Flexural Strength of Consolidated Natural Fibers for Floor Tiles

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ABSTRACT

The focus of this study is to design and develop a natural based floor tiles. The tiles are consolidated natural fibers, sand, cement and water ratio matrix medium. Consolidation involved six steps process. Banana stem and rice hull were the natural based constituents, considered abandoned biomass source. Fiber content of 15%, 20% and 25% were mixed with the sand and cement water ratio. Floor tiles are consolidated with natural fibers like rice hulls and banana stem fibers. With a size of 30.5 cm by 30.5 cm, three types of samples are considered: one with rice hull, one with banana stem and one with hybrid fibers. The study underwent three major stages which include the preparation of the raw materials, fabrication of the tiles, and testing and data analyses. A three-point bending test was performed to generate the modulus of elasticity (MOE).

Findings revealed that among the samples, the tiles with 20% particulate rice hull achieved the highest MOE with 13.05 GPa. On the other hand, the tiles with 25% particulate banana stem fibers obtained the lowest MOE of 1.2 GPa. However, the 20% particulate banana stem fibers gave favorable results but with significant difference with particulate rice hull thus, the rice hull and banana stem in particulate type were successfully consolidated into floor tiles. As a whole, findings show that the 20% proportion performs better than the pure cement sand tile. The 20% rice hull proportion shows better performance than that of 15% and 25%. The same result can be said for banana stem tiles. In hybrid conditions, the 20% hybrid, with a proportion of 50% particulate rice hull and 50% particulate banana stem show better MOE than pure cement sand tiles.

KEYWORDS: *Floor tiles, natural fibers, modulus of elasticity composite materials*

1. INTRODUCTION

Natural fibers are hair-like materials that are continuous filaments or in discrete elongated pieces which are similar to pieces of threads. Vegetable and plant fibers are generally based on arrangements of cellulose, often with lignin[1].

The interest in natural fiber composite is rapidly growing due to its great performance, renewable resources, biodegradability and low cost. It is potential future substitute for wood and an answer to some environmental issues such as waste disposal.

Natural fibers in building materials has also some disadvantages like low modulus of elasticity, high moisture absorption, and variability in mechanical and physical properties[1].

Since ancient times, natural fibers have been utilized to reinforce brittle materials. Egyptians began using straw to improve mud bricks. Studies have been made utilizing natural fibers like sugarcane fibers, coconut fibers, banana fibers, rice stalks, rice hulls, and many more for the production of textiles, papers, handicrafts, feeds, fertilizers and many more. These studies have shown impressive results and remarkable outcomes. Indeed natural fibers which are being set aside before are now beneficial to the community. The use of natural fibers like banana fibers and rice hull can help in utilizing waste products of banana harvests and rice paddy milling. Banana is the fourth largest produced fruit crop of the world and also in the Philippines next to rice and coconut[2].

This applied research uses natural fibers specifically banana fibers from the stems and rice hulls as raw materials for floor tiles. Different mixtures are to be made. Modulus of elasticity will be determined for all samples.

2. OBJECTIVES

The major purpose of this study is to fabricate floor tiles consolidated with natural fibers. This study is mounted on hypothesis that floor tiles can be made out of non-synthetic material guided upon by the following specific objectives:

1. To answer the waste disposal problems of banana harvests and rice paddy milling.

2. To determine the modulus of elasticity of samples with 15%, 20%, and 25% fiber content.

3. To compare the results with pure sand cement tiles.

3. MATERIALS AND METHODS

The main function of floor tiles is to cover the floor with aesthetic durable material. This makes it a cheap and easy solution for water absorption and keeping the area mud free. Aesthetically, a simple building will be more beautiful with a nice yard floor and parking area. Different shapes, motives and patterns can be found in the market depending on the taste of the customers.

3.1 Materials

Rice hulls are the coatings of rice grains. These are the major by-product of rice milling industries. The chemical compositions of rice husk are 40-50% cellulose, 25-30% lignin, 15-20% ash and moisture 8-15%[3]. The physical properties of rice husk fibers are presented in Table 1[4]. Rice hull is a potential material which is used both in raw form and ash form. Most of the hull from milling is either burnt or dumped as waste while some are used as fuel and agriculture processes[3]. The reasons behind the use of rice hull in the construction industry are its high availability, low bulk density.

