A STUDY OF THE ENGINEERING FEASIBILITY OF LIGHT WEIGHT BLOCKS PRODUCED FROM RECYCLING RICE HUSK IN SANDCRETE

[1]Atikpo, E and [2]Kayode-Ojo, N

[1]*Department of Civil Engineering, Faculty of Engineering, Delta State University, Oleh Campus, PMB 1, Delta State, Email: eguasbridge@gmail.com, Phone: +2348038665352*
[2]*Department of Civil Engineering, Faculty of Engineering, Benson Idahosa University, Benin City, Edo State Email: engrngozi@yahoo.com, Phone: +2348023522239*

ABSTRACT
The abundance of rice husk in Nigeria requires that its alternate economic use be considered instead of polluting the environment by the waste heap and through burning. Therefore, this work studied the engineering feasibility of light weight blocks produced from recycling rice husk in sandcrete.

Twelve (12) control sandcrete cubes of 100 x100 x 100 mm³ size were made from a thorough misture fine aggregate (sand), cement and water; and seventy two (72) of 100 x100 x 100 mm³ size were produced by substituting rice husk for fine aggregate in sandcrete in the percentage order 10, 20, 30, 40, 50 and 60; summing up to eighty four (84) cubes. These built in details from three (3) cubes per curing time and twelve (12) cubes per percentage of replacement and control sandcrete. The sample cubes produced were cured and experimented in triplicate for 7, 12, 21 and 28 days to determine their bulk densities, compressive strengths and water absorption capability; the average results were determined and recorded; the compressive strengths recorded on the 28th day of curing were compared with the standard provided in the National Building Code (2006).

The study shows that rice husk is not feasible for substituting sand in sandcrete blocks at these percentages of substitution tested. This is obvious from the recorded, very low maximum compressive strength of 0.51N/mm2 of partial sandcrete which is far below the minimum acceptable compressive strength of 1.50N/mm2 of individual blocks specified in National Building Standard Code (2006).

The volume of water used for mixing sandcrete of partially replaced sand with rice husk was far greater than that used during the mixing of total sandcrete for control experiment. This volume of water used was highest at 50 and 60 % replacement; and it was observed that sandcrete containing rice husk required more binder (cement) than the one used for control experiment. Another work with different range of percentage substitution of sand with rice husk is recommend to study the possibility of producing light weight blocks for partitioning and temporary structures.

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Keywords: *waste recycling, rice husk, building block and building construction.*

INTRODUCTION

Refuse heaps from rice husk constitutes serious environmental nuisance in areas where rice is produced, milled and the husk disposed. The stake holders are usually concerned about the disposal of theses wastes from their environment without looking at the benefits that can accrue from them. Millers do not see relevance in rice husks, so they give them out freely in an attempt to free their environment from the wastes. Meanwhile, researchers like Opara (2006), Nicholas and Folorunsho (2012), Opeyemi and Makinde (2012) have done some recycling works using rice husk in some forms, especially in the form of rice hull ash (RHA) to prove the economic benefit of rice husk in the building industry. Carter et al (1982) dealt with the incorporation of ungrounded rice husks into handmade, kiln–fired bricks. The properties like density, compressive strength, modules of rupture, water absorption and initial state of absorption were measured; and their conclusion is that it was possible to substitute up to 50% rice husks (by volume of clay) into bricks without the properties of brick falling outside the acceptable limits in developing countries.

Rice husk which is also called rice hull are the hard protecting covering of rice grains. They are obtained as by-product of threshing paddy and constitute about 20% of the dry mass of harvested paddy. It contains about 50% cellulose, 23-35% lignin and 15-20% silica. And it is readily available and economically within the purchasing power of an ordinary man. Its presence in cement will not only reduce carbon dioxide emission, but will improve the work ability and durability structures made of concrete.

Research of wastes recycling in building materials are relevant now since large demand has been placed in the building material industries owning to the increase in population resulting in shortage of building materials.

Sandcrete block commonly used for building construction in Nigeria is a homogeneous mixture of composite material made up of cement, sharp sand and water National Building Standard Code (2006). The specified sandcrete blocks are dense aggregate concrete blocks, Lightweight concrete blocks for load bearing walls and Lightweight concrete blocks for non-load bearing walls (National Building Standard Code, 2006); with standard compressive strength of 2.00 N/mm2 (300 psi) for average strength of blocks, and 1.50 N/mm2 (250 psi) for the lowest strength of Individual block. This strength, when achieved by substituting wastes in the production of building blocks for the construction industry, will save cost and spead up development which partly hinges on the availability of shelter.

This study therefore investigated the potential of rice husk for producing a low cost and light weight composite block as building material to replace the more expensive sandcrete blocks commonly used by builders. This is tied to the increase in the popularity of using environmental friendly, low cost and light weight construction materials in the building industries without compromising standard.

