Effect of Fibre Content on Compressive Strength of Reinforced Soil

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Synopsis: This paper aims to investigate effect of using fibre on strength of composite. A series of laboratory tests has been carried out to investigate the using of plastic fibre as reinforcement to increase the strength of the soil composite. Fibre percentage varied from 0% (for unreinforced samples) to 0.3%. Two methods of compaction test were used (i.e. Standard and Modified compaction methods). Unconfined compression tests were conducted in this study. The objective of using unconfined compression test was to determine the UU (unconsolidated, undrained) strength of a cohesive soil in an inexpensive manner. The results showed that fibre dosage was significant factor that affected the strength of the soil specimens. The results also indicated increasing in fibre content caused increase in compressive strength. The strength and ductility considerably increased with increasing the fibre content. Furthermore, Unconfined Compression Strength (UCS) found to be slightly greater for Modified method than Standard one. In addition, a series of tests have been conducted to examine permeability coefficient of the specimens. The results showed that length and fibre dosage had considerable effects on permeability of samples. It was proved that increase in fibre content and length caused increase in hydraulic conductivity.

Keywords: UCS, reinforced, fibre, clay, permeability.

1. Introduction

The paper presents the effect of fibre inclusion on unconfined compressive strength and permeability 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. The mixing of randomly oriented fibres to a soil sample may be considered same as other admixtures used to stabilize soil. Material used to make fibres for reinforcement may be obtained from paper, metal, nylon, polyester and other materials having widely varied physical properties. However, there have been some papers published on the topic of fibre strengthening of sand [e.g., 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15]. The investigation on clay composite is very limited. All of the papers listed above indicated that; strength of the soil, mainly sand, was improved by fibre reinforcement. The purpose of this survey is to evaluate clay behaviour induced by fibre inclusion.

Second part of this paper deals with permeability of composite clay. The permeability test is one of the oldest tests for soils. In this study, permeability test will be used to determine the hydraulic conductivity of a fibre reinforced soil. Effect of fibre inclusion on the hydraulic conductivity of a kaolinite-fibre composite investigated with different type of material and concluded that hydraulic conductivity of the soil increases as the percentage of fibre increases [e.g., 1, 13]. The originality of this study is using rough fibre rather than smooth one. This study will focus on effect of fibre on both permeability and Unconfined Compression Strength (UCS) of composite clay.

2. Material

Composite soils consist of two parts. The first part is soil part which can be dealt as pure 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 kaolin 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 Fibre Type

The plastic fibre has been used for this investigation. The fibre is commercially available and is called fibre Meyco FIB SP 65 macro structural synthetic polypropylene fibre which generates a very high energy absorption rate when used in the matrix. Table 2 shows the used fibre properties.

Table2. Fibre properties

No.	Type	
1	Material	Polypropylene
2	Specific Gravity	0.92
3	Width	1.6825 mm

3. Effect of fibre on Unconfined Compressive Strength of Composite clay

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

3.1 Unconfined Compression Test principle

The unconfined compression test imposes uniaxial stress conditions on a sample of soil, and is therefore a special case of the trixial test with zero confining stress. The unconfined compression test has a significant 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 Equipment

The following equipments were used:

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

3.3 Sample Preparation

The samples were prepared by mixing clay and three percentage of fibre. Specimen preparation method was the standard and modified compaction method, which was used in an ongoing experimental research on fibre-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 fibre-soil mixture was placed in a closed container for 24 hours after mixing was completed. A split mold and a specific hammer were used to compact the specimen. The specimens were prepared in different fibre content (i.e. 2% and 3%,) and different fibre length (aspect ratio) which were 10mm, 20mm, 30mm.

3.4 *Test Methodology and Procedure*

Following procedure performed to conduct the tests:

- The specimens were prepared in the laboratory with 90% compaction effort, special care was taken during this process(this step has been done with two methods (i.e. standard and modified))
- The size of samples were checked to be suitable for the test purpose
- The samples were put for 24 hours in geotxtile and packed
- Special attention was applied for preventing any moisture loose
- The samples were put in triaxial 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

3.5. Results and discussions

The result of the test can be analyzed in to two parts. The first part is regarding to use of standard method for deriving maximum dry density and therefore assuming 90% of compaction effort. The second part is related to results from UCS for sample provided with target dry density achieved from modified method.

3.5.1 Standard results

The unconfined compression tests were conducted in order to determine effect of fibre inclusion on Unconfined Compressive Strength (UCS). Figure 3 showed the stress-strain curve obtained from the tests. The tests were conducted on cylindrical specimen of 60 mm diameter and 170 mm height. The presented results in Figure 3 are at fibre length of 10mm.