Banana stem fibers come from the stems of banana plants. The banana stems are grown with leaves and are about 1.4 meters long and 0.7-1 meters wide. Banana leaves and stems are by-products of banana plants. The leaves are used as food wrappers or food keepers and placemat. The stems are usually thrown away. Banana fibers have density of 1.35 gm/cc, and elastic modulus of 8-20 GN/m^2 [5].

3.1.1 Preparation of Raw Materials and Mixtures

Banana stems that came from the residues of banana farm in Sibulan, Negros Oriental were cleaned with water and wiped to dry so as to remove other particles like dirt and mud before feeding to the fiber stripper. Then the banana fibers are sun dried for seven days to remove the moisture content of the fibers. These were chopped to smaller pieces approximately 1 inch in size and then pulverized using the pulverizing machine so that the size of sand and banana fibers are almost the same. These pulverized fiber goes through a no. 16 sieve to regulate the size of the pulverized fibers. Fibers that do not pass through the sieve will go through the pulverizer again. Rice hulls coming from the rice mills of Sibulan, Negros Oriental were fed directly to the pulverizer. The rice hulls that were collected from the rice mills were already dry enough to be pulverized. The sand was taken from Ajong, Sibulan, Negros Oriental. To prepare the sand, it must go through no. 16 sieve to make sure that the size of the sand is almost uniform and almost the same with the fibers. The cement used is Portland cement. It is the most expedient binder when concerned with strength, durability and acoustic insulation properties [6]. Portland cement should be dry, powdery and free of lumps. The cement sand ratio is the volume of cement per volume of sand. The cement sand ratio (in terms of volume) is 1:3[7].

3.2 Methodology

The configuration and constituents of floor tiles are two important factors for its success as alternate building material without compromising the environment. Improvement of medium density fiber board can be done with the use of appropriate binding agents as matrix in composite materials. This study is applied research in which the method is based on.

3.2.1 Fabrication

Particulate fibers and mortar are mixed thoroughly. After mixing, the mixture was placed in a molder and pressed up to 3 tons using the Compac hydraulic press with 15 tons capacity. The molder was made of steel with a size of 30.5 cm by 30.5 cm. After 4 hours, it was removed and placed in a secured area ready for curing. A curing time of seven days is enough for it to harden and be ready for testing.

Ten samples for each kind are prepared for testing. Samples were conditioned for seven days under atmospheric conditions. A three-point bending test was performed. Flexural test were performed on sand-cement tiles without fibers and with particulate rice hull and banana stem at 15%, 20% and 25% by weight.

Table 1. Mixture of pulverized banana stem fibers and sand/cement

FIBER:SAND/CEMENT	PULVERIZED BANANA FIBER	SAND	CEMENT
	ρ = 0.3501 g/cm3	ρ = 1.44 g/cm3	ρ = 1.36 g/cm3
25:75	154.88 g	453.90 g	1436.4 g
20:80	124.69 g	484.50 g	1533.60 g
15:85	92.93 g	510.00 g	1620.00 g

In Table 2, the weight of rice hull, sand, and cement are shown.

Table 2. Mixture of pulverized rice hull and sand/ cement

FIBER:SAND/CEMENT	PULVERIZED RICE HULL	SAND	CEMENT
	ρ = 0.5536 g/cm3	ρ = 1.44 g/cm3	ρ = 1.36 g/cm3
25:75	244.97 g	453.90 g	1436.4 g
20:80	197.22 g	484.50 g	1533.60 g
15:85	147.00 g	510.00 g	1620.00 g

Table 3 displays the amount of banana stem fiber and rice hull for the hybrid fibers, sand and cement.

Table 3. Mixture of pulverized hybrid fibers and sand/ cement

FIBER:SAND/CEMENT	HYBRID		SAND	CEMENT
	PULVERIZED BANANA FIBER	PULVERIZED RICE HULL	ρ = 1.44 g/cm3	ρ = 1.36 g/cm3
	ρ = 0.3501 g/cm3	ρ = 0.5536 g/cm3		
25:75	77.44 g	122.49 g	453.90 g	1436.4 g
20:80	62.35 g	98.61 g	484.50 g	1533.60 g
15:85	46.47 g	255.00 g	510.00 g	1620.00 g

4. RESULTS AND DISCUSSION

Figure 1 shows the performance test of the tiles based on flexural strength with the governing equation given in Equation 1 under three-point bending load[8].