METHODOLOGY

MATERIALS

These include: rice husk obtained from rice mill producing it abundantly in Auchi; fine aggregate - sharp sand of 3.35mm, 0.85%, 2.64, and 2.91 sieve size, moisture content, specific gravity and coefficient of uniformity respectively; and free from loam, organic matter, clay, dirt and any chemical matter; binder - ordinary Portland cement and tap water.

SANDCRETE AND RICE HUSK CUBES PRODUCTION

In consonant with the National Building Standard Code (2006), cement and sand were mixed thoroughly in the ratio of 1:6 until a mixture of even colour and consistency was obtained. Sufficient quantity of water was added to produce a material of adequate work ability. In the same vein, rice husk was introduced as one of the composites in different percentage to produce other blocks. This was done as sand, cement and rice husk were thoroughly mixed together to form a uniform colour before water was added to it make the mixture workable before being poured into the mould of 100 mm x 100 mm x 100 mm dimension for block production.

METHODS

Twelve (12) absolute sandcrete cubes were moulded from a mixture of fine aggregate (sand), cement (binder) and water. Seventy two (72) cubes of partially replaced sand with rice husk in the steps of 10, 20, 30, 40, 50 and 60% were produced. The absolute sandcrete cubes were made for control experiment.

The cubes were cured for 7, 12, 21 and 28 days, weighed and examined for compressive strength, bulk density, and water absorption in triplicate with average values recorded and documented.

Laboratory results of examined cubes were scrutinized and the 28th day compressive strengths of tested cubed were compared with the standard strength of sandcrete block specified in the National Building Code (2006) with the aim of making recommendations for practice in the building industry.

RESULTS AND DISCUSSION

The results of the compressive strength are carefully presented in Figures 1 and2, with Figure 1 looking at the variation of strengths of control cube with curing age, while Figure 2 cantered on the comparison of the compressive strengths of rice husk composite cubes at the various replacement percentages with that of the control cube at curing age 7 days. It was necessary to compare strengths of partial sandcrete cubes with the 7th day strength of the total (control) sandcrete because of the tremendous shoot in strength of the control cubes over the partial sancrete cubes.

The study showed an increase in compressive strength with age, but a decrease in compressive strength with increase in percentage of rice husk used from 10 to 20% and rose again to its peak strength at a replacement of 30% before decreasing with replacement of sand in sandcrete. The best strength of 0.51N /mm2 for partial sandcrete obtained at the least percentage of 30 for rice husk use dat 28th curing age was found to be far low in comparison with the minimum strength of 1.50 N/mm2 specified in (National Building Standard Code, 2006).

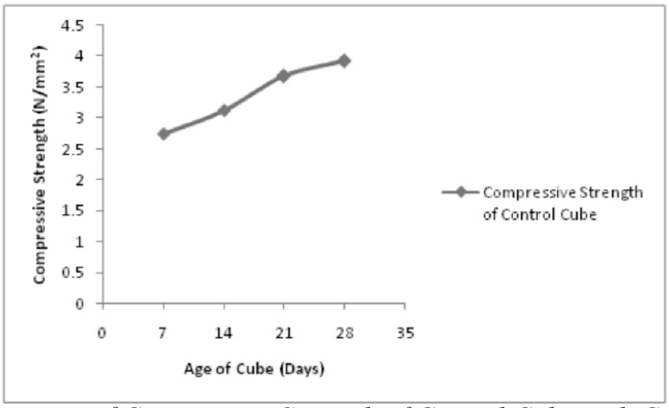


Fig 1: *Variation of Compressive Strength of Control Cube with Curing Age*

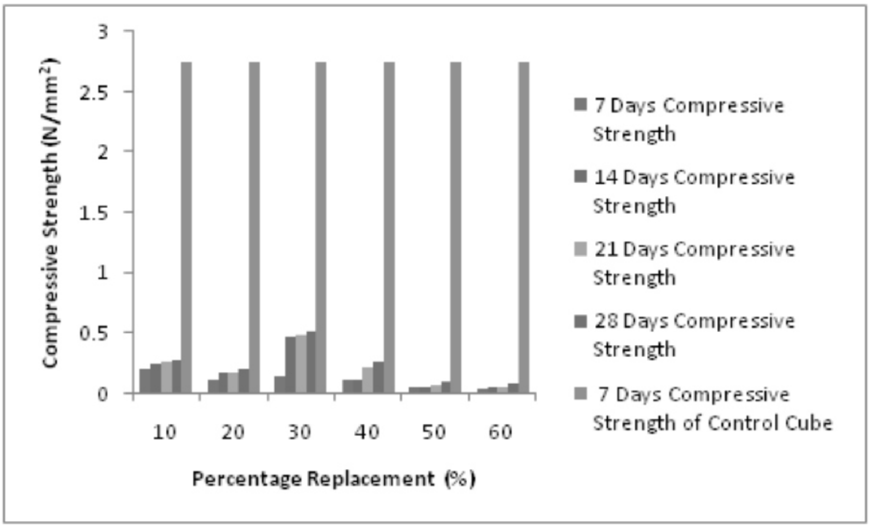


Figure 2: Comparison of Compressive Strengths of Rise Husk Composite Cubes with 7 Days Strength of Control Cube

