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GREEN BUILDING: DENSITY AND COMPRESSIVE STRENGTH OF FIBRE REINFORCED MUD BRICK

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ABSTRACT

Laterite bricks with local sponge (*Chasmanthera dependens*) fibres were produced at the Wood Reconstituted Laboratory, Forest products Development and Utilization Department, Forestry Research Institute of Nigeria. The study evaluated the compressive strength of reinforced mud brick with local sponge fibres. The Laterite mud and local sponge fibres were mixed beforehand in the laboratory before they were mixed with water. Laboratory experiments were conducted using sponge fibre waste with fibre proportions of 0%, 1.0%, 1.5%, 2% by weight. . 150 mm x150 mm x150 mm bricks were reinforced with fibre and all the tests were carried out after the bricks had been cured for 28 days; physical such as volumetric shrinkage and compressive strength test were carried out according to BS 3921:1985. Results showed that the higher the fibre content in the mud mix, the higher the compressive strength and the lower the fibre content in the laterite mix, the higher the weight of the bricks formed. The bricks with 2% sponge fibre by weight had the highest compressive strength (13.06 N/mm^2). The fibre reinforced mud bricks have been found to fulfill the compressive strength requirements of the BS 3921:1985. The sponge fibre added to the strength of the bricks and prevented cracking during drying.

Keywords: Reinforced bricks, Sustainability, Mud, sponge fibre, Compression strength.

INTRODUCTION

The use of earth as a building material reaches far back in humanity; this has been used in the construction of shelters for thousands of years. Approximately 30% of the world's population still lives in earthen structures (Binici and Bingol, 2007). Most houses in ancient Africa, Europe, Asia, and many in the Americas, were built out of mud brick. It has been used extensively for wall construction around the world and particularly in developing countries (Ren and Kagi, 1995)

Earth is a cheap, environmental friendly and abundantly available building material (Binici and, Bingol, 2007). It has been used extensively for building houses, wall, and fences especially in the rural areas of Nigeria. House brick-makers have long been using fibrous materials like straw to improve the tensile strength of mud bricks (Binici and Bingol, 2007). However, they have not had a chance to carry out scientific experimental investigation on the balance of materials and the optimization of this production (Binici and Bingol, 2007). The stress–strain relation of mud bricks under compression is very important. The compressive strength of fibre reinforced mud brick has been found to be higher than that of the conventional fibreless mud brick, because fibres are strong against stresses (Binici and Bingol, 2007). In this study, the mud brick produced have fibres in both the longitudinal and transverse directions, thus standing as reinforcement for the mud brick.

Earth requires two properties to make it suitable enough for building; these are compressive and tensile strength. Fibre in mud bricks reinforces the strength of the brick in the same way that steel works in concrete. For example, even though concrete when supported can take an enormous amount of pressure / compression without disintegrating, if someone is to cast a concrete lintel without steel and suspend it between two points and apply pressure / tension, it would snap (Binici and Bingol, 2007). Steel has enormous strength in tension while concrete has enormous strength in compression. Compressive strength is the important parameter when considering the design of bricks. The loads acting on brick while in service are compressive in nature, and their ability to withstand such loads without failure is a measure of their reliability

A good mud-brick has a MPa strength of around 1.6 to 1.9 MPa, while a clay-fired brick has a MPa strength of around 14. Concrete ranges between 15 and 25 MPa. Obviously these figures vary widely, but these are good averages. A mud-brick at 1.4 MPa is 14 times stronger than gravity, a clay-fired brick at 14 MPa is 140 times stronger than gravity or 140 atmospheric pressures (Peter , 2014).

The quality of bricks depends on the compression strength of which bricks can withstand load applied on it (Hassan and Abukar, 2009). Historically it was learnt through trial and error that a soil must contain clay in order to form a cohesive brick. It is now recommended in the literature that soils must contain a clay content of 10-22% depending on the researcher proposing the mixture (Delgado and Guerrero, 2007).

In recent decades earth construction has received a renewed attention by the academic community, (Pacheco-Torgal and Jalali, 2012). This is due to the common knowledge that populations are growing, resources are finite and relying on energy intensive materials such as steel and concrete is not practical. Environmentally sustainable solutions must be researched. In response, countries such as France, New Zealand, Australia, Germany, Spain, Peru, Zimbabwe and the state of New Mexico have all put forth national documents regarding the use of natural earth as a construction material (Maniatidis and Walker, 2003). There have also been recommendations put forth for the continent of Africa by Delgado and Guerrero (2007), Maniatidis and Walker (2003).

