Performance of Oil Palm Fibres on Improvement of Soil Strength

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ABSTRACT
Randomly distributed fibre-reinforced soils have recently been used to improve soil properties by increasing soil strength. The use of cost-effective and environment-friendly natural fibres has been suggested as an alternative. Oil palm empty fruit bunch (OPEFB) fibre is a waste product palm-oil milling and is used in this investigation to identify and quantify the effect of OPEFB fibres on soil stabilization. OPEFB fibre was coated with acrylic butadiene styrene (ABS) thermoplastic to protect the fibres from biodegradation. Series of triaxial tests were performed with fibre reinforced silty sand specimens prepared with OPEFB fibres of different lengths (15, 30, and 45mm) and at different concentrations (0.25% and 0.5%) of dry soil weight. Inclusion of randomly distributed discrete fibre significantly improved the shear strength of silty sand. Shear strength was shown greater Improve for coated fibres than uncoated fibres. The results show that the shear strength parameters of soil-fibre mixture can be improved significantly. The ABS was protected the fibre from degradation.

1. INTRODUCTION

Soil reinforcement is a useful and reliable method for improve the strength and stability of the week soils. Randomly distributed fibre reinforced soils have recently attracted increasing attention in geotechnical construction. Short discrete fibres can provide isotropic increase in the strength of the soil composite without introducing continuous planes of weakness. The discrete fibres are simply added and mixed randomly with soil, much like cement, lime, or other additives (Yetimoglu and Salbas, 2003).

The short discrete fibres used as improvement of shear strength of soil, studied by earlier researchers were made of polymeric or natural material (Gray and Alrefeai, 1986; Gray and Ohashi, 1983; Maher and Gray, 1990). Some researchers reported that plant roots increase the shear strength of the soil, consequently, the stability of natural slopes (Fan and Su, 2008; Prandini et al., 1977; Wu et al., 1979). With development of using polymeric fibre since the late 1980s, unconfined compression tests and direct shear tests have been conducted to study the effect of synthetic fibre reinforcement on shear strength.

Many studies conducted to evaluate the strength behaviour of soil mass reinforced with fibre under unconfined compression strength (UCS). Fibre inclusion can increase the peak shear strength and limited post peak reductions in shear resistance and decreased the stiffness of the soil. Previous study show significant increase in strength due to effect of fibre content, aspect ratio, fibre-surface friction along with the soil and fibre.

The importance of environment and protecting the natural resources need more attention to the new materials. Natural resources due to their cost-effective and environment-friendly properties could be an alternative material for soil structure improvement (Prabakar and Sridhar, 2002). Oil palm empty fruit bunch (OPEFB) fibre was identifying in this study due to its reliable strength and bulk availability in Malaysia. Oil palm belongs to the species *Elaeis guineensis* under the family Palmacea, and originated in the tropical forests West Africa. The oil palm is major industrial in cultivation for Southeast Asian region such as Malaysia and Indonesia (Sreekala et al., 1997). The OPEFB fibre needs to protect from biodegradation to be use in soil reinforcement, the coating method with Acrylonitrile Butadiene Styrene (ABS) was used in this study to treat the OPEFB fibres.

2. MATERIAL AND METHODS

2.1 Soil

The silty sand soil classifies as SM according to the Unified Soil Classification System (UCS) ASTM used in the present experimental tests. The silty sand was gained from the area of Penang, Malaysia. Figure 1 shows gradation curve base on the curve, the coefficient of uniformity is 4.82, and the coefficient of curvature is approximately 1.12. The soil properties were summarized in Table 1.