Figure 3 shows that total sandcrete absorbs less water compared to partial sandcrete (of sand replacement with rice husk), and this water absorption rate increases with the percentage replacement of sand with rice husk. Previous research has shown that the more water absorption capacity of a block the weaker the block and vice versa (Subramani et al,2015). Water absorption values of blocks largely influence the bond between blocks and mortar. If the water absorption rate of a block is high it absorbs water from fresh laid mortar and this ultimately results to poor strength (Subramani et al,2015).

In this study, most of the cubes from partial replacement of sand with rice husk had higher water absorption than the minimum 12% requirement specified in (National Building Standard Code, 2006).

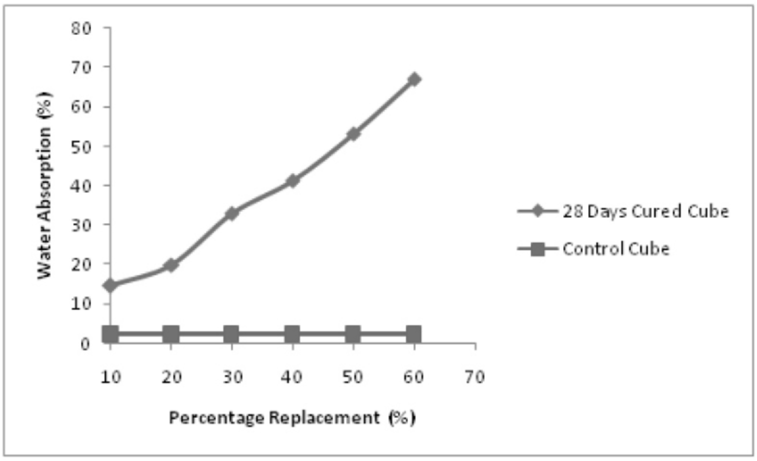


Fig 3: *Water Absorption Comparison*

The results of bulk density are shown in Figures 4 and 5. Figure 5 displays the variation of bulk densities of control cube with curing age, while Figure 4 zeroed on the comparison of the bulk densities of rice husk composite cubes at the various replacement percentages with that of the control cube at curing age 7 days because of the extremely high values in strength of the control cubes over the partial sancrete cubes.

The bulk density of total sandcrete was far greater than that of partial sandcrete, and it decreased with curing age. The bulk density of Sandcrete cube at day 7 was 1990kg/m³ while that of partial sandcrete cube at 10% replacement was 1511kg/m³, which were the highest values for each of them. The bulk density decreases with increasing replacement of sand with rice husk. The control sample exceeded the minimum (British standard - BSI, 2002) of 1500 Kg/m³ for bulk density, while only 10% of rice husk replacement at curing ages 7 and 14 days exceed this minimum requirement.

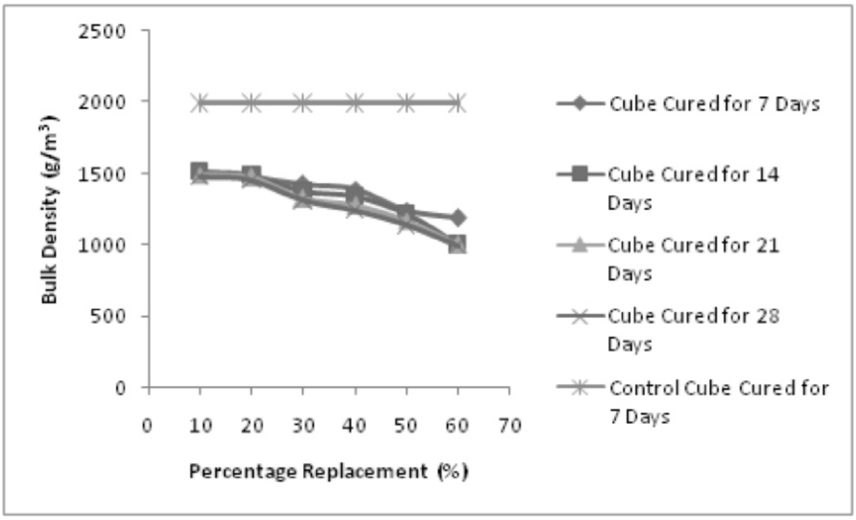


Fig 4: *Comparison of Bulk Densities of Rise Husk Composite Cubes with 7 Days Bulk Density of Control Cube*

