Oil Palm Empty Fruit Bunch-Polyurethane Composite: The Effect of PU-EFB Mixture on Strength Characteristics

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Abstract: Currently, the race for creating biodegradable items has expanded immensely. Distinctive methodologies have been endeavored to utilize biomass as common biopolymer. Accessible arrangement is to join the petroleum and bio-assets (plant and horticulture stock) to create a helpful item having the imperative expense execution properties for genuine applications. There are many methods that have been applied to improve the behavior of the soil and increase the strength and characteristics of the soil. In this research, polyurethane (PU) foam/resin was utilized and consolidated with oil palm empty fruit bunch (EFB) as fiber from palm oil. PU foam are normally utilized as a part of numerous applications including bundling, padding, space filling and protection yet all the more frequently in geotechnical designing while oil palm EFB is a unique reinforcing material as it is non-hazardous, renewable, and readily available at relatively low cost due to established technology to extract the fibers compared to other commercially available fibers. Different ratio of PU and EFB was used to optimize the composition in order to increase the ultimate strength of the composition. Shear strength of these two combinations were measured by conducting the specific test which was Unconfined Compression Test (UCT). This test measured the undrained strength and stress-strain characteristic of these mixtures. From the analysis, it was found that fiber changed the failure mode of PU foam into a more ductile behavior. Having a 25 % of fiber can double the strength of the foam, but increasing the fiber further reduces the strength.

Keywords: Empty fruit bunch, Polyurethane, Strength, Unconfined Compression test

1. Introduction

Malaysia is a developing country. Rapid development can be seen in the construction sector and the government is putting sustainable development as key objectives for the construction sector. Sustainable development includes the use of labor, use of raw materials of construction, construction period, the problems that may occur, and so on.

In ensuring Malaysia achieve this objectives, many researchers and academics has conducted researches related to materials that can be used in the construction of which the materials are not only economical and available, but at the same time can increase the strength and stiffness of the soil and structure. They do not have negative impacts on the environment and able to improve people's economy.

In the course of the most recent decade, composites of polymers fortified with common strands have received increasing consideration, both from the academic world and from different commercial enterprises. Accessible arrangement is to join the petroleum and bio-assets (plant and horticulture stock) to create a helpful item having the imperative expense execution properties for genuine applications. Short fiber strengthened polymeric composite have picked up significance because of extensive transforming focal points and change in certain mechanical properties (Khalid et al., 2008). There are many methods that can be applied to improve the behavior of the soil and increase the strength and characteristics of the soil, such as use of mechanical and chemical or additive. One of the additives that can be used is Polyurethane (PU). PU is a concoction name of a polymer which contains carbonate bunches (-NHCOO), likewise alluded to as urethane gatherings, in their spine structure. PU is acquired by the response of a di-isocyante with macroglycol, a supposed polyol, or with a blend of a macro-glycol and a short chain glycol extender (Chun et al., 2000).

1.1 Polyurethane Foam/Resin as Ground Treatment

PU are a broad group of polymers that can be made to accomplish an extensive variety of physical attributes in either extended or nonexpanded states (Buzzi et al., 2010) and PU froths are normally utilized as a part of numerous applications including bundling, padding, space filling and protection yet all the more frequently in geotechnical designing. As indicated by the use of the froths in assembling and industry, consideration is generally centered on one or more particular crucial properties (Buzzi et al., 2008).

For geotechnical designing purposes, there are a few focal points of ground treatment, for example, expand the bearing limit, decrease the settlement, diminish the capability of liquefaction in immersed fine and water powered fills, uproot the underground water and decrease the pressure driven conductivity of the ground (Sreekala et al., 1997). Buzzi et al. (2008) state that the water permeability and the behavior of the polyurethane foam in compression are of interest while Canteri (1998) reported that establishment remediation strategies utilizing PU froths have just showed up in the most recent 25 years and a "profound lifting" procedure has been licensed all the more as of late hitch from a geotechnical point of view is at the fringe in the middle of supporting and grouting (Buzzi et al., 2008). Buzzi et al. (2010) founded that the injection of extending polyurethane gum is a typical distinct option for supporting for individual houses, structures, and clearing chunks for a wide mixture of differential settlement circumstances. The weight applied by advanced gas amid the substance shows that the tar lifts the structure.

1.2 Fiber Derived From Empty Fruit Bunch

These days, EFB pack is utilized as fuel, compost, and a mulching material and in making fiber on the grounds that the staying of this waste material can make ecological issues (Mahjoub et al., 2013). Therefore, engineers and researchers have been attracted to use natural fibers for industrial applications. As stated by Khalid et al. (2008), Malaysia is one of the biggest makers of palm oil. This EFB is the highest contributor of oil palm biomass, whereby about 15.8MnT have been produced per year (Sidek et al., 2014).

