clay was constructed with 0.5% of cement content.

6.1 Effect of fiber on normal clay

The tests were conducted on cylindrical specimen of 60 mm diameter and 170 mm height. Figure 3 showed the stress-strain curve obtained from the tests. The results in Figure 3 proved that strength of the composite increased with increasing in fiber content. It should be noted that the results in Figure 3 is at fiber length 10mm.

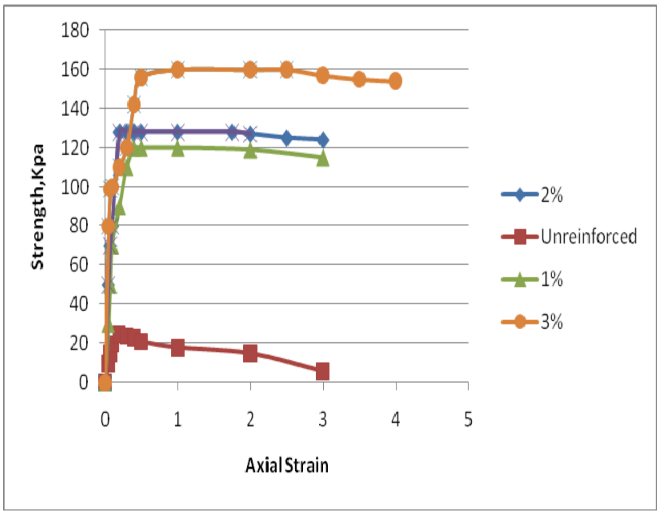

Figure. 3 UCS results with different fiber content (at 10mm fiber length)

The presented results in Figure 4 are at fiber content of 0.2%. Figure 4 shows effect of fiber length on composite samples. As can be found from the results, with increasing in fiber length, strength of composite was increased.

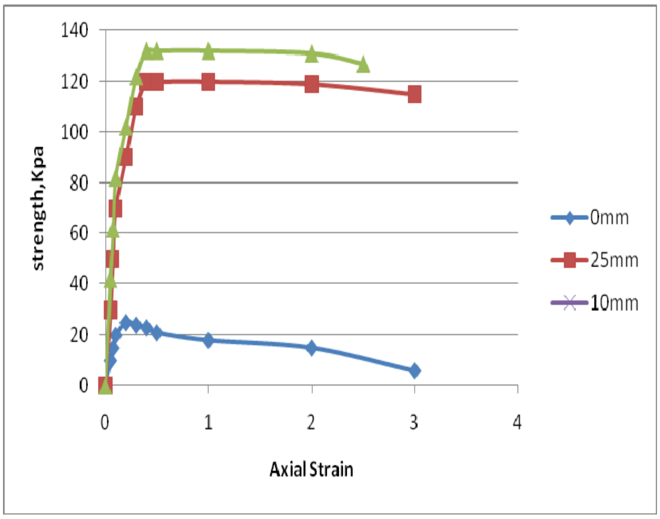

Figure. 4 UCS results with different fiber length(at fiber content of 1%)

6.2 Effect of fiber on cemented clay

In this section, effect of fiber inclusion investigated on cemented clay. As previously mentioned, the cemented samples were provided by 0.5% and 1% of cemented material. Similar to previous section, UCS tests were performed and following results obtained. Figure 5 indicates the effect of fiber content on UCS of composite cemented clay.

As it can be seen inclusion of fiber in cemented specimen increased the strength of the composits. More importantly, usage of cement of cement in soil will increase the brittle behaviour of the composite. The results proved that usage of fiber will help to increase ductility of the cemented clay.

Therefore, fiber inclusion would be an option to solve the brittle behaviour of cemented composite. It should be noted that results in Figure 5 is at constant fiber length of 10mm.

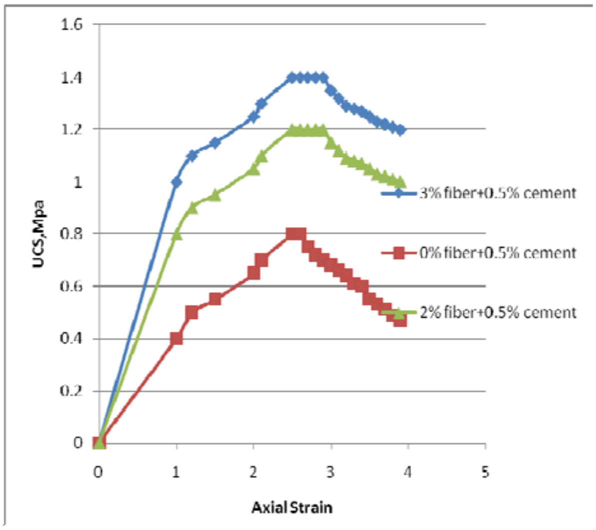

Figure. 5 UCS results with different fiber content (at 10mm fiber length)

Figure 6 shows the effect of fiber length on clayey cemented composite. As, it can be observed the strength of the composite increased with increasing in fiber length.