Reinforcement is among things used to improve the compression strength of mud bricks. The concept of using natural fibres is not new in the construction industry, as the utilisation of fibres in materials and construction can be traced back to many centuries ago. During the Egyptian times, straws or horsehairs were added to mud bricks, while straw mats were used as reinforcements in early Chinese and Japanese housing construction (Li, 2002).

Azeko *et al.*,(2015) found that laterite bricks stabilized with 20% polyethylene by volume had the best combination of compressive strength and fracture toughness. Compared to the traditional bricks (0.5 –1 N/mm^2),

Binici, *et al* (2005) concluded that stabilization with plastic fibres, straws and polystyrene fabrics improved the compressive strengths of fibre reinforced mud bricks (3.7 –7.1 N/ mm^2). They further explained that these fibre reinforced bricks had lower dead weight leading to lower material handling costs.

Few studies have explored the use of sugarcane fibre waste in stabilizing bricks using conventional, sustainable and cost-effective methods that are most familiar to the indigenous populations in developing countries (Rahman, 1988). The aim of this study is to evaluate the compressive strength of unfired compressed bricks made from mud reinforced with sponge (*Chasmanthera dependens*) fibres.

MATERIALS AND METHOD

Preparation of the brick specimens

Laterite bricks with local sponge fibres were produced at the Wood Reconstituted Laboratory, Forest products Development and Utilization Department, Forestry Research Institute of Nigeria, which is located at Jericho, Ibadan. The Laterite mud and local sponge fibres were mixed in the laboratory before they were mixed with water in the factory. The fibres were weighed and divided into 1%, 1.5% and 2% weight of the mud. The fibres (1%, 1.5% and 2%) were mixed by hand with the mud to ensure an even dispersion of the fibres in the mixture to prevent balling up. After that, the laterite/fibre mixes were packed separately in plastic bags based on the different mixing proportions and replicated five times.

Afterwards, the laterite and fibre mixtures were moved to the factory. At the factory, the laterite and fibres were further mixed with water, according to the specified mix proportion using a hand shovel on a piece of plywood at ground level. It was thoroughly mixed to ensure an even dispersion of all the matrix and fibres. The study was carried out in a completely randomize design.

The pressing of bricks

After mixing by shovel, the materials were scooped into the fabricated mould, poured into the mixer at the pressing machine to press out the bricks at 21Mpa.

The wrapping and curing of bricks

After pressing, the bricks were stacked on timber palettes and marked according to their fibre contents. The bricks were then wrapped with a plastic film to avoid rapid drying and stored under a sheltered area for 24 hours prior to spraying with water. The bricks were then stored in open air for 14 days and they were also allowed to cure for 28 days prior to testing.

Test methods

A Compressive strength is an important parameter when considering the design of bricks. The loads acting on brick while in service are compressive in nature, and their ability to withstand such loads without failure is a measure of their reliability. In this study, density and compressive strength, were determined according to BS 3921:1985

For the compressive strength tests, the bricks of the three proportions were moved from the curing or stacking area to the laboratory two hours prior to the test to normalise the temperature and to ensure that the brick was relatively dry. The weight of each brick was measured before the brick was placed onto the compression testing machine (Model 50-C34A2, Serial no. 0294910. The five replicated samples of the block were then crushed, and the corresponding failure load was recorded.

RESULTS AND DISCUSSION

Brick Dimension

Brick strength is influenced by material content and the density of the constituent materials.

Table 1: The dimensions of the fibre bricks

Type (R)	Length(mm)	Width (mm)	Depth (mm)	Area (m^2)	Volume (m^3)
R0(0%FIBRE)	150	150	150	0.0225	0.003375
R1(1%FIBRE)	150	150	150	0.0225	0.003375
R1(1.5%FIBRE)	150	150	150	0.0225	0.003375
R2(2%FIBRE)	150	150	150	0.0225	0.003375

It can be summarised from the table 1 above that there are uniformity in dimension of bricks produced with fibre and that without fibre. The presence of fibre in the brick did not informed increases in dimension or volume of the brick. This observation is in agreement with Binici (2017) submission that fibres used in mud brick production led to smooth surface and fixed brick dimensions and these also led to reduction in the thickness of plaster paste and good bonding between the bricks and plaster paste; uniform dimension will accommodate plaster uniformly and evenly, unlike face that is not uniform that requires more plaster at uneven face to attain uniformity of plaster.