Plenitude of oil palm cellulosic material that can be promptly acquired from the repercussions gives another territory to research improvement. Prabakar et al. (2002) reported that it has been proposed that natural resources may give better materials than enhancing soil structure, in view of their expense viability and environment- amicable viewpoint. Oil palm EFB fiber was chosen for this study due to its reliable strength and bulk availability in Malaysia.

Mahjoub et al. (2013) reported that oil palm EFB fiber was characterized in terms of tensile strength, Young's modulus, elongation at break and density. Other researchers reported that the EFB is a unique reinforcing material as it is non-hazardous, renewable, and readily available at relatively low cost due to established technology to extract the fibers compared to other commercially available fibers. To date just a little amount of these deposits are transformed into helpful items and the rest is either left to spoil or most noticeably awful, blazed and dirtying the earth (Kolop et al., 2008).

1.3 Composite PU-EFB Initiations

In reducing the cost by controlling the amount of percent of PU in a mixture and at the same time improving the strength and stiffness of the soil, this study was conducted with the use of natural fiber, the oil palm empty fruit bunch (EFB). According to environmental concerns and financial problems, natural fibers have become interesting and fascinating nowadays to be used as an industrial material and structural material for rehabilitating of structures. Oil palm EFB fiber is a characteristic fiber which is discovered in a considerable measure in the tropics (Kolop et al., 2008).

2. Materials and Methods

The shredded EFB (Figure 1) were used to improve the strength of the PU. Different ratios of PU and EFB were used to optimize the composition which contributes the ultimate strength and stiffness of PU foam. PU foam is produced from the reaction of a polyol (R-OH) and isocyanate (R1-NCO) (Figure 2). The ratios of PU foam were fixed to 1:1 (Sreekala et al., 1997). Four samples with various volumes of EFB were tested as shown in Table 1.Three samples were prepared for each volume of PU in order to take the average results of Unconfined Compression Test (UCT). One of the aims of this study is to obtain the influence of EFB volume to the strength of PU foam. In this research, 50 mm diameters and 100 mm height sample were prepared. The sample moulds were produced from the (Polyvinyl Chloride) PVC pipe.

2.1 Unconfined Compression Test (UCT)

UCT was carried out to determine the unconfined compressive strength of specimens in accordance to BS 1377:1990 as shown in **Fig. 3** and also to obtain the stress-strain relationship of the specimens tested. In this test, the effect of pore water pressure is not considered as the samples are high water resistance.

Table 1. Sample Preparation

Mixture Proportion	1	2	3	4
PU (%)	100	75	50	25
EFB (%)	0	25	50	75

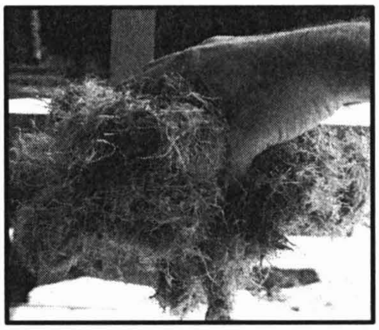

Fig 1. Shredded Empty Fruit Bunch

Fig 2. Polyol and Isocyanate Solutions

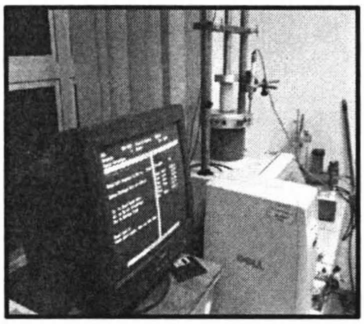

Fig 3. Unconfined Compression Test Set Up

3. Results and Discussion

Twelve (12) specimens were analyzed in this study based on the ratio of fiber and PU in the PU foam in terms of volume, strength of the fiber reinforced PU and stress-strain relationship of the fiber reinforced PU. The strength of the specimen was determined by the amount of maximum deviator stress before it failed or the amount of deviator stress when the strain reached 20%. The results are shown in Table 2.

Table 2. Strength of the Fiber Reinforced PU

PU:EFB	Maximum Stress, kPa			
(% volume)	A	B	C	Average
100:0	425.5	460.7	449.3	445.2
75:25	1100.2	1072.4	1125.5	1099.4
50:50	400.2	428.6	510.7	446.5
25:75	266.7	230.5	306.6	267.9

To conduct a better analysis, we have constructed stress-strain curves based on the data obtained using UCT (Figure 4). The graphs were plotted using the average value for each composition.

