Stress – Strain Behaviour of an Oil Palm Fibre Reinforced Lateritic Soil

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ABSTRACT

This paper presents the use of oil palm fibre in the reinforcement of a lateritic soil. The results show considerable improvement in the strength of the reinforced clay soil, with optimum palm fibre content of about 0.7% of the dry weight. However, further increase in fibre content did not significantly affect the strength. Stress-strain curves show inverse relation between peak stress and strain. It is therefore concluded that oil palm fibre cements soil particles and fibre together; thus, promotes stress distribution evenly and improves deformation resistance.

Keywords: Oil palm fibre, Stress-strain, Deformation resistance, Lateritic soil, Strength.

INTRODUCTION.

Improvement of the mechanical properties of soil range from the mitigations of complex slope hazards to increasing the subgrade stability (Sharma et al 2012; Otoko and Esenwa 2014). There are several widely varied methods. The mixing of randomly oriented fibres to a soil mass has been reported by Otoko et al (2014). Fibres for reinforcement may be derived from paper, metal, nylon, polyester and other materials having widely varied physical properties (Miller 2004; Nataraj and McManis 1997; Tang et al 2007; Viswanadham et al 2009, Arvind et al 2006), but mostly using synthetic fibres and polymers; which are not biodegradable, thus pose a serious disposal problem at their life. Thus, biodegradable bio-based polymer products are preferred in recent years. Infact, plant-based natural fibres are even more widely used as they are cheap and light weight, having relatively high tensile strengths and flexural moduli of elasticity and are biodegradable (Zhou et al 2012; Pietak et al 2007). Oil palm fibre is a hard fibre obtained from the leaves of oil palm trees, which are abundant in the Niger Delta, Nigeria. It consists of mainly cellulose, hemicellulose, lignin and small amounts of wax and impurities. As a result of its high strength of up to 600MPa, similar fibres have been commonly used in making ropes, mats, carpets, kitchen cloths as well as composite materials (Jun and Anil 2010).

Otoko et al (2014) and others have investigated use of oil palm fruit fibre in soil reinforcement, but the use of palm fibre obtained from palm leaves has not been used for clay soil reinforcement. This study therefore focuses on the reinforcement of laterite using oil palm fibre addictive in various proportions.

EXPERIMENTAL METHODS.

Palm fibres were obtained from Essene, Ikot-Abasi, Nigeria; and chopped into 10mm length pieces. The chemical constitution of the palm fibre (%) is shown in table 1. The laterite soil sample was obtained from Emohua, the properties of which are shown in table 2.
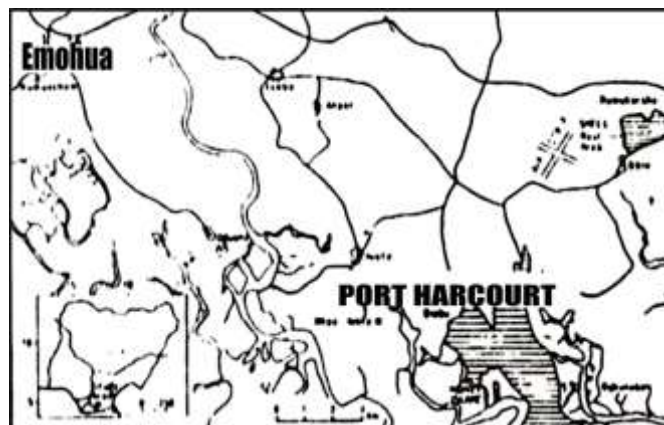

Figure 1: Map of the Niger Delta, Nigeria, showing the location of Emohua and Port Harcourt City, Nigeria.

Table 1: Chemical Constitution of Palm Fibre (%).