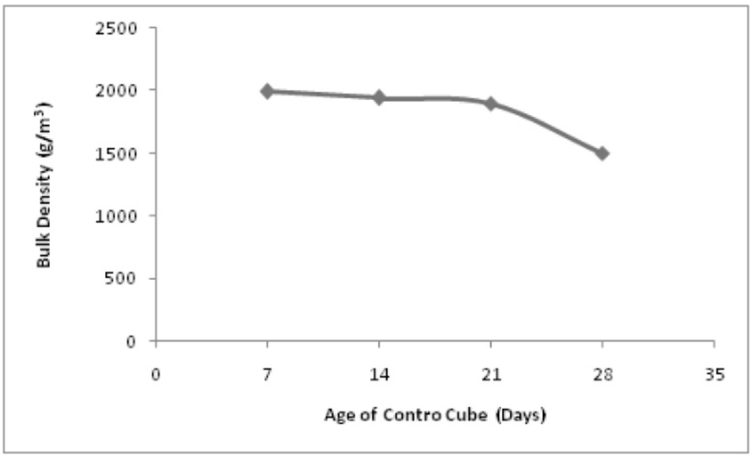


Fig 5: *Variation of Bulk Densities of Control Cube with Curing Age*

CONCLUSION

The study shows that rice husk is not feasible for substituting sand in sandcrete blocks at these percentages of substitution tested. This is obvious from the recorded, very low maximum compressive strength of 0.51N/mm2of partial sandcrete which is far below the minimum acceptable compressive strength of 1.50N/mm2 of individual blocks specified in National Building Standard Code (2006).

The volume of water used for mixing sandcrete of partially replaced sand with rice husk was far greater than that used during the mixing of total sandcrete for control experiment. This volume of water used was highest at 50 and 60 % replacement; and it was observed that sandcrete containing rice husk required more binder (cement) than the one used for control experiment. Another work with different range of percentage substitution of sand with rice husk is recommend to study the possibility of producing light weight blocks for partitioning and temporary structures.

RECYCLING OF WASTE PAPER FOR LIGHT WEIGHT BLOCK PRODUCTION FOR ECONOMIC BUILDING CONSTRUCTION

[1]Atikpo, E and [2]Kayode-Ojo, N

[1]Department of Civil Engineering, Faculty of Engineering, Delta State University, Oleh Campus, PMB 1, Delta State, Email: eguasbridge@gmail.com, Phone: +2348038665352

[2]Department of Civil Engineering, Faculty of Engineering, Benson Idahosa University, Benin City, Edo State. Email: engrngozi@yahoo.com, Phone: +2348023522239

ABSTRACT

Solid wastes are viable materials for building the wealth of a nation. Therefore, before solid wastes disposal option is considered, the reuse and recycling management alternatives should be explored. From this consideration, this study investigated the engineering properties of light weight blocks produced from partial replacement of fine aggregate (sand) with papers for economic building construction.

Sandcrete cubes measuring 100 x100 x 100 mm³ were produced from a uniform mixture of fine aggregate, cement and water. Other cubes were produced by partial replacement of fine aggregate with paper pulp in the steps of 10, 20, 30, 40, 50 and 60% making a total of eighty four (84) cubes culminated from three (3) cubes each for the curing ages and twelve (12) cubes each at the different percentage replacement and zero replacement (pure sandcrete). These cubes were cured, weighed and tested in triplicate on 7, 12, 21 and 28 days for compressive strength, bulk density, and water absorption. The average values of test results were recorded and documented. The 28th day compressive strengths were compared with the required strength standard for sandcrete block specified in the National Building Code (2006) and recommendations for practice in the sandcrete block moulding industry for building construction were made.

The study showed a mix ratio of 1:8 and 10% replacement of sand as adequate for internal walls of non load bearing structures. The low bulk densities indicated lightweight papercrete blocks suitable for use used in hollow form or solid blocks for internal wall; but should not be used for exter wall and within 1m above ground level for internal wall owing to its high water absorption capacity. If it external walling use necessary, it should not be used within 1m above ground surface and with adequate damp proof membrane.

