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SUSTAINABLE ECO-BRICKS MANUFACTURED USING PLANTAIN FIBRE AND MASTERGLENIUM SKY 504

Uche Emmanuel Edike[1], Adegboyega Sunday Sotunbo[2] and Hosea Shemang Yohanna[1]
[1]Department of Building Technology, College of Environmental Sciences, Bells University of Technology, Ota, Ogun State, Nigeria
[2]Department of Building, Faculty of Environmental Sciences, University of Lagos, Akoka, Lagos, Nigeria
E-Mail: edikeuche84@gmail.com

ABSTRACT

Utilization of waste from demolished structures in the production of concrete and mortar has received considerable attention from researchers in addressing environmental problems. However, the use of agricultural waste has received very little consideration. This research investigates the potential use of plantain fibre and master glenium sky 504 in the production of eco-bricks as an alternative building material. A total of 72 eco-bricks were produced with variable amount of plantain fibres in six different sample sets contingent upon the compressive strength, bulk density and water absorption. The study found that eco-bricks manufactured with 2% plantain fibre passed the minimum compressive strength specified for building works. The study therefore recommends the use of plantain fibre in the production of eco-bricks.

Keywords: compressive strength, eco-brick, fibre, plasticizer, water absorption.

INTRODUCTION

In recent time, the construction industry and the built environment have raised concerns over the production of building materials that contribute to greenhouse effect. Production process of clay bricks involves heating dried mixture of clay, coal and water in kiln at temperature between 700-1100°C. Harris (2009) noted that the entire process generates large amount of Carbon (IV) Oxide and it is energy intensive. In fact, clay bricks have been identified as a low-cost housing material but a major CO_2 emission construction material in Malaysia (Gardezi *et al.* 2014). The high carbon emission signature is due to high curing temperature of bricks to improve the properties and therefore making it preferable to other building materials.

The principal properties of bricks that make them superior building materials are good compressive strength, fire resistance, durability, aesthetics and satisfactory bond and performance with mortar (Hendry and Khalaf, 2001). Also, bricks do not cause indoor air quality problems. The thermal mass effect of brick masonry is a useful component for fuel-saving, natural heating and cooling strategies such as solar heating and night-time cooling. However, the enormous benefits of bricks have not been holistically exploited and the benefits will continue to elude the built environment if brick curing at outrageous temperatures persist with its encompassing high thermal energy usage and CO_2 emission. Oti *et al.*, (2009) remarked that the use of stabilized unfired clay bricks for masonry construction may solve these problems.

Sun-baked clay brick is one of the earliest basic building materials used by mankind and are still used today. Sun-baked clay bricks are easy to manufacture and low cost, good thermal and acoustic properties, and at the end of a building's life, the clay material can be reused by grinding, wetting or returned to the ground without any interference with the environment. But, the vulnerability of clay bricks to water damage is a major delinquent that hampers its application in building. Rao and Shivananda, (2005) and Oti *et al.*, (2009b) noted that the susceptibility of clay bricks to water is overcome in recent times by stabilizing clay soil with the addition of cement and lime, thereby producing an improved construction material to meet the increasing demand for housing units.

With the rising demand for housing units and consequently walling materials in many parts of the world coupled with the increasing demand for sustainable eco-building material, it is important to incorporate environment- friendly elements into bricks. One of the characteristics of sustainable building materials is the ability of being sourced through preservation of the environment and products that do not release toxic wastes. Also, identified as sustainable building materials are products that can save energy or water and contribute to a healthy and safe environment. Shibib, Qatta and Hamza (2013) stated that building materials can be assessed as suitable for the environment if it contains base material made with safe, recyclable or agricultural waste content. Utilizing agricultural waste (cellulose fibre) in the production of bricks would not only ensure sustainable eco-building material but also enhance the physical and thermal properties of bricks.