Cellulose	Hemicellulose	Lignin	Pectin	Hydrotrope	Waxiness	Water Ratio
65.5	11.8	10.0	0.7	1.1	0.7	10

The maximum dry unit weight and optimum water content of the laterite were obtained from Proctor Compaction Tests. Thereafter, the preparation of

the samples for the compressive strength test were at optimum water content. Care was taken to lubricate the inside of the mould to ease removal. The mould was

Figure 2: Proctor Compaction Mould for the compaction tests

filled with the laterite and compacted to the brim. Thereafter, samples were removed and were immediately trimmed to the desired height, and fibres top and bottom trimmed with scissors. Unconfined compressive strength (UCS) tests were then carried out on the samples in accordance with ASTM D2166-06; but keeping strain rate content at 0.5% per minute throughout the testing program.

Standard uniaxial compressive test as described in ASTM D3080-04 was carried out and the test samples prepared in accordance with ASTM standard specifications. The uniaxial compressive test modules of compression and compression index are determined from equations 1 and 2.

$$E_s = \frac{1 + e_i}{a_v} \quad \text{……………………} ①$$

Where e_i and a_v and are the void ratio and compressibility coefficient respectively.

$$C_i = \frac{e_i - e_{i+1}}{\ln p_{i+1} - \ln p_i} \quad \text{………..………} ②$$

Where e_i and p_i and e and p_{i+1} are the initial and final void ratio and load values respectively.

The direct shear test was carried out in accordance with ASTM D3080-04: whereas, the indirect tensile test on dry samples was carried out in accordance with ASTM D3967-08. Determination of the tensile stress was by equation 3:

$$\sigma_t = \frac{2F}{\pi DL} \text{ x } 100\% \quad \text{…………..} 3$$

Where L and D are the length and the diameter of the cylindrical samples.

RESULTS AND DISCUSSIONS

The unconfined compressive strength test results is shown in fig. 3, which shows clearly that the unconfined compressive strength is directly proportional to the palm fibre content. This may be because fibre addition strengthens the ability of the clay to withstand compression forces; and so the compressive strength for reinforced clay may be in the order of 1.2 times that of the unreinforced clay. However , beyond about 0.7% palm fibre content,
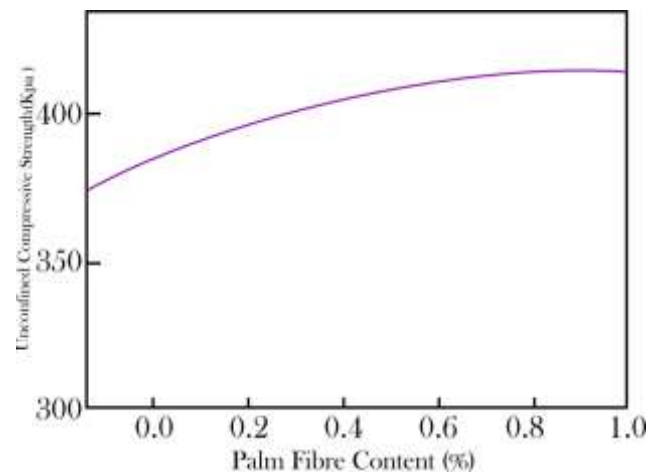

Figure 3: Variation of palm fibre content with unconfined compressive strength. the curve is almost flat, showing that further fibre addition may not necessarily increase strength, which agrees with Temel et al 2005.

Table 2: Uniaxial Compression Test Results.

Palm fibre content	Es/(Mpa)	C_i
0	2.015	0.397
0.2	2.232	0.381
0.4	2.418	0.369
0.6	2.627	0.364
0.8	2.631	0.361
1.0	2.645	0.358

It is clear from the uniaxial compression test result shown in table 2, that the compression modulus is directly proportional to the palm fibre content, while the compression coefficient and compression

index are inversely proportional to the palm fibre content. This means great improvement in resistance to deformation of the clay.
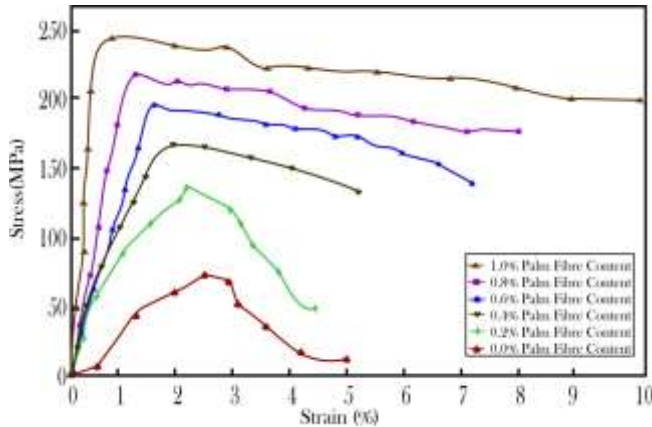