Keywords: *waste recycling, perpercrete, sandcrete, economy and building construction*

INTRODUCTION

Solid waste management is a great challenge annually in urban areas (Awomeso et al., 2010). Human produced wastes filled up disposal sites and new sites are further away and difficult to reach (Nzihou, 2010). The most effective approach limiting the health and environmental effects of a waste is preventing waste generation (Rumyantseva et al., 2017). Because this is not possible, generated wastes are discarded as unwanted materials (Atikpo et al., 2009). However, exploration of reuse and recycling options of waste management techniques will prevent economic losses accruing from waste wastage (Atikpo et al., 2009) and promotes natural resources (Orebiyi et al., 2010) besides achieving pollution attenuation objective of waste management (Orebiyi*et al*, 2010). These partly have made reuse and recycling indispensable Waste management alternatives before disposal is considered (Berezyuk et al., 2016; Atikpo et al., 2009).

Recycling is a type of reuse of waste, but it is directly connected to waste components that are disintegrated into forms of new raw materials (Bugayan, 2015). The options for recycling relate to the generated wastes types (Alvarengan et al., 2016) with numerous benefits from new products obtained with great market values making it economically sustainable.

Good shelter is a great need in the world till date and it impacts on sustainable development. In developing states like Nigeria, housing is costly due partly to expensive building blocks for walling. Until this problem is solved, societal development and economic advancement will be difficult. This points to the requirement for cheap, adequate and durable housing. This challenge of low cost housing coupled in relation to increase in population has propelled Engineers to convert waste to useful building materials.
Over four hundred and fifty million tons of paper is generated globally yearly and the demand for it is expected to reach five hundred million tons per yearly by 2020 ending (Ali et al., 2013). The discarded parts of these papers result in environmental pollution yearly. According to the United States Environmental Protection Agency – USEPA (2014), Paper in all its forms constitutes a great percentage of the United States municipal solid waste generation.

One outstanding waste paper recycling benefit is the production of blocks for building construction. This consequently helps in reducing the demand pressure on natural resources for building wall construction, thus promoting sustainable development.

As stated by Solberg (2002), landfills in greater portion of the country are clogged with wastepaper while millions of humans are poorly housed or not at all, and when wastepaper are recycled as papercrete to build houses, shelter and waste problems will be addressed.

For years, environmentalist have constructed buildings with by recycling waste paper into alternative construction material (papercrete) made with cement and other component. This papercrete structures were found to be strong, durable and insulating (Fuller et al., 2006).

Sandcrete block is defined by the first edition of the National Building Code (2006) in section 10.3.13 as a homogeneous mixture of composite material made up of cement, sharp sand and water. The hollow or solid sandcrete blocks are of external dimensions: 450mm x 225mm x 150mm , 450mm x 225mm x 225mm, and 450mm x 225mm x 100mm (National Building Code, 2006).

The code specifies three types of solid or hollow sandcrete blocks as dense aggregate concrete blocks, lightweight concrete blocks for load bearing walls, and lightweight concrete blocks for non-load bearing walls (partitions); and specifies that mix used for sandcrete blocks should not be more than one part by volume of cement to six parts of fine aggregate (sand) except that the proportion of cement to mixed-aggregate may be reduced to 1:4 or 1:2 where the thickness of the web of the block is 25mm or less.

The code specifies that compressive strength for sandcrete blocks at 28 day for a load bearing wall of two or three storey building shall not be less than 2.00 N/mm^2 (300 psi) for average strength, and 1.50 N/mm^2 (250 psi) for lowest strength individual block.

Papercrete is a building construction material consisting re-pulped paper fibre and Portland cement or clay or other soil added. Structural examination conducted by fuller on several papercrete formulations revealed the compressive strength of papercrete to be above 140psi, while the ones by Kelly revealed strength of 260 psi. (Fuller et al, 2006). The stiffness – the extent to which papercrete compresses under load is a more valuable property and is many times less than that of concrete but adequate for the support of roof loads in some low rise buildings (Fuller et al, 2006).

Tonks et al (2004) experimented buildings constructed from re-pulped discarded telephone books and found them viable and conformable to the New Zealand Building Act. Claire et al (2010) constructed papercrete building from low grade waste paper heading to landfill and concluded on the papercrete as suitable for application in high performance and low cost building construction.

This study further investigated the potential of wastepaper for producing a low cost and light weight composite block for building construction. The increase in the popularity of using environmental friendly, low cost and light weight construction materials in the building industries has brought about the need to investigate how this can be achieved by benefitting the environment as well as maintaining the material requirement affirmed standards.

METHODOLOGY

MATERIALS

The materials used include: papers (mainly old newspapers) collected from various newspaper vendors and offices in bulk; fine aggregate - sharp river quartzite sand free from clay, loam, dirt and any organic or chemical matter with 3.35 mm sieve size, 2.64 specific gravity, 0.85% of average moisture content, and 2.91 coefficient of uniformity; binder - ordinary Portland cement (Dangote brand); and tap water.

Pulp Production

The papers could not be used in their unconverted form. Therefore, they were converted into paper pulp. To achieve this, the papers were shredded into pieces and submerged in 100 litres capacity drum filled to 2/3 of its capacity with water for two days. The pulp was then extracted through the process of filtration.

