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THE EFFECT OF DIFFERENT LENGTH OF FIBER IN CONCRETE

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ABSTRACT

Concrete is known to have high compressive strength, stiffness, low thermal and electrical conductivity and low toxic. Another important thing that concrete can be shaped into geometrical properties. However, concrete is brittle and weak in tension. When subjected to tensile stress, unreinforced concrete will crack and fail. Reinforcement with randomly distributed short fibers presents an effective approach to curb the crack propagation and improving the ductility and tensile strength of concrete. Even though there a lot of researches have been done on the use of oil palm waste or fiber in concrete and mortar but none of the researchers have use fiber from oil palm trunk as concrete reinforcement. Therefore in this study, an investigation was made on the use of fiber from oil palm trunk in concrete. Five different concrete mixes with different length of fiber content namely 0mm, 25mm, 35mm, 45mm and 55mm were cast at a constant fiber volume of 1%. The parameters tested are flexural strength and compressive strength. It was found that there is an increase in compressive strength when compared with normal concrete but among the different length there is not much different. In terms of flexural strength there is an increased in strength as the length of fiber increases.

Keywords : *Fiber Reinforced Concrete, Oil Palm Trunk Fiber, Strength*

INTRODUCTION

Cementitious materials in the form of mortar or concrete are attractive for use as constructional materials since they are cheap, durable and have adequate compressive strength and stiffness for structural use. However concrete is inherently brittle material with a relatively low tensile strength compared to compressive strength.

Reinforcement by fibers can offer a convenient, practical and economical method of overcoming these deficiencies, particularly in applications where conventional reinforcement by steel bars, is unsuitable. Furthermore, fiber reinforcement is likely to be used in preference to conventional reinforced or prestressed concrete if these properties can be exploited in conjunction with advantageous in construction or fabrication technique.

A variety of fiber types, including man-made fibers or synthetic fibers such as steel, glass, polypropylene and natural cellulose fibers. Investigations have been carried out in many countries on various mechanical properties, physical performance and durability of concrete materials reinforced with natural fibers from coconut husk, palm, bamboo, sugarcane, wood and other vegetable fibers. Trends in the fibrous concrete applications over the last two decades indicate that no one fiber material and fibrous composite material system has emerged to dominate the marketplace [1].

The trunk of oil palm tree can also be processed to form a good source of fiber. The process of attraction of fiber does not require a sophisticated engineering process like the synthetic fiber. With regard to the previous research on oil palm fibers, higher lignin was found in trunk fibers. The higher content of lignin in trunk fiber helps to reduce water absorption in MDF (medium density fiber) board. MDF board from OPTF (oil palm trunk fiber) was stronger and had better fiber-to-fiber strength [2]. Hopefully similar advantageous will apply to concrete.

Important properties of the hardened fiber reinforced concrete composite are strength deformation under load, crack arrest, durability, permeability and shrinkage. In general, the strength is considered to be the most important property and the quality of natural-fiber reinforced concrete is judged mainly by their strength. The ultimate strength depends almost entirely upon the fiber types, length and volume fraction of fibers and also on the properties and proportion of other constituents materials [1]. The critical factors affecting the modulus of rupture for composite in which the fibers pull out, rather than break, are the volume, length, shape and orientation of the fibers and the bond strength between fiber and matrix [3].

This study is a part of a broad research program on the compatibility study of oil palm trunk fiber as concrete reinforcement. From previous studies done on the mechanical properties of oil palm trunk fiber reinforced concrete with varies volume of OPTF, it was found that at 1% volume fraction there is significant improvement on the mechanical properties (the length was fixed at 25mm) [4]. Therefore in these studies, the volume of OPTF was fixed at 1% but the length of OPTF was varied. The main objective of this study is to determine the effect of fiber length in enhancing the mechanical properties of concrete materials.

MATERIALS AND METHODS

The oil palm trunk fibers were taken directly from the plantation when the trees newly fell using special excavator machine. Freshly shredded fibers were obtained at random from trees aged between 20 – 30 years. After that the fibers were undergone cleaning process to remove the parenchyma. This parenchyma needs to be removed since it contains carbohydrates, which can retard the concrete hardening process. Since the effective technology in processing oil palm trunk fibers has yet to be accomplished, the methods used were restricted to conventional processing methods that are manually. OPT fiber was light yellowish when in fresh state. However, the colour changes as the fiber tend to become dry, from light yellowish to brown. Even though the color changes but the fiber still carries strength. OPTF must be clean and free from impurities so that it will not disturb the concrete chemistry.

According to ACI 544.1R [5], the length of fibers to be added to the concrete may vary from 25-500 mm. For this study the fiber length is varied at 25mm, 35mm, 45mm and 55mm.