Figure 4: Stress-strain curve of soil with various fibre content

The stress-strain curves for various palm fibre content is shown in fig. 4; which clearly shows that the unconfined compressive strength (UCS) is directly proportional to the palm fibre content up to the peak stress, beyond which the UCS drops in value with further increase in palm fibre content.

Colour photograph of palm fibre reinforced clay test specimens is shown fig. 5; which clearly shows how the fibre has kept the specimens intact, as crack arrestors; thus, improving the ability of the soil to withstand fracture.

Figure 5: Photograph showing fibre reinforced test specimens after testing.

Variation of the maximum shear stress with palm fibre content is shown in fig.6; which clearly shows that the maximum shear stress is directly proportional to the palm fibre content.
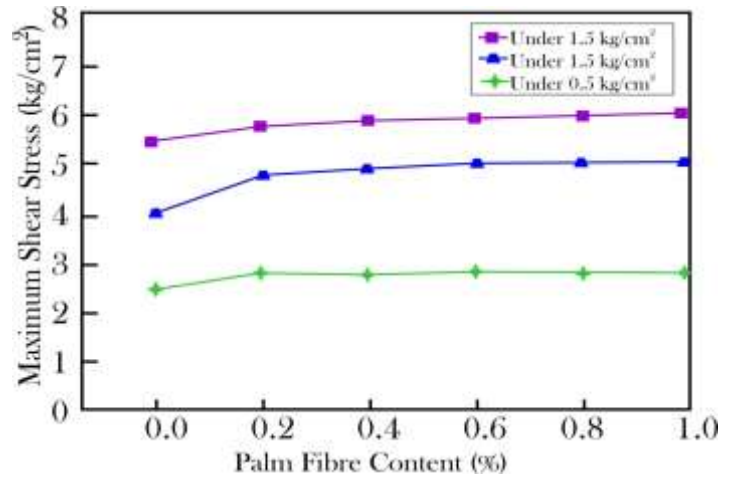

Figure 6: Ultimate shear strength under various loads

Fig. 7 shows the variation of indirect tensile test with palm fibre content; which clearly shows that the tensile strength is directly proportional to the palm fibre content up to the peak value at 0.7% palm fibre content.
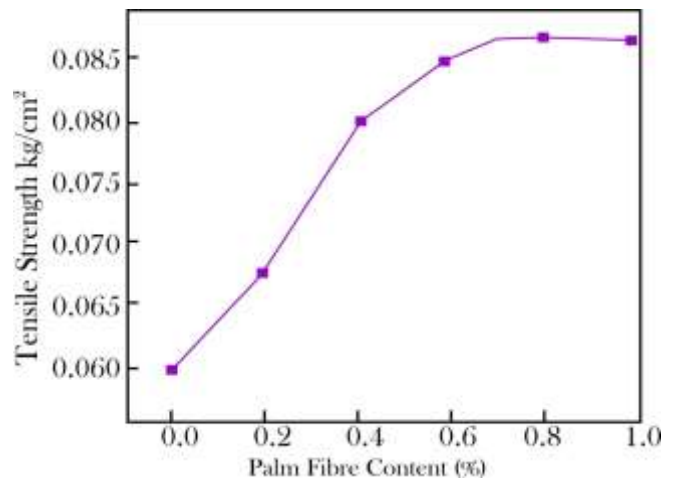

Figure 7: Indirect tensile test results

CONCLUSIONS

It can be concluded from this work that addition of palm fibre to the lateritic soil, has ability of increasing the deformability resistance potential of the soil, while improving the strength of the soil as well. The optimum fibre content is about 0.7%.

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