Many attempts have been made to incorporate wastes into the production of bricks. For example, rubber, limestone dust, wood sawdust, processed waste tea, fly ash, polystyrene and sludge have been used in brick production. These materials apparently vary from the most commonly used wastes such as the various types of fly ash and sludge, to sawdust, kraft pulp residues, paper, polystyrene, processed waste tea, tobacco, grass, spent grains, glass windshields, PVB-foils, label papers, phosphogypsume (waste used by phosphoric acid plants), boron concentrator and cigarette butts. However, literature on the use of plantain trunk cellulose fibre in the manufacture of eco-bricks is considerably scarce.

Plantain trunk cellulose fibre is agricultural waste and may not be fully utilized in production of brick unless

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the brick satisfies specific requirement and comply with relevant standards. Hence investigating the properties of eco-bricks manufactured with plantain trunk cellulose fibre is the focus of this research. The aim of this study is to determine the effects of plantain fibre and master glenium (sky 504) on the properties of eco-brick with a view to furthering the knowledge of bricks choices for construction work.

MATERIALS AND METHOD

Plantain stalk fibre

Plantain is one of the most important crops of the tropical plants. It belongs to the family Musaceae and the genus Musa. Musa paradisiaca, also known as plantain in English, is a tropical plant that is native to India. The plant consists of long, overlapping leafstalks and bears a stem which is 1.22 to 6.10 m high (Oladiji, Idoko, Abodunrin & Yakubu, 2010). Plantain fruit requires about two and a half to four months after shooting before the fruit becomes ready for harvesting or a total of about eight to twelve months after planting (Swennen, 1990). Plantain has high potassium content and is found to be useful in the prevention of rising blood pressure and muscle cramp (Ng & Fong, 2000). Various parts of the plant such as the leaves, root, fruit stalk, bract and fruit are used for medicinal and domestic purposes but not much has been recorded on its potentials for construction material.

The use of plantain agro-waste in the construction industry has not being substantially explored. Aremu, Aperolola and Dabonyan (2015) observed that plantain stalk has high cellulose content of 57.86%. Cellulose is the component that makes fibre content of non-wood materials to be strong. The study also noted that plantain stalk has a low value of lignin content, 4.60% compare to corn husk of 12.04%. Lower lignin content enhances fibre strength and makes fibre difficult to break. However, previous research has shown that the introduction of fibre in bricks reduces the total mass of the brick and create voids which ultimately makes brick lightweight while maintaining the required properties. Lightweight bricks are lighter than the standard bricks and commonly preferred because they are easier to handle and thus has less transportation implications. Dondi et al., (1997a and 1997b) observed that waste fibre lowers energy consumption during brick firing due to the contributions of high calorific value provided by many types of waste.

Glenium SKY 504

MasterGlenium SKY 504 is a chemical admixture of an advanced second generation superplasticizer based on polycarboxylic ether (PCE) polymers. It is particularly designed for ready-mix concrete. MasterGlenium Sky 504 can enhance the production of high quality concrete mix with accelerated strength development and extended workability without delayed setting characteristics. MasterGlenium SKY 504 enhances delivery of high performance concrete at any time to the job site and advances the production of a concrete with low water cement ratio without loss of workability.

The shelf life of MasterGlenium SKY 504 is 1 year when stored out of direct sunlight and protected from extreme temperature. The normally recommended dosage rate of MasterGlenium SKY 504 is 0.8 to 1.5 litre per 100kg of total cementitious material. For optimal result, MasterGlenium SKY 504 is poured into concrete mix right after the addition of the first 80% of the mixing water, i.e. when all solids are wet.

Mix design

Ratio method of mix design was used in this experiment. The bricks ingredients were mixed in 1:3 cement, sand, and variable percentages of plantain Fibre (0 to 2% of cement) and 0.015% Sky 504 of cement. The batching of mix was by weight and a mix ratio of 1:3 was adopted for a target mean strength. Table-1 shows the mix proportion of materials used for the batching and the code for each brick samples. The mix was chosen to provide the most suitable mortar which will be readily workable to enable the production of satisfactory work at an economic rate and provide adequate durability. The choice of the mix also birthed by the compositions provided in BS 5628.

Table-1. Mix Proportion.