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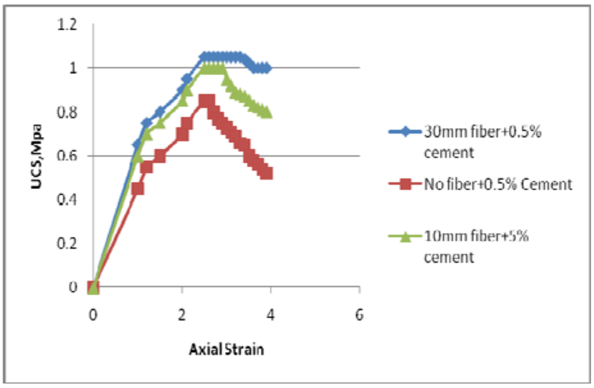

Figure. 6 UCS results with different fiber length (at 0.5% cement content)

The second step was to run UCS test with 1% cement. Figure 7 indicates that the effect of fibre content on cemented samples with 0.5% cement.

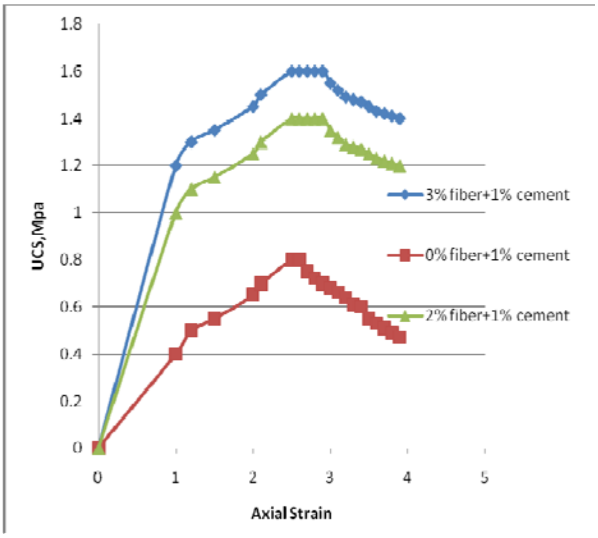

Figure. 7 UCS results with different fiber content (at 1% cement content)

Figure 8 shows the effect of fibre length on cemented sample which was reconstructed with 1% cement content.

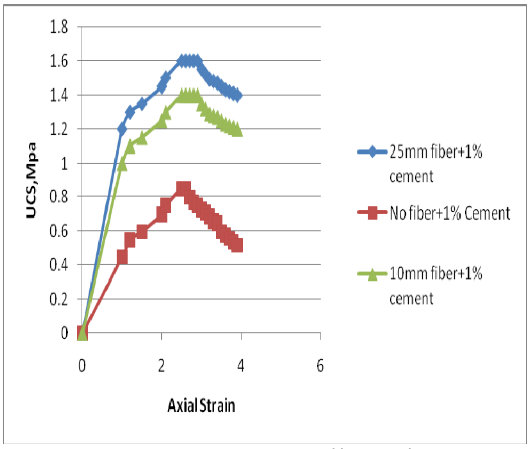

Figure. 8 UCS results with different fiber content(at 1% cement content)

7 CONCLUSION

A series of Unconfined Compression Test were performed to evaluate the effect of fiber inclusion on strength behaviour of composite material. The following results were derived:

- Increasing in fiber percentage increased strength in clay samples
- During the test, it was observed that ductility behaviour of reinforced clay increased because of fiber inclusion.
- The results proved that with increasing in fiber length, the UCS of composite clay was increased.
- The effect of fiber on cemented clayey composite observed in this study. The results proved that with increasing in fiber content the strength of composite increased.
- Fiber inclusion can be a good solution for cemented soil as it helps composite to have more ductile behaviour.
- Short and randomly Fiber inclusion showed to be reliable in industry projects as it helps to minimize the cost of projects.

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