Sandcrete Preparation

Cement (binder) and sand (fine aggregate) were measured in the standard mix ratio 1:8 by weight in accordance to the provision in (National Building Code, 2006). The materials (sand and cement) were mix thoroughly until an even colour and consistency was attained. Water was then added in sufficient quantity to ensure work ability of the mixture. This sufficiency was ascertained by pressing a quantity of the mixture between the palms caked without bringing out water.

PROCEDURE

Well compacted sandcrete cubes were produced from a uniform mixture of fine aggregate, cement and water with moulds. Other cubes were produced by partial replacement of fine aggregate with paper pulp in the steps of 10, 20, 30, 40, 50 and 60%. The internal dimensions of cubes measured 100 x100 x 100 mm³. Eighty four (84) cubes, three (3) cubes at each curing age making twelve (12) each at the different percentage replacement and zero replacement (pure sandcrete) were produced.

These samples were cured, weighed and tested on 7, 12, 21 and 28 days for compressive strength, bulk density, and water absorption. These tests were conducted in triplicate and the average values were recorded and documented. The compressive strengths, bulk density and water absorption were evaluated from equations 1, 2 and 3.

Compressive strength = Load/ surface Area ....(1)

Bulk Density = mass/(volume) .... (2)

Water absorption = (wetweight-dryweight)/dryweight x 100.....(3)

The sandcrete blocks were for control - three blocks moulded without replacement of sand, that is 100% conventional sancrete were tested to provide for control data, Compressive strength, water absorption and bulk density values of cubes were compared on 7, 14, 21 and 28 days. The 28th day compressive strengths of tested cubed were compared with the required strength standard for sandcrete block specified in the National Building Code (2006) and the strength of cubes produced from paper replacement of sand which met with the national building code standard for sandcrete block were identified and recommended for practice in the sandcrete block moulding industry for building construction.

RESULTS AND DISCUSSION OF RESULT

The results of the compressive strength as presented in Figures 1 and 2 showed the compressive strength variation of the control sample (100 % Sandcrete) cubes and papercrete cubes. Figure 1 displaced this variation at different ages of 7, 14, 21 and 28 days and percentage replacement as compared with the strength of the control sample at age 7 days. It was observed in Figure 2 that the control cubes increased progressively in strengths with increase in age. Strength of sandcrete cubes reduced with increase in percentage of paper pulp substituted for sand. Their strengths were low all ages compared with the strength of sandcrete cube at age 7 days.

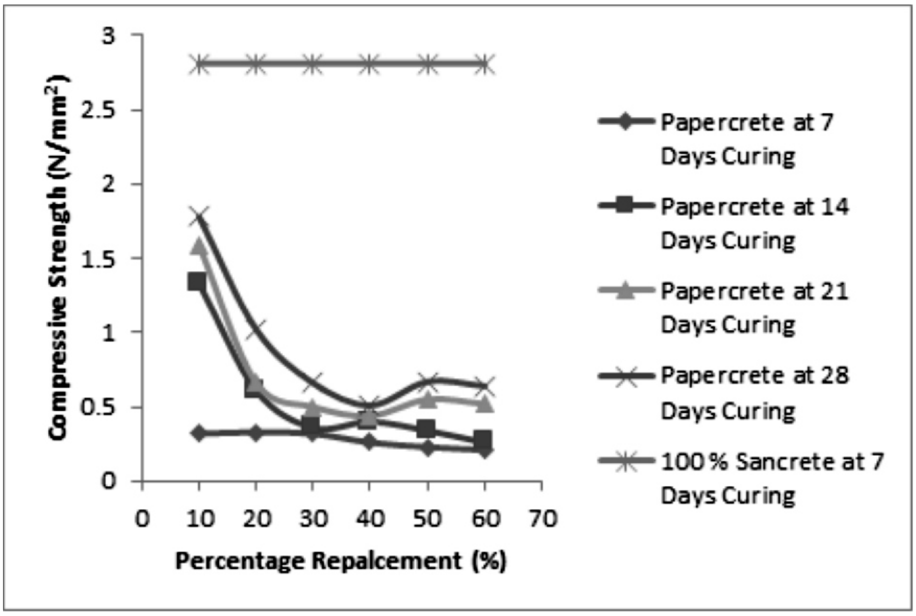
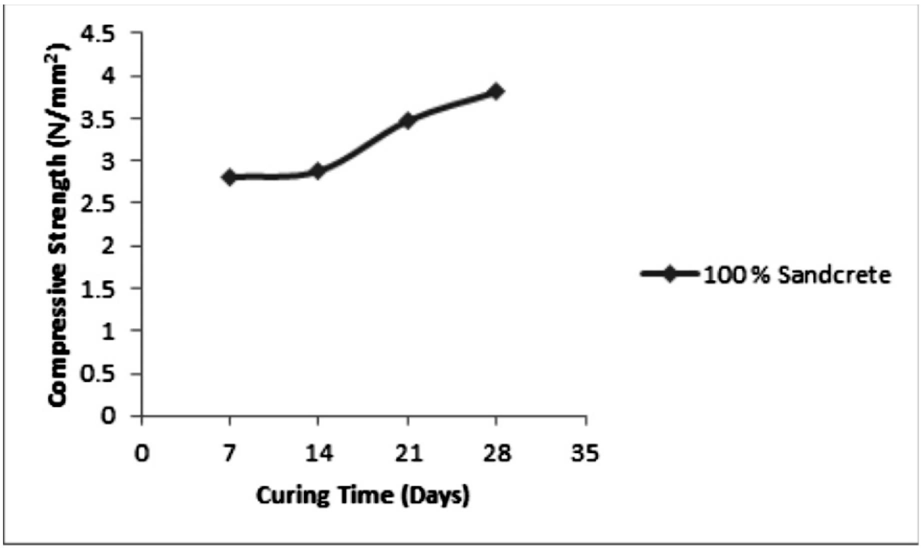