S/N	Eco-brick Samples	Plantain Fibre	Cement	Sand	MasterGlenium SKY 504
1	EBC	0.000	1.000	3.000	0.000
2	EB1	0.500	1.000	3.000	0.015
3	EB2	1.000	1.000	3.000	0.015
4	EB3	1.500	1.000	3.000	0.015
5	EB4	2.000	1.000	3.000	0.015
6	EB5	0.000	1.000	3.000	0.015

Water/cement ratio of 0.3 was employed. Twelve bricks (225mm x 112.5mm x 75mm) were cast for each type of brick produced for different curing period, namely; 3 days, 7 days, 28 days for compressive and water absorption test. The fresh bricks were thoroughly tampered in the mould with steel rod and reference

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numbers were given to the moulds for easy identification of the bricks. The moulds were removed after 24hours and the ponding method of curing, in which the bricks were totally immersed in water throughout the curing period, was adopted.

RESULTS AND DISCUSSIONS

Bulk density

The effect of plantain fibre reinforcement on the bulk density of eco-bricks is presented in Figure-1. The result indicates that the bulk density decreases as the percentage of plantain fibre content increases. This characteristic could be ascribed to the light weight of plantain fibres in the mix, consequently there is a decrease in the mass of the specimen at equal volume resulting to a decrease in the density of the specimen. This agrees with a similar assertion by Aggarwal (1995) that increase in natural fibre content in composite materials, decreases the density of the composite. Also, Nibudey *et al.* (2013) observed a reduction in bulk density of PET fibre reinforced concrete as the fibre content increases. The bulk density of the reference sample (2355kg/m^3) in the current study is higher than the control sample of 1923kg/m^3 in Neno *et al.* (2014). This is expected because of the higher mix ratio used in this study.

On the other hand, the specimen with Sky 504 but without fibre had a higher bulk density (2379kg/m^3) approximately 1.03% higher than the control sample. This variation noted could be attributed to reduced void as a result of Sky 504 plasticity effect.

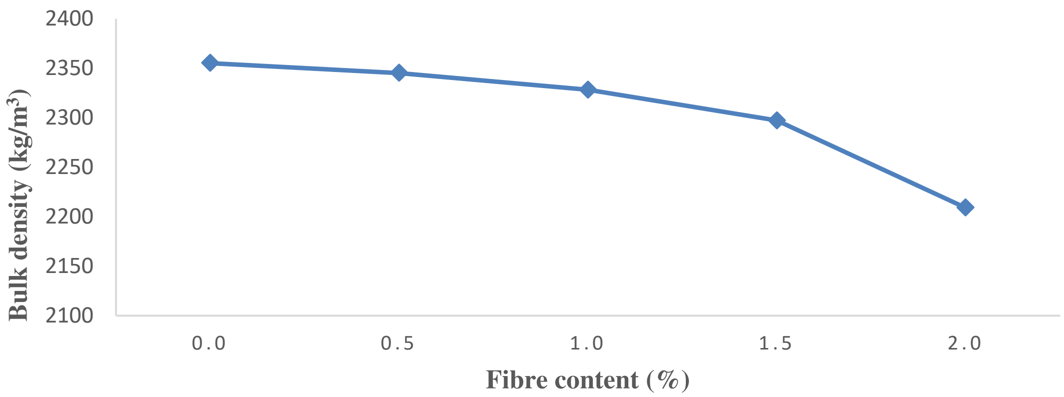

Figure-1. Variation of bulk density with percentage fibre content.

Compressive strength

During the experiment, accurate and precise procedures were ensured and results were recorded appropriately. The result of the three days compressive strength test is presented in Table-2.

Table-2. Average Compressive Strength Results of Samples at 3 days.

