STRENGTH BEHAVIOR OF POLYMER-FIBER AND CEMENT IMPROVED SOFT SILTY CLAY OF SHANGHAI

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ABSTRACT

This paper presents a laboratory investigation on the strength behaviour of the admixture of soft silty clay improved by polymer-fiber and cement. The test results show that the strength of the admixture is related to the length, content of polymer-fiber and cement content. When the cement content is less than 4%, the strength increases with the increase of the fiber content linearly. However, when cement content is greater than 4%, there exists threshold for strength with the fiber content. When cement content is 4%, the fiber content for maximum strength is from 1% to 1.5%; when cement content is 8%, the fiber content for maximum strength is from 0.5% to 1%.The length of fiber also affects the strength of admixture; the strength increases with the increase of the fiber length only when the fiber content is 2.0% or higher. However, when the cement content is 2%, 8%, the strength decreases with the increase of fiber length at low fiber content. When the cement is 4%, the strength increases significantly with the increase of the fiber length at low fiber content. Besides, the strength of the improved clay is also related to the cement content. The strength will increase significantly with the increase of the cement content.

Keywords: Improved soft silty clay, polymer fiber, cement, unconfined compression strength

INTRODUCTION

Underground structures such as subway and tunnel are generally buried in the soft clay which is widely existed in Shanghai. The soft clay will be removed as waste during underground construction. Reutilization for the excavated soft soil is as subgrade after improvement. In present, the clay can be improved by the strips, cement, fly ash, etc. (Indraratna et al., 1991; Kim et al., 2008; Kolias et al., 2005). And fiber had been proved to be an effective additive for improving engineering properties of the soft clay because of its strength isotropy, absence of potential failure plane, low price, friendly environmental nature and largely existing (Consoliet al., 1998; Ismail et al., 2002;Kaniraj and Havanagi, 2001; Tang et al., 2007).Many Tests had proved the improvement the engineering properties of the reinforced soil(Abdulla et al., 1997; Athanasopoulos, 1996; Fabian et al., 1986; Li et al., 1995). But the experiments above did not study the variety of cement content or the variety of fiber content and length.

The purpose of this paper is to investigate the unconfined compressive strength (UCS) of the fiber-reinforced cemented clay. A series of unconfined compression tests were carried out on soil samples with different percentages of fiber and cement. A optimum fiber content or fiber length or cement content or the optimal proportion of them are expected to be obtained to guide the engineering practices.

LABORATORY TEST PROGRAM

Materials

Soft silty clay collected in Shanghai, China from a depth of -2.58m was used in this experimental program. The soils were sealed for a few days to achieve uniform water content. The basic properties of the silty clay are given in Table 1. Polymer fiber was used throughout this investigation to reinforce the cemented soil. The basic properties of the polymer fiber are given in Table 2.Ordinary Portland cement was used as a cementing agent for the preparation of cemented samples.

Table 1 Physical properties of the silty clay.

Properties	Value
Water content (%)	48.2
Dry density (g/cm^3)	1.16
Wet density (g/cm^3)	1.72
Void ratio	1.26
Liquid limit (%)	37.3
Plastic limit (%)	20.9
Plasticity index	15.8
Plasticity index	1.48

Sample Preparation

For the unconfined compression tests, cylindrical specimens, 39.1 mm in diameter and 80 mm in height, were used. Initially, the water content of the clay was determined so that the amount of additional water, needed to achieve the desired water content for testing, could be determined. Then the amount of the fiber and the cement was determined according to the target content. A three axial saturation appliance was used to make the mixture of clay, cement and fiber into the standard specimens. The specimens were prepared with cement contents varying from 0% to 8% with an increase rate of 2%, fiber content varying from 0% to 2.5% with and increase rate of 0.5%, and fiber length of 3, 9, 15mm.

Table 2 Behavior parameters of the polymer-fiber.

Behavior parameters	Value
Fiber type	Single fiber
Unit weight (Mg/m)	0.91
Wet density (g/cm^3)	1.72
Diameter (μm)	30~40
Length (mm)	3, 9, 15
Fusion point (°C)	160
Burning point (°C)	590
Acid and alkali resistance	Very good

TESTS RESULTS

The conventional unconfined compression apparatus was used in the tests. Unconfined compression tests were carried out at a shearing rate of 1%/min (1.4 mm/min).The test procedure was performed according to the ATSM D2166 – 06(ATSM, 2006).