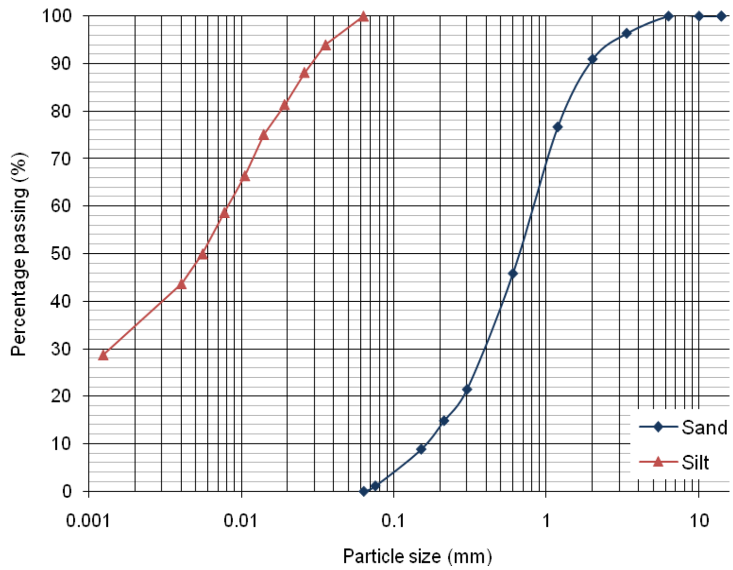

Figure 1: Gradation curve for soil Time

Table 1: Mechanical properties of soil (silty sand)

Property	Test method	Value
Classification (USCS)	ASTM D2487	Silty Sand (SM)
Gs	ASTM D 854	2.575
LL %	ASTM D 4318	45
PL %		32.5
PI %		12.5
γ_{max} (kN/m³)	ASTM D698	16.67
γ_d (kN/m³)		14.50
Dr %	ASTM D4253	75

2.2 OPEFB Fibre

OPEFB fibres used for reinforcing the soil mass are available in oil palm factories produced from empty fruit bunch from palm oil mill (Figure 2). OPEFB fibres cut in to the different size (e.g. 15mm, 30mm and 45mm). Two fibre contents, 0.25% and 0.5% by weight of dry soil, were randomly mixed with silt sand. The properties of OPEFB fibre were summarized in Table 2. Series of tensile test conducted on OPEFB fibre a universal tensile testing machine Instron 3367 at room temperature (25±2).

Figure 2. Oil palm empty fruit bunch fibre

2.3 Treatment of the Fibres

The ABS thermoplastic used to protect the fibres from biodegradability. Natural OPEFB fibres have been coated with ABS thermoplastic to study the behaviour of fibre reinforced soil with protected fibre and effect of coating on performance of fibre reinforced soil mass.

2.4 Sample Preparation

Fibre-reinforced silty sand prepared with three different percentages of fibre content of f = 0%, 0.25% and 0.50% by weight of dry soil. The tests were repeated at three different lengths (l_f) of 10mm, 20mm and 30mm mixed with soil randomly used in the present study to carry out triaxial tests. The soil was initially prepared at the optimum water content and the mixing of soil with fibres was conducted until it reached approximately homogeneous mix of soil and fibres. Fibre silty sand mixed was compacted in three layers, with optimum moisture content (OMC) of 15.29% and a same dry density of 1.45 g/m^3.

2.5 Triaxial Consolidate Undrained Test

A series of hydrostatically consolidated drained (CD) triaxial shear tests are performed on both reinforced and unreinforced silty sand to evaluate their strength behaviour. Pore pressure valve closed during shearing test and pore water pressure determined. Consequently, the pore water pressure changes as the test proceeds and the sample responds to the change of total stress at constant volume. Axial stress and pore-water pressure used to evaluate the effective stresses.

3. RESULTS AND DISCUSSION

3.1 Effect of OPEFB Fibre on Compression Strength of Silty Sand Soil

Triaxial compression test result obtained from consolidate drained test condition were used to evaluate the behaviour of fibre reinforced silty sand. The selected fibres had three different fibre lengths (15 mm, 30 mm and 50 mm). The specimens were placed using two different gravimetric fibre contents (0.25% and 0.5%). The effect of the OPEFB fibres coated by ABS thermoplastic on increase of the shear strength of reinforced silty sand compare with the natural OPEFB fibres. Figure 3 shows the increase on deviator stress of silty sand was reinforced with both the coated and uncoated OPEFB fibres. Inclusion of the coated fibres to soil is shown the larger increase deviator stress than the uncoated OPEFB fibres.