S/N	Eco-brick Samples	Avg. Mass of Sample (kg)	Compressive Strength (N/mm^2)
1	EBC	4.40	21.53
2	EB1	4.40	14.85
3	EB2	4.18	9.69
4	EB3	4.38	7.70
5	EB4	4.18	6.12
6	EB5	4.50	15.35

In Table-2, the compressive strength of the control sample (1: 3 cement, fine aggregate brick) EBC is 21.53 N/mm^2. While EB1 (1: 3: 0.5: 0.015 - cement, fine aggregate, plantain fibre and sky 504) eco-brick has an average compressive strength of 14.85 N/mm^2. The average result of samples 3 days compressive strength tests shown in Table-2 partially reveals a decrease in compressive strength of eco-bricks with increase in plantain fibre at 0.015 glemiun sky 504 plasticizer and 0.3 water/cement ratio. Also, Table-2 shows that the average mass of EBC is 4.40 kg while eco-brick manufactured with 2% plantain fibre had a mass of 4.18 kg. Partial decrease in mass of eco-brick with increase in plantain fibre is detected.

Table-3 presents the results compressive strength test at 7 days curing age. In Table-3, the compressive strength of control sample (1: 3 cement, fine aggregate brick) EBC is 23.70 N/mm^2. While EB4 (: 1: 3: 1.5: 0.015

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- cement, fine aggregate, plantain fibre and sky 504) eco-brick has an average compressive strength of 12.04 N/mm^2.

Table-3. Average Compressive Strength Results of Samples at 7 days.

S/N	Eco-brick Samples	Avg. Mass of Sample (kg)	Compressive Strength (N/mm^2)
1	EBC	4.55	23.70
2	EB1	4.52	22.32
3	EB2	4.52	20.54
4	EB3	4.31	14.02
5	EB4	4.20	12.04
6	EB5	4.53	17.12

The average result of samples 7 days compressive strength tests shown in Table-3 also partially reveals a decrease in compressive strength of eco-bricks with increase in plantain fibre at 0.015 glemiun sky 504 plasticizer and 0.3 water/cement ratio. Also, Table-3 shows that the average mass of EBC is 4.55 kg while eco-brick manufactured with 2% plantain fibre had a mass of 4.20 kg. Partial decrease in mass of eco-brick with increase in plantain fibre is noticed. The Table also shows considerable increase in mass of the eco-bricks with increase in currying period indicating that the samples continually absorbed water from the currying tank during the first 7 days.

At 28 days curing age, the compressive strength of the eco-bricks was tested and the results are shown in Table-4.

Table-4. Average Compressive Strength Result of Sample at 28 days.

S/N	Eco-brick Samples	Avg. Mass of Sample (kg)	Average Crushing Load (kN)	Cross Sectional Area (mm^2)	Compressive Strength (N/mm^2)
1	EBC	4.45	815.10	25312.50	32.20
2	EB1	4.45	675	25312.50	26.67
3	EB2	4.55	650	25312.50	25.68
4	EB3	4.40	506.76	25312.50	20.02
5	EB4	4.20	380.79	25312.50	15.04
6	EB5	4.52	764.94	25312.50	30.22

In Table-4, the compressive strength of control sample (1: 3 cement, fine aggregate brick) EBC is 32.20 N/mm^2. While EB4 (1: 3: 2: 0.015 - cement, fine aggregate, plantain fibre and sky 504) eco-brick has an average compressive strength of 15.04 N/mm^2. The average result of samples 7 days compressive strength tests shown in Table-4 also partially reveals a decrease in compressive strength of eco-bricks with increase in plantain fibre at 0.015 glemiun sky 504 plasticizer and 0.3 water/cement ratio. Also, Table-4 shows that the average mass of EBC is 4.45 kg while eco-brick manufactured with 2% plantain fibre had a mass of 4.20 kg. Partial decrease in mass of eco-brick with increase in plantain fibre is noticed. The Table also shows that there is no substantial increase in mass of the eco-bricks at 28 days in comparison with 7 days currying period. The non-increase in mass indicates that the eco-brick samples must have been saturated at the 7 days currying duration and therefore no longer absorb water. The compressive strength of the eco-brick samples and the curing are presented in Figure 2 to understand the trend of strength development.