Nine groups of unconfined compression tests were carried out to investigate the strength of fiber-reinforced cemented clay, as shown in Table 3.

Figure 1 shows the stress-strain curves for fiber-reinforced cemented clay of 3mm and Cement ratio of 2%. As illustrated in Fig. 1, when the cement content was 2%, five different fiber content of specimens all showed ductility, namely no peak condition, and when the fiber content was 0.5% its strength was less than the no-cement specimens. Besides, no matter how long the fiber length was, when the cement was 2%, specimens all appeared no peak strength, ductile, and the strength was all greater than that of no-cement specimens. When the fiber content was equal to or greater than 2.0%, specimens showed peak strength.

Table 3 Nine groups of unconfined compression tests.

Group number	Fiber length(mm)	Cement ratio
F3-C2	3	2%
F3-C4	3	4%
F3-C8	3	8%
F6-C2	6	2%
F6-C4	6	4%
F6-C8	6	8%
F15-C2	15	2%
F15-C4	15	4%
F15-C8	15	8%

Note: Fiber ratio is 0, 0.5%, 1.0%, 1.5%, 2.0%, and 2.5%, respectively in each test group.

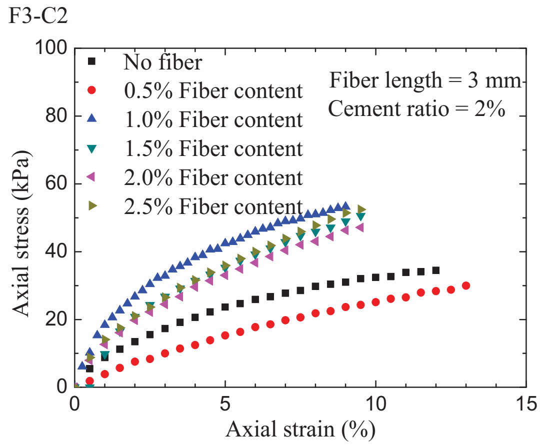

Fig. 1 Stress-strain curves for fiber length of 3mm and cement ratio of 2%.

As showed in Fig. 2, with the increase of cement content, when the fiber content was less than or equal to 1.5%, there was peak strength condition. When the fiber content was equal to or greater than 2.0%, specimens showed no peak strength and with the fiber content increased, its change trend obviously tended to be more quietly which indicated that the ductility of the same cement and fiber content of specimen tended apparent with the increase of that fiber length.

When cement content continued to increase, Fig. 3 showed that all specimens appeared peak strength, but their brittleness reduced gradually with the increase of fiber content. When cement content was 8%, only when the fiber content was 2.5%, there was no peak strength for the three fiber length.

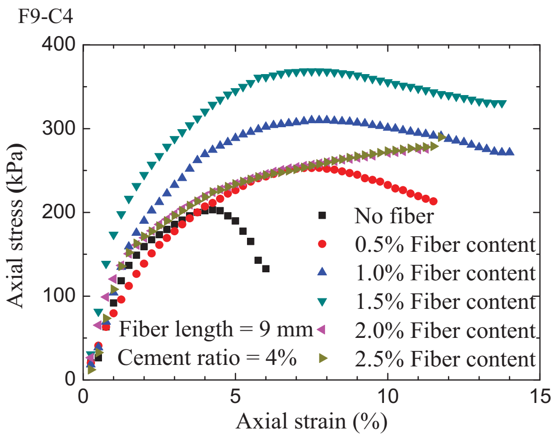

Fig. 2 Stress-strain curves for fiber length of 9 mm and cement ratio of 4%.

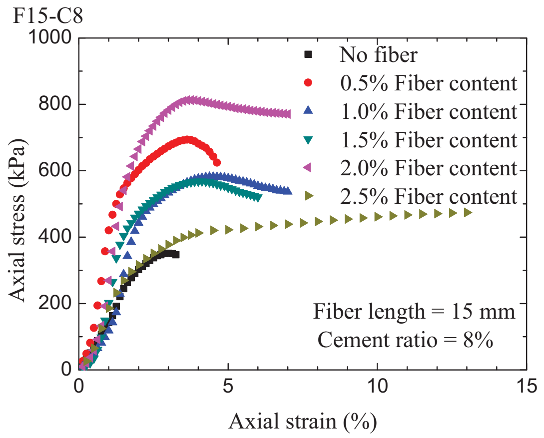

Fig. 3 Stress-strain curves for fiber length of 15mm and cement ratio of 8%.