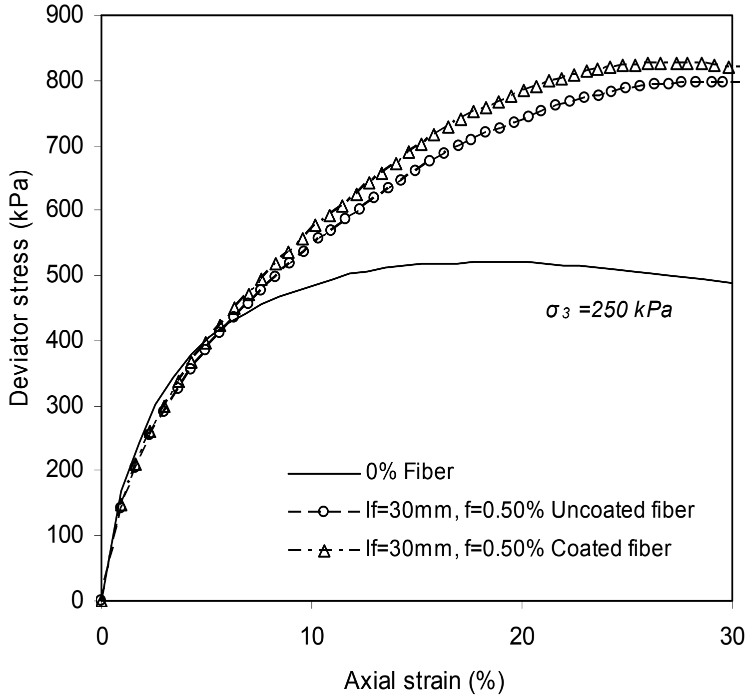

Figure 3: Typical stress-strain curves obtained from triaxial CD test on soil reinforced with OPEFB fibres

3.2 Effect of Fibre Content

The shear stress–strain curves obtained from the triaxial undrained tests for reinforced sands with the coated OPEFB fibre with length of 30mm are shown in Figure 2 together with those for unreinforced silty sand. Compared to the unreinforced specimens, the fibre reinforced specimens showed higher deviator stress. It can be also seen that the larger strain corresponding to the peak deviator stress is affected by fibre content.

Figure 5 shows the volumetric strain evolution during the test for the same tests as shown in Figure 4. The volumetric shrink of fibre reinforced specimens was found to be larger than that of unreinforced specimens. This observation indicates that fibre-reinforcement helps to restrain the dilation of the soil. Test result was shown the volumetric strain increased with increasing the fibre content and increasing the confining pressure.

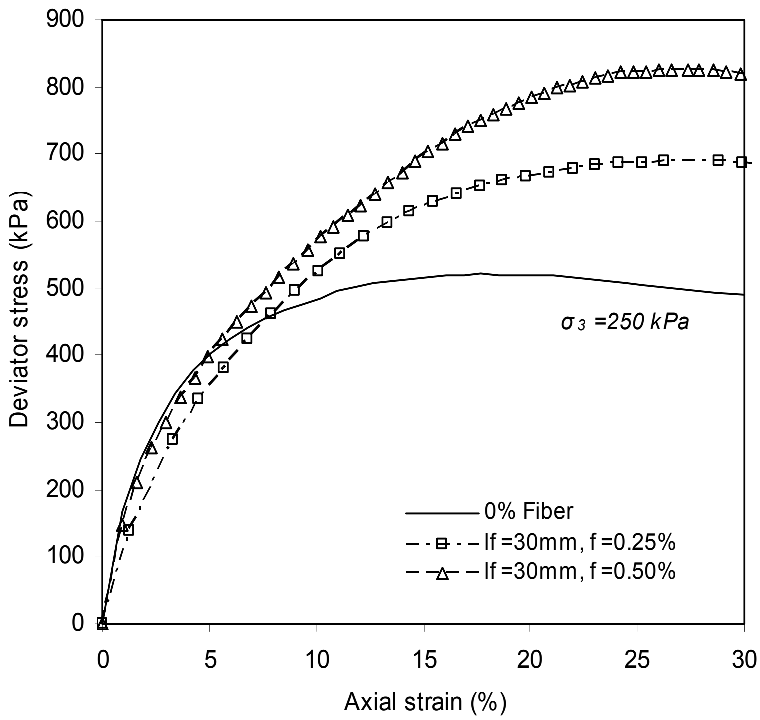

Figure 4: Typical stress-strain curves obtained from triaxial CD test on soil reinforced with OPEFB fibres