The concrete constituents used were ordinary Portland cement, fine aggregate, coarse aggregate and OPTF. Design Grade 30 concrete was employed and the mix details is shown in Table 1. Ordinary Portland cement confirmed the requirements of BS 12:1958. Fine and coarse aggregate confirmed the grading BS 882:1992. Coarse aggregate has a maximum size of 20 mm. The relative density assumption for aggregate is 2,650 kg/m^3. The ratio of coarse aggregate and sand to cement was also remained unchanged at 1.5 and 3 respectively. Water-cement ratio was kept constant at 0.5.

Table 1.0 : The mix details of the proportion in kg/m^3

Mix	Fibre By Volume	Cement	Water	Coarse Aggregate	Fine Aggregate
1	0%	360	180	1075	530
2	1%	358	179	1061	522
3	2%	355	176	1046	515
4	3%	350	175	1037	511

Fresh plain and fibrous mixes were tested for workability by slump (BS 1881: Part 102: 1983) and Vebe (British Standard 1881: Part 104: 1983) test methods. Specimens for hardened material tests were then manufactured by casting fresh concrete inside moulds with compaction achieved through external vibration. All the hardened specimens were cured according to BS 1881: Part 111: 1983 by water immersion.

For each series of concrete mix, at least 3 specimens were prepared for each parameter to be tested. The following tests were performed on hardened concrete specimens;

1. Flexural Test : BS 1881: Part 118: 1983[6]
2. Compressive strength Test: BS 1881: Part 119: 1983[7]

The test specimen used for this investigation was 150 x 150 x 750 mm beam for flexural test. In total, 72 specimens have been cast. The mixing of fiber in concrete was performed according to the ACI 544-1R recommendations[5].

RESULTS AND DISCUSSION

Fiber

The tensile strength of the fiber was found to be 600 - 800 N/mm^2, which is higher than coconut fiber (120-200 N/mm^2) and jute sisal fiber (280 – 568 N/mm^2) [8] Bulk density of fibers is 1200 kg/m^3. Because OPTF are natural materials, they are not uniform in diameter and length. The diameter of clean fiber is between 0.3 – 0.6 mm. The fiber morphology was observed by Scanning Electron Microscope (SEM) and shown in Figure 1.0. One of the criteria for a fiber to possess high tensile strength is that the fiber is solid and has thick wall [9]. Therefore, the high tensile strength value of the OPTF may be due to the thick wall and it was found that OPTF is not easily collapse even though the fiber lost moisture. By looking at the SEM photo on the fiber structure as shown in figure 1.0, the fiber can be considered solid does not have the hollow in the middle like other fiber such as wood fiber[10]. The other advantages of OPTF are that it possesses high density, which is 1200 kg/m^3. The high density also indicates that the fiber is strong. The high content of lignin in OPTF (23.03%) also gives extra merit to the fiber because lignified cellulose fibers retain their strength better than delignified fibers when exposed to moisture [9]. OPTF have low cellulose content when compared with other fibers used in the fiber-cement composite. With all these reasons, oil palm trunk fiber was found to be suitable to be used as concrete reinforcement.

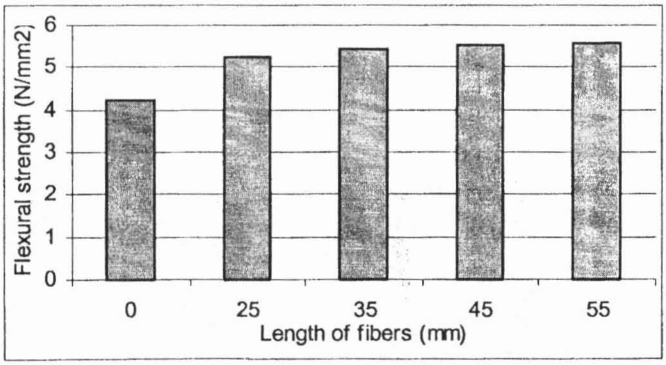
(a) (b)

Figure 1.0 : The SEM photograph showing the morphology of the OPFT at (a) 50X and (b) 1200X magnification

Effects of Different Volume Percentage Upon The Flexural Strength

This experiment was conducted to determine the effects of 5 different length of OPTF on the flexural strength properties. An analysis of variance was performed to determine if there were differences in mean flexural strength values among the different length of fiber tested. F-test indicated that there were significant differences in the mean flexural strength [p value = 0.000] at 5% significant level, which indicates that the different length of OPTF influenced the flexural strength properties of OPTF reinforced concrete.