Compressive Strength

Compressive strength (C) tests were carried out to determine the load-bearing capacities of the bricks. The crushing force (P) was divided by the sectional area (A) of the block $\left(C = P/A\right)$ to arrive at the compressive strength values which ranged from 10 N/mm^2 to 13 N/mm^2, for fibre ratio 0% to 2% the increase in compressive strength could be attributed to the fact that laterite obtained contains less fine material, more gravel, more fibre and is less permeable

Table 2: Mean of the compressive strength of the different mud bricks

Fibre Ratio (%)	Compressive Strength	Weight of the brick (g)
control	10.00	8946.60
1	11.03	8745.00
1.5	12.05	8261.00
2.0	13.06	7753.20

Table 3: ANOVA of Compressive strength of bricks produced

Source of variation	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	26.031	3	8.677	17983.530	0.000*
Within Groups	0.008	16	0.000		
Total	26.039	19			

From table 2 above, it was observed that the higher the fibre content in the laterite mix, the higher the compressive strength and the lower the weight in bricks which ranges from 8946.06 – 7753.00g, and the lower the fibre content the higher the weight of the bricks formed as reflected in the mean value of samples with 1% fibre and bricks without fibre (8946.6-8745.00 respectively). From the results, it can be deduced that the fibre added to the strength of the bricks and prevented cracking during drying. The presence of fibres in mud bricks has been reported to provide flexibility to structures (Binici and, Bingol, 2007). Sutco and Akkurt (2009) reported that porous earthenware bricks stabilized with paper processing residues (30%) had a 50% reduction in thermal conductivity and higher compressive strengths. In their study incorporating cotton and limestone powder in a brick material, Algin and Turgut (2007) obtained improved flexural strength (2.19 MPa), compressive strengths (7 MPa), water absorption, and energy absorption. Rahman (1988) found that rice husk stabilized bricks had improved compressive strength, water absorption, and linear shrinkage.

The result of the analysis of variance in table 3 above shows that there is significant difference in the mixing ratio of the bricks produced. The higher the fibre the lesser the weight and the higher the compressive strength of the bricks, this is in accordance with the work of Algin and Turgut (2007) and Sutco and Akkurt (2009) where they found that addition of fibre improved the compressive strength of mud brick.

In another study, fibre reinforced mud bricks are reported to fulfill the compressive strength and heat conductivity requirements of the ASTM C 384–98, ccompressive strength of mud brick was given as 0.5-1MPa in Turkish standard (Binici and Bingol, 2007). In his study, Binici, (2017) determined compressive strength of mud bricks with fibres as 2.2–3.7 MPa. However, the values in the case of the fibre reinforced mud bricks tested in Binici *et al.,* (2004) study are much higher (3.7–7.1 N/mm^2). Algin and Turgut (2007) obtained improved flexural strength (2.19 MPa), compressive strengths (7 MPa). This showed that fibres improved the mechanical properties of mud bricks. Fibres in mud production also led to an increase in the compressive strength and tensile modulus of elasticity of mud bricks (Binici, 2017).

CONCLUSION AND RECOMMENDATION

Raw soil as a construction material has generated renewed interest primarily because of its availability, low cost and compliance with global sustainability goals. In this study investigation was conducted to assess the compression strength of reinforced mud brick sponge. It was observed that the higher the fibre content in the mud mix, the higher the compressive strength the lower the weight of the bricks and the lower the fibre content in the laterite mix, the higher the weight of the bricks formed, it can be deduced that the fibre added to the strength of the bricks and prevented cracking during drying. The bricks with 2% sponge fibre by weight had the highest compression strength. The sponge fibre added to the strength of the bricks and avoided cracking during drying. The improved sponge-fibre mud bricks will contribute to the production of more durable and sustainable brick structures. In the long term, the production of sponge-fibre reinforced bricks should contribute to the advancement of global housing sustainability goals leading to reductions in environmental deterioration.

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