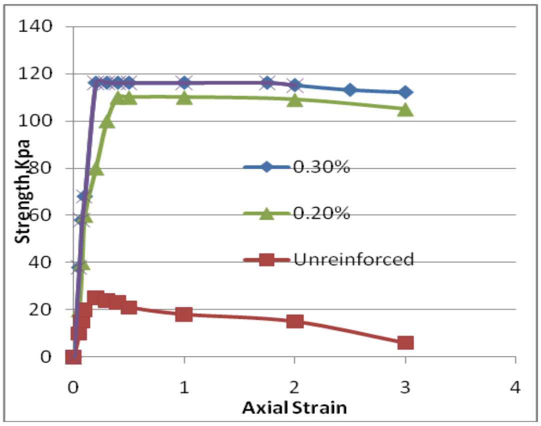

Figure 3. Effect of fibre content at 10mm

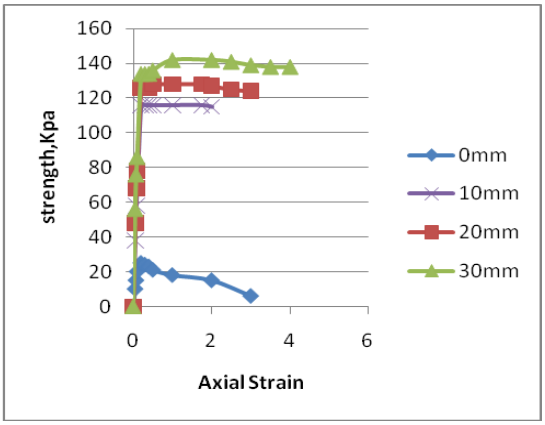

Figure 4. Effect of fibre length at 0.3%

Figure 3 proved increasing in fibre content will increase the strength. As can be observed with increasing in fibre content from zero (unreinforced) to 0.2% the peak strength increased from 26 Kpa to 117 Kpa. The second increase in fibre content from 0.2% to 0.3% also showed increasing in peak strength. Figure 4 evaluated the effect of fibre length on UCS strength and showed that with increasing in fibre length UCS strength also increased.

3.5.2 Modified results

This section is related to results from UCS test for samples were provided with more compaction effort (i.e. modified method). Similar procedure as standard one performed and results are presented in Figure 5 and Figure 6. Figure 5 indicated that with increasing in fibre content the UCS increased (same results as standard) and Figure 6 showed that with increasing in fibre length UCS increased (same as standard one).

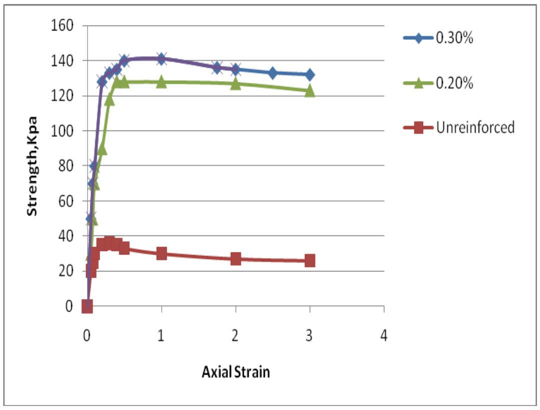

Figure 5. Effect of fibre content at 10mm

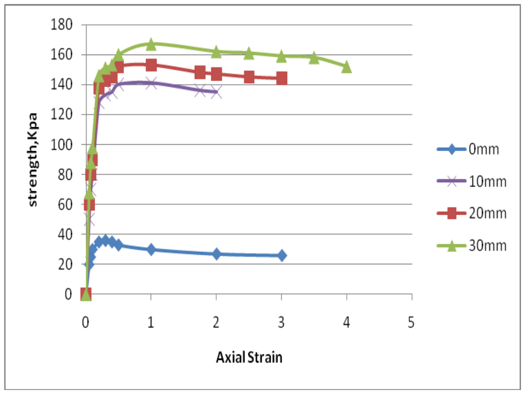

Figure 6. Effect of fibre length at 0.3%

4. Effect of fibre inclusion on permeability of reinforced clay composite

Effect of fibre inclusion on composite clay sample permeability is investigated in this section.

4.1 Permeability Test

Permeability is a measure of the ease in which water can flow through a soil volume. It is one of the most important geotechnical parameters. However, it is probably the most difficult parameter to determine. In large part, it controls the strength and deformation behavior of soils. It directly affects the following:

- Quantity of water that will flow toward an excavation
- Design of cutoffs beneath dams on permeable foundations
- Design of the clay layer for a landfill liner.

For fine grained soil Falling head permeability test is done, whereas constant head permeability test is done for the coarse grained soil.