Figure 2.0 shows that flexural strength of concrete increases with increasing length of fiber. To determine how the length of fibers affects the compressive strength, a linear regression was performed. The regression analysis yielded strong evidence that length affected the flexural strength [p-value =0.005]. However, the relationship between flexural strength and length of fiber was not very strong [R^2 = 0.627] at 28 days. However after removing the 0% fiber data (the control), the regression analysis indicated that there was strong evidence that the length of fiber affected the flexural strength [p-value = 0.001] and [R^2 = 0.825]. This means that 82.5% variation in the flexural strength has been explained by the variation in the length of fiber used and the other 17.5 percent variation can be explained by other factor such as volume, moisture content, absorption capacity of the fiber. This result suggests that the length of fiber not only influenced the concrete strength properties but also have the possibility of interfering with other basic properties of concrete. The flexural strength obtained with different length of in the range of 1.2 to 1.4 times the corresponding properties of plain concrete. It was also observed that while the unreinforced specimen specimens broke suddenly into two, the fiber reinforced specimens remained in one piece even when the maximum load was applied. In this case, the fiber can acts as crack arresters as shown in **Figure 3.0**. The maximum load carrying capacity of the reinforced concrete is controlled by pullout of the fiber strand from the concrete matrix because fiber reinforcing does not have a deformed surface like larger steel reinforcing bars and this can limits the performance. It is usually assumed that the fibers do not influence the tensile strength of the matrix, and that only after the matrix has cracked do the fibers contribute by bridging the cracks [11]. Therefore the length of the fiber has to be sufficient in order to mobilize the interfacial bond face. In fact after the concrete specimen has broken the fiber does not collapse which can be seen from **Figure 4.0**. In this figure, it also shows that the fiber is well dispersed which can indicate the right mixing technique. This is important because the strength can be affected by the distribution of the fibers in the concrete. Moreover the post-cracking behavior is also considerably influenced by the volume fraction, fiber length and the mechanical properties of the fiber as well as the distribution of the interfacial bond stress between the fibers and the matrix [8]. This can also suggest that concrete with OPTF is tougher. The fiber-reinforced composites thus behave like a ductile material.



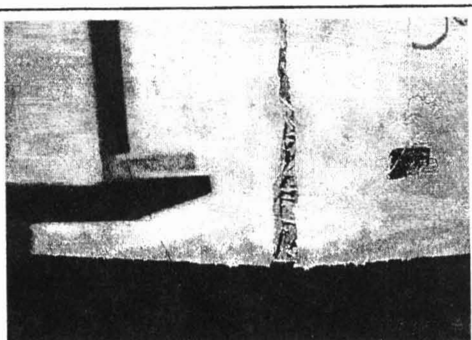


Figure 3.0 : Beam under bending, showing the fiber acts as crack arrester

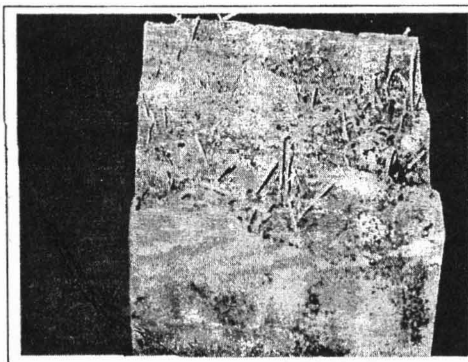


Figure 4.0: Fracture Surface of Concrete Reinforced With OPTF, showing fiber pull-out

Effects of Different Volume Percentage Upon The Compressive Strength

The volume of OPTF study on the compressive strength was performed to determine if fiber length affects compressive strength. The ANOVA indicate there was significant length effect on the compressive strength [p-value =0.001]. By using Duncan multiple comparison test it was found that there is differences in the mean compressive strength between OPTF when compared to plain concrete. The compressive strength development of the strength was drastically increased at 25mm of fiber length but increase moderately at other lengths as shown in Figure 5.0. From the previous research[12,5] it indicates that length of fiber or the volume of fiber does not significantly affect the compressive strength. However in this investigation it was found that OPTF improves the compressive strength. Up to this point of investigation, the optimum length and volume of OPTF in enhancing the properties of concrete was not determined.

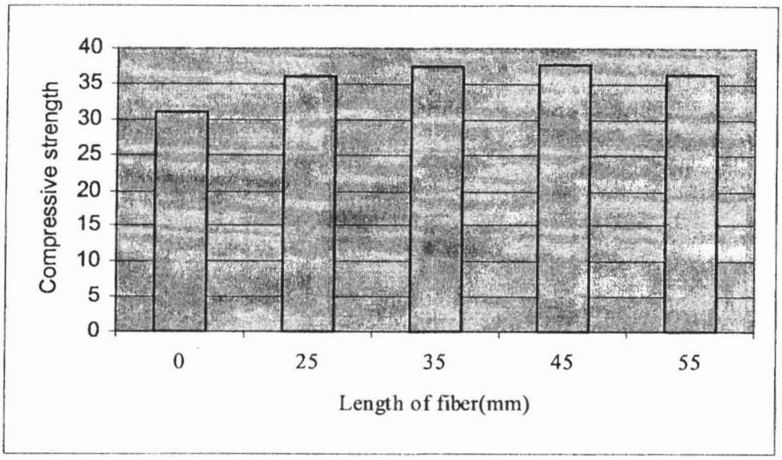


Figure 5.0: Compressive strength at different length of fiber.

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