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Effect of coir fibre and clayey soil on the strength of unglazed roofing tiles

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Abstract. Agricultural waste based roofing materials can be useful in the construction of farm structures and green buildings. This study evaluated the transverse breaking strength, flexural strength and Water Absorption properties of concrete roofing tile replacing the conventionally used sisal fiber which provides transverse strength with coir fiber and plaster sand with clay soil. Five roofing tile samples of different mix design were produced. The result attained for the flexural test and transverse breaking strength for all roofing tile samples at 28 days test showed that roofing tile replace with 100% coir fiber can also be used commercially although it is not as strong as the roofing tile with 100% coir fiber. The result attained for water absorption was within the acceptable value according to ASTM C1492.

1. Introduction

Civilizations in China (Neolithic) and the Middle East has revealed the positive properties of clay tiles as a roofing material which are its good fire resistance and effectivity in water repellant from buildings [1]. The need to develop a cheaper and lightweight clay tile has resulted in the use of clay and bamboo fiber for roof covering. Clays (and clay minerals) are products of in situ alterations or deposited as sediment during erosional cycle or developed in situ as antigenic clay deposit [2]. There are many different clay minerals available in commercial quantity that can be used for industrial applications in Nigeria. Interests are on the increase in the construction sector on the use of clay products as against the neglect it has experienced in the last decades [3]. The quality variation in clay production is mainly due to fluctuation in raw material mineralogical composition, the degree of firing and the difference in the manufacturing method. Mineralogical content of clay soil is one of the most important factors which determine the quality of burnt clay bricks. Silica and alumina makes the main composition of clay with additions of metallic oxides and impurities [4–7]. Clay is the basic materials in the production of roof tiles. The unique plastic characteristics of clay soil are a result of the enormous amount of surface area inherent in the particle size and shape, these characteristics makes it suitable in the production of roof tiles. When mixed with water, its plasticity allows it to be easily shaped into desired forms with the use of moulds and the formed shapes are easily maintained after been demoulded due to its good tensile strength. Clay particles are highly fused at high temperatures [8].

Industrialization has been attracted by biodegradability and environmental protection benefits in natural plant fibres, using its composites to develop variety of products [9–12]. Coconut being a product from the palm tree has been proved to be the most versatile fruit used with every part of the tree found useful across different countries in numerous ways [13–18]. Coconut fiber materials have attracted broad attention as reinforcement polymer composites due to their environmental sustainability, mechanical properties, and recyclability, and they can be compared with glass fibers. Among the natural fibers, Coconut fiber can be suitably used as reinforcing materials due to its higher fracture toughness, easy availability at low cost and rapid renewability [19,20]. Numerous research works have been done on the different parts of Coconut, its parts have been utilized in construction activities, for example, coconut shell [19,21–23], coconut husk [24,25], coconut ash [26] etc.

2. Methodology

The materials used for this research are Plaster sand, Clay soil, Sharp sand, Coir fiber, Sisal fiber, Water (portable), Cement and the Bolyn Roman Tile Vibrating Table. The cement was used as a binder in the production of roofing tile while the fiber is used to increase the flexural strength, sharp sand was used to provide compressive strength for the roofing tile, while plaster sand makes the roofing tile surface smooth. The Bolyn Roman Tile Vibrating table is used to remove void from roofing tile. The coir fiber and sisal fiber were cut to 25±3 mm length, batching method used was by volume using ratio 1:1.5:1.5 which is cement, sharp sand and plaster sand respectively. Table 1 shows the percentage mix for each material in the different roofing tile compositions. The materials were mixed thoroughly to form a homogenous mix before the addition of water. The mixture was placed in Bolyn Roman Tile Vibrating Table and vibrated manually. Thereafter, the vibrated mortar was placed in formwork, smoothed and air-dried for about 24 hours before curing.

Table 1. Unglazed Roofing Tile Experimental Design.

	Fiber Sisal	Coir Fibre	Plaster Sand	Clay Soil
$S_{100}C_0P_{100}CL_0$	100%	-	100%	-
$S_{50}C_{50}P_{90}CL_{10}$	50%	50%	90%	10%
$S_0C_{100}P_{90}CL_{10}$	-	100%	90%	10%
$S_{50}C_{50}P_{100}CL_0$	50%	50%	100%	-
$S_0C_{100}P_{100}CL_0$	-	100%	100%	-

3. Result and discussions

The Water absorption and average mass of the tiles produced are given in table 2. The composite with 50% coir fibre, 10% clay has the highest water absorption value (17.765%), ASTM C1492 states the allowable water absorption ranges from 10.5% to 18%, all the roofing tile samples are within the acceptable range [27]. The transverse breaking strength (TBS) and flexural strength are presented in table 3. ASTM C1492 states the acceptable TBS to be 700N minimum, in which all samples pass acceptability except for 100% coir fibre and 100% plaster sand [27].

Table 2. Mean Water Absorption and Mass of Unglazed Tiles.

Sample	Mean Water Absorption (%)	Mass (Kg)
$S_{100}C_0P_{100}CL_0$	15.245	4.92

$S_{50}C_{50}P_{90}CL_{10}$	17.765	5.24
$S_{0}C_{100}P_{90}CL_{10}$	15.644	5.32
$S_{50}C_{50}P_{100}CL_{0}$	16.764	5.1
$S_{0}C_{100}P_{100}CL_{0}$	16.021	4.82

Table 3. Mean Transverse Breaking and Flexural Strength Values of Unglazed Tiles.

Sample	Transverse Breaking Strength (N/mm^2)			Flexural Strength (N/mm^2)		
	7 Days	14 Days	28 Days	7 Days	14 Days	28 Days
$S_{100}C_{0}P_{100}CL_{0}$	480.637	673.139	806.729	3.493	4.892	5.863
$S_{50}C_{50}P_{90}CL_{10}$	469.491	624.979	781.293	3.412	4.892	5.678
$S_{0}C_{100}P_{90}CL_{10}$	455.731	597.597	720.198	3.312	4.343	5.234
$S_{50}C_{50}P_{100}CL_{0}$	461.235	611.357	705.338	3.352	4.443	5.326
$S_{0}C_{100}P_{100}CL_{0}$	452.704	587.139	677.68	3.29	4.267	4.925

Roofing tile composite $S_{100}C_{0}P_{100}CL_{0}$ performed better in strength compared to all other samples. This implies that roofing tiles with sisal fiber performs better in strength than coir fiber. Also, the transverse breaking strength and flexural strength of samples $S_{50}C_{50}P_{90}CL_{10}$ and $S_{0}C_{100}P_{90}CL_{10}$ in which plaster sand is replaced with 10% clay soil performed better than samples with 100% plaster sand. This shows that clay soil gives an added advantage in strength to the roofing tiles.

$S_{50}C_{50}P_{90}CL_{10}$ having 10% clay has the highest water absorption while samples with clay have averagely lower water absorption values. Also all the roofing tile samples are within the acceptable water absorption value according ASTM C1492. There is increase in mass with increase in clay in roofing tile $S_{50}C_{50}P_{90}CL_{10}$ and $S_{0}C_{100}P_{90}CL_{10}$. This implies increase in clay soil causes increase in soil mass.

4. Conclusion

The roofing tiles with sisal fiber performs better in strength than coir fiber. The roofing tiles with 10% clay soil has better transverse breaking strength and flexural strength. The water absorption value and the mass increases with increase in the clay sample. It is recommended that sisal fibre should be encouraged, the use of coir fibre should be limited to small percentage and with high sisal fibre volume. Clay soil should be discouraged for light weight roofing tiles and low water absorption properties.

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