4.2 Falling Head Permeability Test Application

• Settlements in structures

• Methods for lowering the ground water Table during construction

• Design grouting pressures and quantities for soil stabilization

• Freeze Thaw movements in soils (Note that coefficient of permeability (k) varies with temperature as the viscosity of the fluids changes with temperature, Curtin laboratory temperature was 23 ˚c)

• Design of recharge pits

4.3 Main Equipment

The main equipments used for the permeability tests are:

- Sample Chamber
- Specimen preparation equipments such as compaction tools
- Balance
- Falling head device

4.4 Test Methodology and Procedure

- the sample was compacted in the lower chamber section of the Permeameter, in layers approximately 1.5 cm deep, to within about 2 cm of the lower chamber rim. An appropriate tamping device was used to compact the sample to the desired density.(90% compaction effort made for the tests)
- the length of the specimen was measured and recorded.
- the clamp was used to attach the falling head burette to the support rod. the burette was placed as high as is possible for practicality. the meter stick was put directly behind the burette, so the height of water in the burette above the chamber outflow port can be read.
- the specimen was saturated, following the steps outlined above.
- the heights of the two levels from the outflow level were measured.
- After a stable flow has been established, the drop in head (Δh) in 2 hours was recorded.

4.5 Analysing the results

The following equation was used for calculating the results from Falling head:

$$k = \frac{a \times L}{A \times t} \ln \frac{h_0}{h_1} \quad (1)$$

Where,
k = Coefficient of permeability
a = Area of the burette
L = Length of soil column
A = Area of the soil column
h_0 = Initial height of water
h_1 = Final height of water = h_0 - Δh
t = Time required to get head drop of Δh

4.6 Results and discussion

The permeability tests were performed in order to determine effect of fibre inclusion on hydraulic conductivity of reinforced clayey composite. Table 3 shows the effect of fibre on hydraulic conductivity of the samples.

Table 3: Hydraulic conductivity of the samples

Sample type	Coefficient of permeability (cm/s)
Unreinforced sample	1.0 E- 8
Reinforced with 0.1 % of fibre at 15mm	2.2 E -8
Reinforced with 0.2% of fibre at 15mm	2.6 E -8
Reinforced with 0.3 % of fibre at 15mm	3.1 E -8
Reinforced with 10mm of fibre at 0.1% content	2.05 E -8
Reinforced with 25mm of fibre at 0.1% content	2.68 E -8

Figure 8 and Figure 9 visualize the results of the tests. The results proved with increasing in fibre content and length the hydraulic conductivity increased. The best line which could represent the laboratory data was derived and regression of that was determined. A series of permeability test performed. The methodology which applied to the test was falling head method. The clayey soil was reinforced by short plastic fibre .The results from the tests presented in this paper which showed effect of each fibre parameters on permeability characteristics of composite samples. It was proved that increase in fibre content and length caused increase in hydraulic conductivity. The value of coefficient of permeability jumped from 1 E- 8 (cm/s) to 3.1 E -8 (cm/s) with increasing in fibre content from zero to 0.3% and also with increasing in fibre length from 10mm to 15 mm the value of coefficient of permeability increased from 2.05 E -8 (cm/s) to 2.2 E -8 (cm/s). The behaviour of composite soil in terms of hydraulic conductivity was not linear due to change in fibre content and fibre length. Interaction of fibre and soil could be reason of increasing hydraulic conductivity as may cause creating some paths for water to escape in soil matrix.

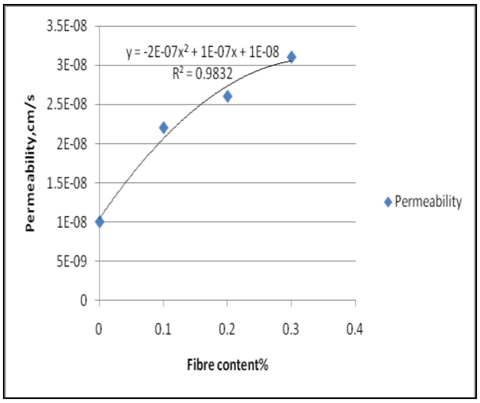

Figure 8. Permeability (at 15mm length)

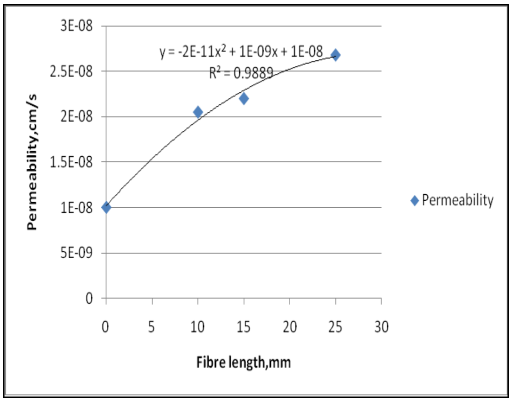

Figure 9. Permeability Test (at 0.1% fibre content)

5. Conclusions

Unconfined Compressive test and permeability test were conducted on composite clay and following results were derived:

- Increasing in fibre percentage increased strength in clayey samples
- The results proved that with increasing in fibre length, the UCS of composite clay was increased.
- Two methods of compactions applied (i.e. Standard and Modified). The results from both methods showed good agreement in case of behavior of composite clay.
- The strength from modified method was slightly greater than standard one.
- Permeability of composite samples was increased with increasing in fibre percentage and length
- Short and randomly fibre inclusion showed to be reliable in industry projects as it helps to minimize the cost of projects

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