DISCUSSIONS

Effect of Fiber Content on the Strength Behavior of the Improved Clay

Figure 4 shows the unconfined compression stress of improved clay with different fiber content of 4 %cement ratio. The strength presented a fluctuation change with the change of the fiber content. And the strength mentioned in this part is the maximum strength. When the fiber content was 4%, the same tendency can be seen that the fiber content can affect the strength in the same way. When the cement content was less than 4%, strength increased with the increase of fiber content linearly. When the fiber was 1.0% or 1.5%, specimens of the three fiber length all reached peak strength. And considering the different length of fiber, it can be concluded that specimen of the 3mm fiber length and the 15mm fiber length almost had the same peak strength. However, when cement content was greater than 4%, there existed threshold for strength with the fiber content. After the fiber content increased to 2.0% or higher, the specimen showed no

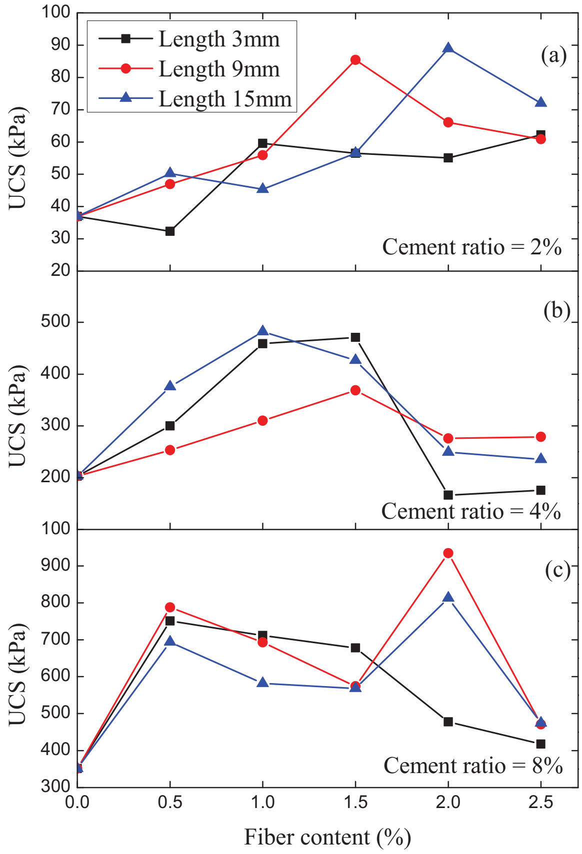

Fig. 4 The effect of fiber content for (a) Cement content of 2%; (b) Cement content of 4%; (c) Cement content of 8%.

difference from the no-fiber specimen. Maybe the strength will be increasing when the fiber length are longer from the tendency. When cement content was 4%, the fiber content for maximum strength is from 1% to 1.5%; when cement content is 8%, the fiber content for maximum strength is from 0.5% to 1%.

Effect of Fiber Length on the Strength Behavior of the Improved Clay

Figure 5 shows the unconfined compression stress of improve clay with different fiber length. When the cement content was 2% and the fiber content was 0.5%, 2.0%, and 2.5%, the strength increased with the fiber length. When the cement content was 4%, the strength of 15 mm fiber length was higher than that of the 3 mm fiber length. And when the cement was 8%, the strength decreased with the increase of the fiber length.

The strength increased with the increase of the fiber length only when the fiber content was 2.0% or higher. However, when the cement content was 2%, 8%, the strength decreased with the increase of fiber length at low fiber content. When the cement was 4%, the strength increased significantly with the increase of the fiber length at low fiber content.

Effect of Cement Content on the Strength Behavior of the Improved Clay

Figure 6 shows the strength of the specimens of all fiber content increased with the increase of the cement content. But the increase speed was not the same among the five fiber content as the increase of the cement content. When the fiber content was 0.5% (sometimes 1.0%) and 2.5% (sometimes 2.0%), the speed was very faster when the cement content increased from 4% to 8%. However, when the fiber content was 1.5% or in the middle, the speed was relatively show. In fact, increasing the cement content of the specimen means increasing the strength of the clay significantly.