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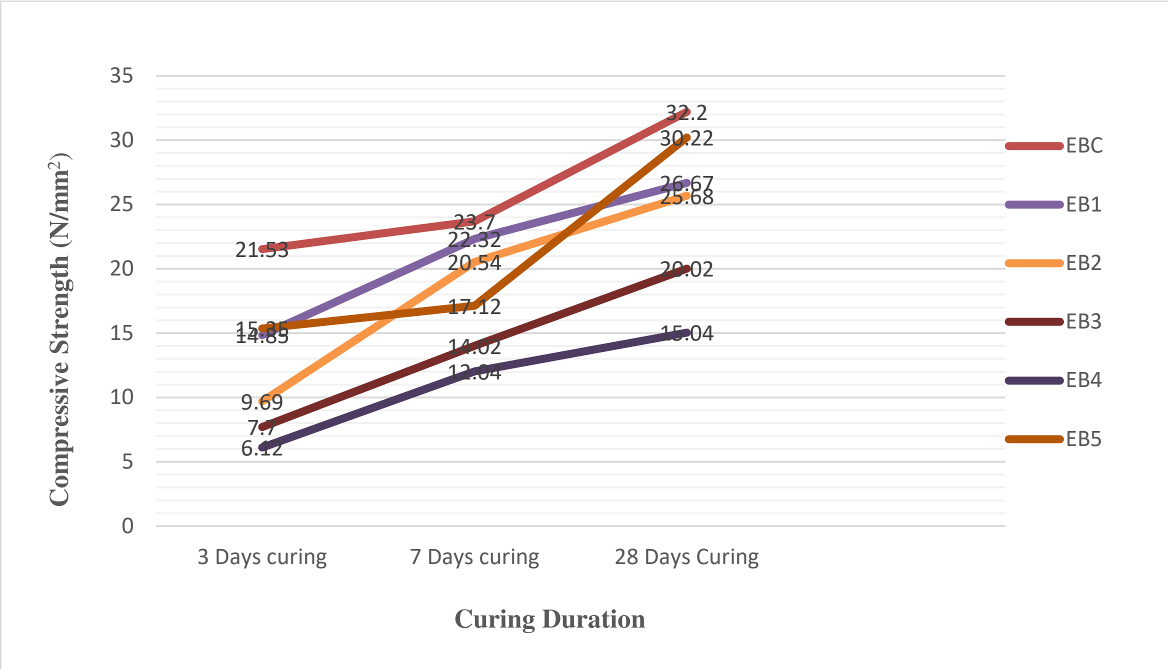

Figure-2. Compressive Strength Development with Curing Age.

The compressive strength of the eco-bricks increases as the curing period increases. Figure-2 shows the graph of the compressive strength of the eco-bricks with the curing duration. The Figure reveals that the rate of strength development among the eco-bricks differs and also differs with the duration of curing. The eco-brick with the fastest early strength development rate is EB2 (eco-brick made with 1: 3: 1: 0.015, cement, fine aggregate, plantain fibre and Sky 504). EB2 achieved a compressive strength of 9.69 N/mm^2 at 3 days compressive strength reaches 20.54 N/mm^2 on the 7 days compressive strength - 112% increase of compressive strength development. Also, 0.5%, 1.5% and 2% plantain fibre reinforced eco-brick showed similar increase in rate of early strength development compered the control eco-brick sample, EBC. The rate of early strength development of eco-brick increases with increase in plantain fibre up to 1.0% fibre content but starts decreasing with further increase in plantain fibre beyond 1.0%. On late strength development, Figure-2 shows that plantain fibre eco-bricks have low percentage of strength development compared to eco-bricks without plantain fibre. The plantain fibre reinforced eco-bricks, EB1, EB2, EB3 and EB4 recorded 19.5%, 25%, 43% and 25% increase in strength at the 28 days curing age respectively. This shows the compressive strength development with age as the fibre content increases up to 1.5% fibre content but reduces beyond 1.5%. EBC, the control eco-brick without fibre and sky 504, achieved 23.70 N/mm^2 compressive strength on 7 days curing and 32.20 N/mm^2 on 28 days curing - 36% increase of strength development. Comparing EBC with EB5, it is observed that sky 504 lowered the early compressive strength while the 28 days strength was not affected. This further revealed the importance of the plantain fibres as early strength inducers in the eco-brick at less than 1.0% fibre content.