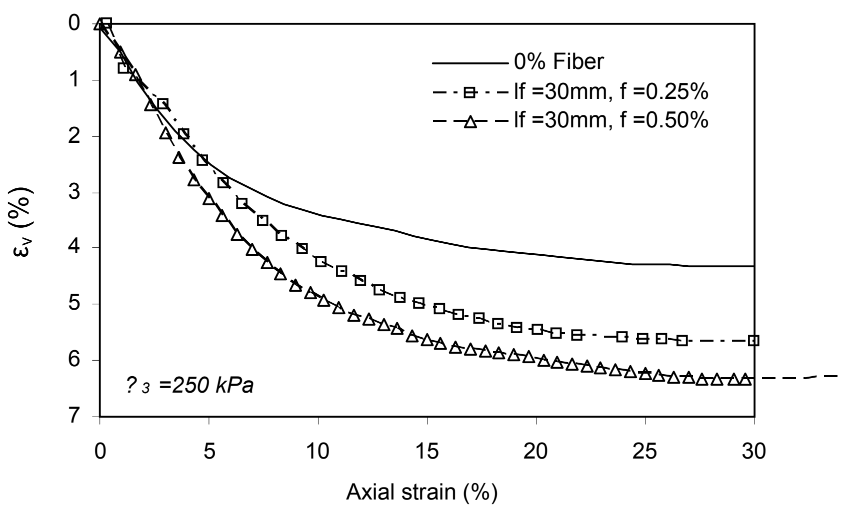

Figure 5: Relationship between volumetric strain and axial strain in triaxial CD test on OPEFB fibre

3.3 Effect of Fibre Length

Figure 6 illustrate the effect of fibre length of 15, 30 and 45mm on increasing the peak stress of soil with fibre content of f =0.5%. But the contribution of further increase of fibre length to peak stress was insignificant. Patterns of stress–strain curves for all reinforced samples indicate improvement in the deviator stress while fibre is included in different percentage and different lengths. Deviator stress of fibre reinforced soil also increased with increase in confining pressure (σ_3). Triaxial test conducted under three confined pressure of 50 kPa, 100 kPa and 250 kPa to study effect of fibres inclusion on shear strength parameter c and ϕ of soil.

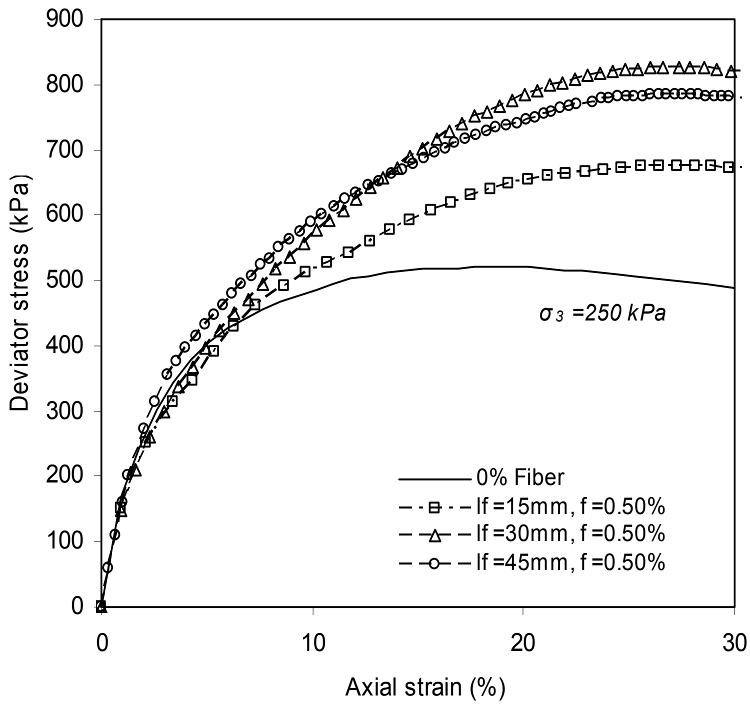

Figure 6: Typical stress-strain curves obtained from triaxial CD test on soil reinforced with OPEFB fibres