Figure 1: Strengths Comparison



F1gure 2: Strength of Control Cubes with Curing Age

Figures 3 and 4 showed the bulk densities of control sample and papercrete cubes. It was observed that the bulk density of the cubes for all specimen were directly proportional to the weight and the compressive strength but inversely proportional to the water absorption capacities. The control sample exceeded the minimum British standard of 1500 kg/m^3 (BSI 2002), while only 10-30% of paper replacement exceeded the minimum British standard requirement.

From the above, it shows that the bulk density of sandcrete was far greater than that of papercrete cubes. The bulk density of Sandcrete cube at day 28 was 1900kg/m³ while that of papercrete at 10% replacement was 1670kg/m³. The bulk density decreases with increasing sand replacement with paper pulp. Blocks with high bulk density showed high compressive strength.

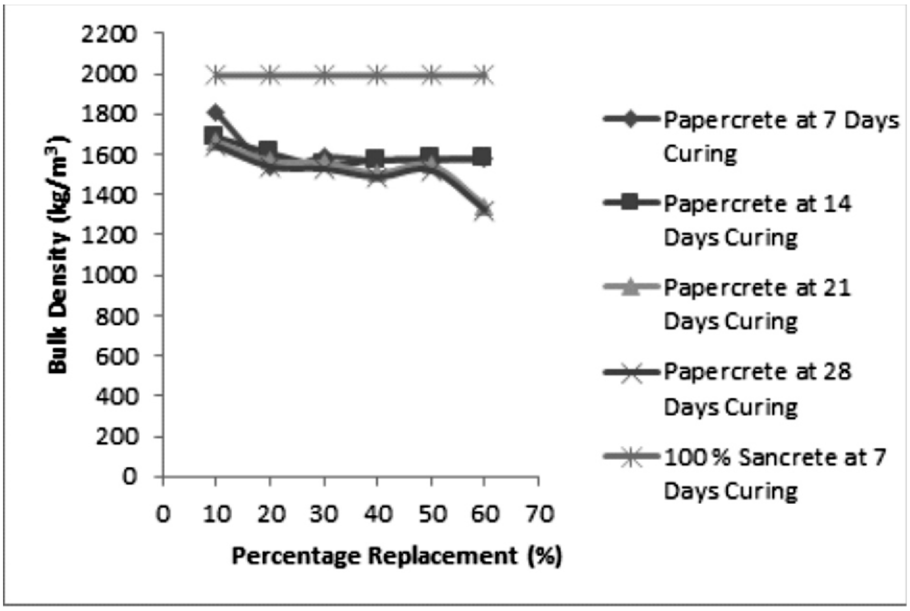


Figure 3: Comparison of Bulk Densities

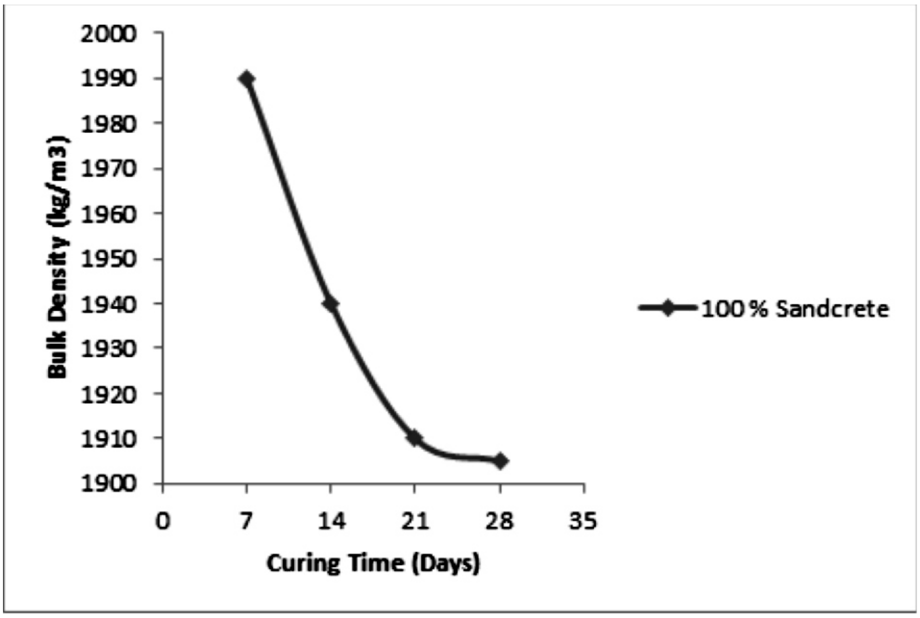


Figure 4: Bulk Densities of Control Cubes

Figure 5 showed the comparison of the water absorption capacities between the control sample and papercrete cubes. Most of the cubes were higher than the minimum 12% requirement specified in NIS (2007).

Figure 5 shows that sandcrete cubes absorbed less water compared to papercrete cubes which water absorption rate increases with increase in sand replacement. Previous research has shown that the more water absorption capacity of a