$$\gamma = \frac{PL^3}{48EI} \qquad (1)$$

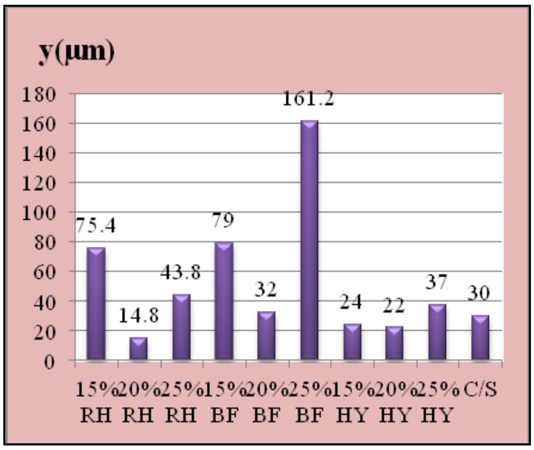
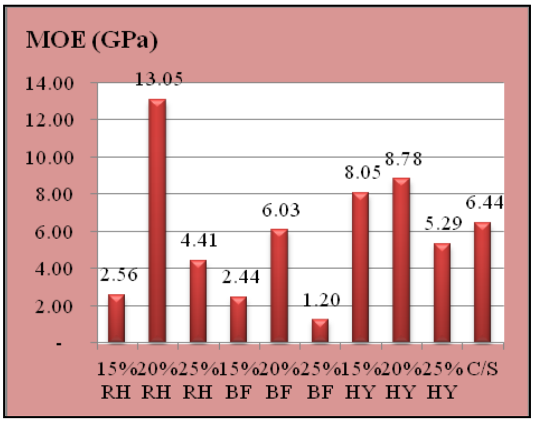


Figure 1. Relative deflection (y) of floor tiles

As delineated, the tiles with 20% fiber content of particulate rice hull achieves the lowest deflection with 14.8 µm followed by hybrid tiles with 20% fiber content has a deflection of 22 µm. The 25% fiber content of particulate banana stem attains the highest value of 161.2 µm while to pure cement-sand tiles experienced 30 µm deflection.

Clearly, this implies that tiles with 20% particulate rice hull can resist deflection better than with pure sand-cement mixture. These results show that the amount of particulate rice hull influenced the bending property of the tiles.

In Figure 2, the graph shows the modulus of elasticity (MOE) of the tiles with different fiber content of particulate rice hull and pure cement-sand. Tiles with 20% fiber content has the highest MOE of 13.05 GPa while those with 15% fiber content has the lowest value of 2.56 GPa. Compared to pure cement-sand, the tiles with 20% particulate rice hull still has the highest



value. This result shows that the tiles 20% of particu-

The Modulus of elasticity (MOE) of tiles are as follows: 15% rice hull - 2.56 GPa, 20% rice hull - 13.05 GPa, 25% rice hull - 4.41 GPa, 15% banana stem fiber - 2.44 GPa, 20% banana stem fiber - 6.03 GPa, 25% banana stem fiber - 1.20 GPa, 15% hybrid fiber - 8.05 GPa, 20% hybrid fiber - 8.78 GPa, and 25% hybrid fiber - 5.22 GPa. The data obtained clearly shows that particulate rice hull achieved higher MOE than particulate banana stem fibers. Among the fibers used and fiber content, the tiles with 20% pulverized rice hull obtained the highest MOE. The top three tiles, with content fiber of 20% particulate rice hull, 20% and 15% hybrid obtained higher MOE compared to pure cement-sand tiles. The tiles with 20% particulate banana stem fibers obtained an almost the same amount of MOE with pure cement-sand tiles.

5. CONCLUSIONS

Natural fibers in particulate form can be consolidated with 1:3 cement sand ratio to produce the floor tiles. Among the different fiber contents, the 20 percent fiber particulate constituent performs better than the pure cement sand tile in terms of flexural strength. When compared with each other, a tile with rice hull particulate performs better than a tile with banana stem particulate. In the case of tile with hybrid conditions, though, the 20% hybrid, with a proportion of 50% rice hull and 50% banana stem fibers shows a better MOE than pure cement sand tiles. Clearly, this implies that tiles with 20% particulate rice hull can resist deflection better than with pure sand-cement mixture. These results show that the amount of particulate rice hull influenced the bending property of the tiles. These results can further conclude that the use of these natural fibers can eventually answer the waste disposal problem of rice hull and banana stems. The once wasted materials are now beneficial to the industry.

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