3.4 Shear Strength of Fibre Reinforced Soil

Both the length of fibre and percentage of fibre content played an important role in the development of shear strength parameters of the fibre reinforced soil. Results of drained test condition shows randomly distributed fibres have an important effect on friction angle (ϕ). Comparison of OPEFB fibres effect on growing of friction angle on soil reinforcing and effect of coated OPEFB fibres presented on Figure 7. The variation of friction angle with fibre length shows a non-linear variation. In general, the angle of internal friction increased with increase in fibre length up to 30mm fibre length and then reduced. The same reduce on shear strength under UCS test condition reported by Prabakar and Sridhar (2002) using the sisal fibre to reinforced the soil. The decrease in the friction angle for 0.45mm fibre length might be due to non-uniform distribution of fibres and the increase in the amount of fibre particles that are associated with the top of the cylindrical mould because of the longer fibres and the smaller cylindrical sampler.

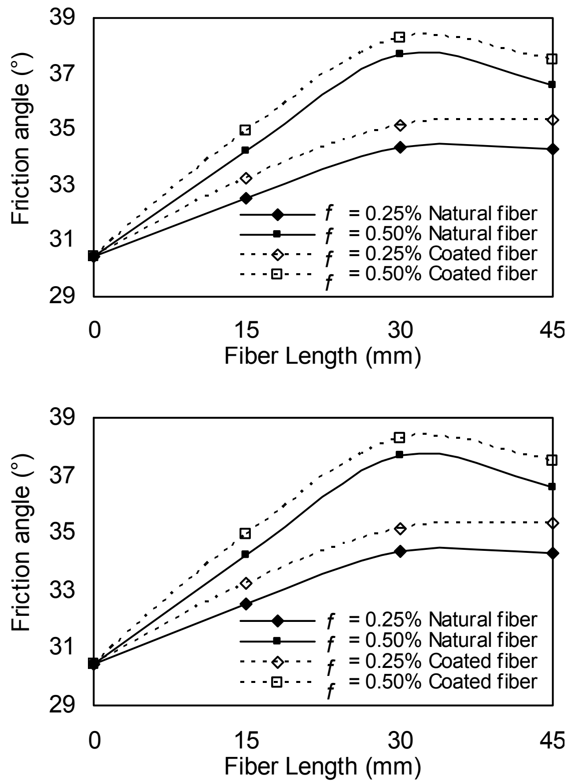

Figure 7 Comparison the effect of fibre content and fibre length between
ABS coated and uncoated OPEFB fibre under triaxial CD test,
(a) effect on friction angle (b) effect on cohesion

Coated fibres exhibit a larger increase in shear strength compared with uncoated fibre, presumably due to their larger surface area and strength. Increased surface area can led to increased interface friction between fibres and soil particles. Coated fibre has greater stiffness and strength than uncoated fibre, and these properties limit the deformation and increase the shear strength of the soil. Cohesion of the reinforced silty sand determined under drained condition exhibits linear increase. However, the amount of cohesion is small.

CONCLUSION

The addition of OPEFB fibres can significantly increase the peak shear strength of silty sand soil. Increasing fibre content leads to increasing strain at failure and, consequently, to more ductile behaviour. The shear stress increased non-linearly with increasing length of fibre up to 30 mm.

Volume dilation decreases fibre content under drained conditions, and fibre inclusion increases the positive water pressure under undrained conditions. Both cause an increase in the shear strength parameters (φ' and c') of the soil. Cohesion increases linearly with the fibre content. The increase in the length of fibre increases the value of friction angle. There is no specific trend in the variation of friction angle with fibre length.

Coating fibres increases the shear strength compared to uncoated fibres. The layer of coating increases the diameter and surface area of the fibre, and consequently, the interface friction of fibre and soil. Otherwise, an increase in the tensile strength and stiffness of fibres leads to an increase in shear strength of fibre-reinforced soil because of the limiting effect on the dilatancy of silty sand.

The ABS thermoplastic that was used in this study to protect fibres from degradability had acceptable effect on protection of fibre as the same as other treatment techniques.

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