block the weaker the block and vice versa. Water absorption values of blocks largely influence the bond between blocks and mortar. If the water absorption rate of a block is high, it absorbs water from fresh laid mortar which results into poor mortal strength (Subramani et al., 2015).

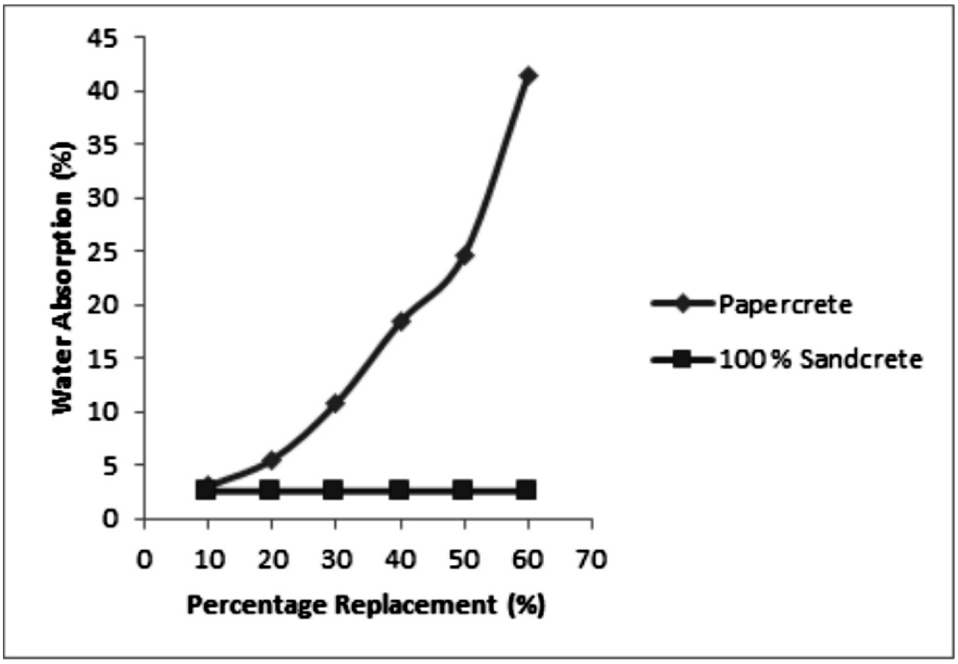


Figure 5: Water Absorption of Cubes

CONCLUSION

For obtaining the best results mix proportion of 1:8 and partially replacing sand with 10% of paper is adequate for internal walls of non load bearing structures. The low bulk densities of papercrete indicate that they are lightweight and can be used in form of either hollow or solid blocks, due to less weight of these bricks, the total dead load of the building will be reduced. Papercrete should not be used for external walls and near ground walls because of its water absorption capacity. If it has to be used for external walls, the surface of the walls must be waterproof. It should not be used within 1m above ground surface. Also a damp proof membrane should be places because it prevents the absorption of water due to capillary rise.

More investigation should be carried out with a larger scope than was used in this study to confirm some of the finding as reported. Further studies should be carried out using a different batching method (machine batching) and also determine the durability of papercrete block in certain aggressive environment such as fire and chemicals.

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