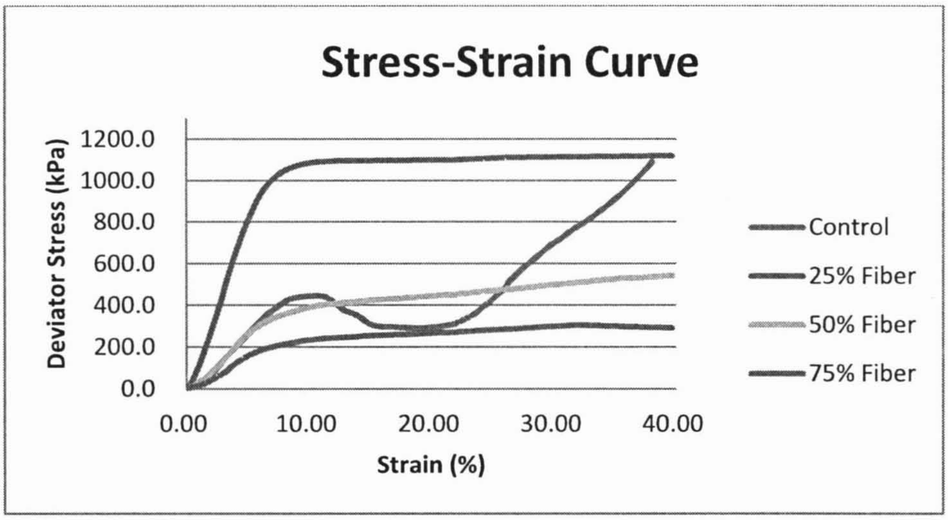

Fig 4. Stress-strain curves obtained from UCT

Based on the stress-strain curve of pure PU foam and fiber reinforced PU foam, it was found that the addition of EFB has significantly changed the way PU foam failed to a more ductile behavior. Compared to the unreinforced PU which fails at 10.25 % strain, the fiber reinforced specimens hardly reached its maximum strength even at 40% strain. Thus the limit for strain was set at 20% which gives the maximum stress as shown in Table 2. The failure mode obtained in this study is in line with the findings by Ahmad et al., 2010 that used EFB to reinforce silty sand.

At a lower content of fiber, the increase of strength is significant; this can be seen by comparing the unreinforced PU with the PU reinforced with 25 % of EFB, the maximum stress increases from 445.2 kPa to 1099.4 kPa. However, when the fiber content increases, the maximum stress recorded decreases to 446.5 kPa for the specimen with 50% EFB and 267.9 kPa for the specimen with 75% of EFB. The stress developed by the 50:50 ratio is quite similar to a pure PU, while for the 75% EFB, it is quite low compared to the pure PU. The reduction in maximum stress is as expected, as it agreed with the findings made by Kolop et al., 2008. It is difficult to compact higher fiber content which might result in the increase of voids, thus it is believed that maximum ratio of 50:50 is tolerable in reducing the volume of PU.

4. Conclusion

PU foams have many applications especially in soil stabilization and their fundamental properties have been widely investigated. However, it requires the use petroleum products, polyols that is not only expensive but also not environmental friendly. Thus, incorporating the use of EFB, which is the byproducts of oil palm mills in PU foam, is believed to be able to reduce the volume of pure PU, which will result in the reduction of cost and at the same time reducing the negative impacts to the environment.

From this study, it is found that EFB not only can replace PU but at the right ratio, it can improve the strength of the foam. As a conclusion, 50:50 ratios are good enough in reducing the volume of pure PU by half without affecting the strength of the foam. Meanwhile if the strength is the main concern, 25% EFB can double the strength of the foam.

As a recommendation, more samples at different ratios can be conducted to further conclude the ideal composition of the EFB reinforced fiber in meeting the characteristics required. EFB is a biodegradable organic matter, thus it is also recommended to further study the degradation of fiber in the foam to ensure it can maintain its performance over long-term.

5. Acknowledgement

The authors would like to acknowledge Progrout Injection Sdn. Bhd. in providing the materials and technical data for this research study. The authors would like to give an endless gratitude to Dr. Ismachayadi Bagus from Institute for Infrastructure Engineering and Sustainable Management (IIESM), Assoc. Prof. Dr. Mohd Jamaludin Md Noor from the Faculty of Civil Engineering, UiTM Shah Alam and the Faculty of Civil Engineering, UiTM Jengka Pahang for the support given in completing this research.

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