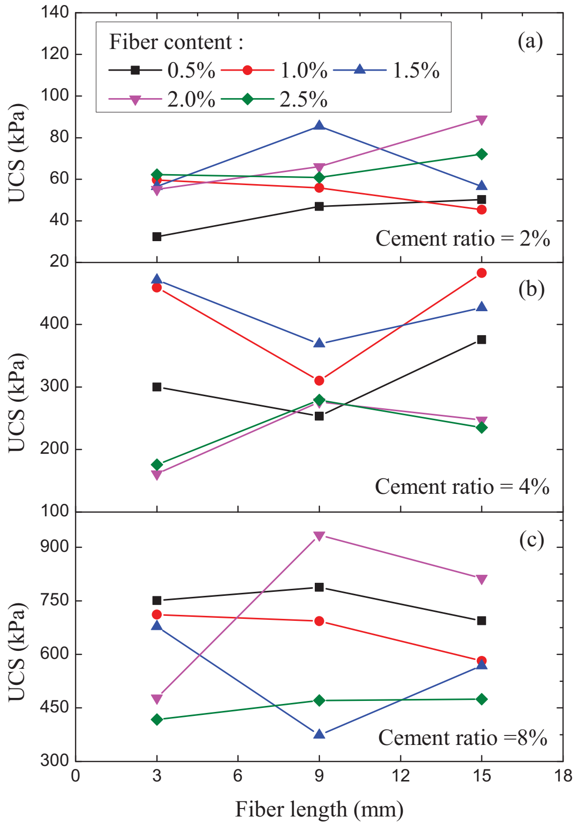

Fig. 5 The effect of fiber length for (a) Cement content of 2%; (b) Cement content of 4%; (c) Cement content of 8%.

CONCLUSIONS

By carrying out the unconfined compression tests on the fiber-reinforced cemented clay the following results were obtained:

1. The strength of improved clay will change with the addition of the fiber and cement. The content and length of fiber and cement content all will affect the strength of the fiber-reinforced cemented clay.
2. The strength of the improved clay is related to the content of polymer-fiber. The strength presented a fluctuation change with the change of the fiber content. When the cement content is less than 4%, strength increases with the increase of fiber content linearly. However, when cement content is greater than 4%, there exists threshold for strength with the fiber content. When cement content is 4%, the fiber content for maximum strength is from 1% to 1.5%; when cement content is 8%, the fiber content for maximum strength is from 0.5% to 1%.

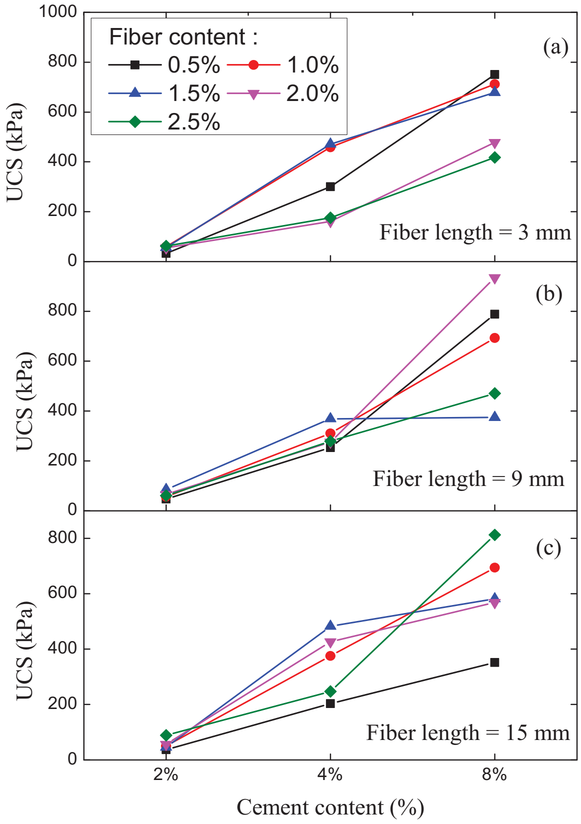

Fig. 6 The effect of cement content for (a) Fiber length of 3mm; (b) Fiber length of 9mm; (c) Fiber length of 15mm.

3. The length of fiber affects the strength of the improved clay; the strength increases with the increase of the fiber length only when the fiber content is 2.0% or higher. However, when the cement content is 2%, 8%, the strength decreases with the increase of fiber length at low fiber content. When the cement is 4%, the strength increases significantly with the increase of the fiber length at low fiber content.
4. The strength of the improved clay is also related to the cement content. The strength will increase significantly with the increase of the cement content.

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