Generally, among the curing age, a reduction in strength of eco-bricks as the plantain fibre content increases is observed. This agrees with the assertions of Borg *et al.* (2016); Nibudey *et al.* (2013); Wang and Meyer (2012) that when the fibre content increased, the compressive strength of FRC degrades. The reduction in compressive strength is attributable to inadequate bond between plantain fibres and surrounding matrix of the eco-brick. On the contrary, Galan-Main et al. (2010) observed an increase in compressive strength with addition of wool fibre for soil stabilization in the presence of alginates – a plant derived polymer binder. The increase in strength recorded in the study was ascribed to the alginates in the soil matrix which acted as a binder. This is not the case in the present study as no additional binder was used other than cement. The Sky 504 used in the study is a plasticizer and not a binder.

Water absorption

The results of water absorption test are presented in Table-5. The water absorption values of the eco-bricks were in the range of 4.76 - 7.89 as shown in Table-5. BS 3921 1985 recommended that the water absorption of bricks for building works most not be more than 4.5% by mass while 7.0%.

Table-5. Detail Result of eco-bricks Samples for Water Absorption Test (kg).

S/N	ECO-BRICK SAMPLE	MASS AFTER OVEN DRYING	MASS AFTER IMMERSION IN WATER	WATER ABSORPTION (%)
1	EBC	4.20	4.50	7.14
2	EB1	4.20	4.45	5.95
3	EB2	4.15	4.40	6.02
4	EB3	4.00	4.25	6.25
5	EB4	3.80	4.10	7.89
6	EB5	4.20	4.40	4.76

by mass water absorption is acceptable for external works. From Table-5, the water absorption of the control sample, EBC is 7.14 while EB1 had water absorption of 5.95. EB2, EB3, EB4 and EB5 had water absorption of 6.02, 6.25, 7.89, and 4.74 respectively. The results show that there is reduction in water absorption with the introduction of glenium sky 504 in EB1 resulting in a lower water absorption value (5.95%) than the control sample EBC (7.14%). Also, the result of water absorption of EB5 (eco-brick produced with Sky 504 but without fibre) further revealed the capability of Sky 504 to reduce ingress and retention of water in eco-bricks. This indicates that the Sky 504 considerably closes up the interstitial voids among particles of the eco-brick. However, results of water absorption of EB2, EB3 and EB4 with further increase in plantain fibre from 1% in EB2 to 2% in EB4 revealed a characteristic increase in water absorption as a result of increase in void within the eco-brick. The void presence is not unexpected because of the increase in fibre content. This result affirms the findings of Abdullah and Jamaai, (2016) that the water absorption values of the eco-brick produced from 0.5, 1.0, 1.5% and 2.0% kenaf fibre increased as the fibre content increases.

CONCLUSIONS

The purpose of this study was to investigate the use of waste plantain fibre and Sky 504 in the production of eco-bricks by assessing their effect on bulk density, compressive strength and water absorption of brick specimens. Six mixes were designed and tested. Four of the mixes were made of four different fibre content and the feasibility of utilizing plantain fibres as reinforcement in eco-brick was assessed successfully. From the results obtained the following conclusions were drawn:

The compressive strength of eco-bricks produced in this study show a decreasing tendency with the increase of plantain fibre content. It is speculated that the bonding of aggregates-plantain fibre in eco-brick is weak compared to the bonding of aggregates-aggregates in the control eco-bricks (EBC) samples. The study also found that eco-bricks produce with plantain fibre and master glenium sky 504 have a very good strength and water absorption properties and can be used in construction. In addition, the failure mode of the control samples and the samples with sky 504 without plantain fibre were virtually without warning. In contrast, the eco-bricks produced with plantain fibres failed with the appearance of fine cracks at the surface of the specimens.

The study found that sky 504 affects the early development of eco-brick strength but has no considerable effect on the late strength. Hence eco-bricks prepared with super plasticizers such as sky 504 should be allowed adequate curing period before use and loading.

Also, plantain fibre content up to 1.0% enhances the early compressive strength development of eco-bricks, but beyond the 1.0% plantain fibre content the compressive strength of eco-brick manufactured with plantain fibre and sky 504 degrades.

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