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Structural Properties of Rice Husk and Sawdust Composite Bricks

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ABSTRACT

What determine whether a material will be suitable for use on a building is its properties. One of the most important properties of building units, desirable, is their compressive strength. The materials of rice husk and sawdust are moulded into bricks in this study and their compressive strength is tested. 432 brick specimens were produced. The design used for this study is Research and Development (R&D) design. The bricks are moulded, cured and tested to determine their compressive strength after yield. Mix ratios of 1;3:3, 1:2:4, 1:4:2, 2:1:1, 2:1:2, 2:2:1, 3:1:1, 3:2:1, and 3:1:2 were used. Two curing methods were also used viz: sun drying curing method and room drying curing method. It was discovered that the bricks attained a compressive strength of 0.025 N/mm2 which is far below the 1.75 N/mm2 recommended for sandcrete blocks. The study therefore recommended that though these bricks have not attained the compressive strength to warrant their use as load bearing bricks they could still be used as in fills or as inner walls in buildings to improve both the thermal as well as sound insulation of the building.

Keywords: Compressive strength, curing method, rice husk, sawdust and mix ratio.

INTRODUCTION

This study is on the need to find ways of utilizing the rice husk and sawdust, which are presently waste materials, into useful products of walling materials (bricks). The study therefore produced walling materials using rice husk and sawdust as aggregates. The utilization of the rice husk and sawdust would solve the problem of waste disposal, environmental pollution and provide alternative walling materials which could improve both thermal and sound insulation to the building.

Rice husk is an agricultural waste product derived through threshing of padi. According to Webley (2001), rice husk is a thin but abrasive skin covering the edible rice kernel. Rice husk contains 75 – 90 % organic matter such as cellulose, lignin etc. and the rest mineral components such as silica, alkalis and trace elements (Kumar, Mohanta, Kumar & Parkash, 2012). Rice husks are found in large heaps round the country and they create disposal problems. In order to minimize the disposal problems therefore, many rice millers burn the husk, though some attempts are being made to put the rice husks to better economic uses. Rice husks are been used in Thailand as Bio-mass for generating energy (ASAPP, 2002). Rice husk is also known to have a thermal conductivity around 0.036 W/m °C, which is comparable to most insulation materials. Rice husk therefore has a potential to be used as a building material.

Uses of Rice Husk

The use of rice husk has however been tried by some persons. The National Research Development Corporation (NRDC, 2003) used rice husk to produce, particle boards and found out that it possessed excellent mechanical properties like, internal bond strength, elasticity, dimensional stability, screw and nail holding capacity, abrasion resistance, and surface hardness. With these qualities discovered by NRDC (2003), it means then that rice husk has promise in building materials. Allen (2003) also asserts that rice husk ash gives a good castable insulating and semi-refractory blocks when mixed with cement and water (2:1 – 3:1), while Rice Talker (2003) stipulates that rice husk ash (RHA) significantly improves the durability of concrete and substantially replaces silica fumes as additive at lower cost. Rice husk is a class 'A' insulating material. The silicon it produces when burnt provides excellent thermal insulation.

Kumar, Mohanta, Kumar & Parkash (2012), stated that rice husk had been used directly, without burning to ashes, in many industrial applications. It has been used directly as fuel in power plants. Rice husk has been used also as source of raw materials for synthesis and development of new phases and compounds. Rice husk has been used in industrial sectors as fuel in power plant, in formation of activated

Carbon, as a source of Silica and Silicon compounds, to get porous SiO_2/C composite, for insulating fire brick.

Kiyomi, Ichiro, Kenichi & Kenichi (2002), in their study on "effects of the combined use of rice husk and fly ash on concrete properties" investigated the characteristics of concrete in the case where rice husk ash is mixed in concrete of low water binder ratio, using a large volume of fly ash. In the investigation, the compressive strength, freezing and thawing, as well as pore size distribution, were specifically studied. It was therefore discovered through tests that, the compressive strength of concrete with rice husk, tested at 3 days and 365 days became 1.1-1.3 times more than concrete without rice husk ash. It was also discovered that concrete with rice husk ash offered similar resistance to freezing and thawing when compared with concrete without rice husk ash. Furthermore, the study measured pore size distribution and found out that total volume in concrete with rice husk ash decreased thereby leading to an increase of strength. The study by Kiyomi *et al;* (2002) centred on the compressive strength, freezing and thawing as well as pore size distribution. This study however concentrated on determination of compressive strength of the bricks. This study also uses rice husk in un-burnt form while they used rice husk ash.

Ibanga & Ahmed (2007) undertook a research on the influence of particle size and firing temperature in burnt properties of rice husk/clay mix. Their main objective was to investigate the scope of the use of rice husk in brick making. The effect of the rice husk/clay mix ratios for the different particle sizes of the rice husks and temperature of the formed bricks were also studied in the context of their effects on the compressive strength and water absorption. Ibanga & Ahmed molded composite bricks containing various additions of rice husks grouped into four particle size ranges. These bricks were molded under 5 MN/m^2 compaction pressure, dried and fired at 500°C, 6000C, 700°C, 800°C respectively. During the measurement of compressive strength, water absorption and density, it was discovered that small additions ($\leq$ 1%) of rice husks led to improved compressive strength and a decrease in the amount of water absorbed. The addition of higher percentages of rice husk reduced the compressive strength and density of the bricks and increased the amount of water absorption. This work further asserted that particle size ranges of 425 – 600μm gave best improvement of the brick properties. The disparity of Ibanga and Ahmed's (2007) work is their use of clay mix with rice husk and the firing of the bricks while this study uses rice husk and sawdust as aggregate and does not subject them to firing.

In another study, Oyetola and Abdullahi (2006), used rice husk ash with cement to produce low cost blocks. They first tested the compressive strengths of some commercial sandcrete blocks in Minna, Niger State, of Nigeria, and found them to be deficient in strength. The possibility of addition of rice husk ash was therefore explored experimentally to augment the high cost of cement which was the reason for its insufficient use which led to the loss of strength of the blocks. Hollow blocks of size 150m x 450m containing various percentages of rice husk ash replacements (0.10, 20, 30, 40, 50%) were cast, cured and crushed at 1,3,7,14,21, and 28 days. The mixture ratio used was 1.8 (one part of binder to eight parts of sand) at different levels of OPC and rice husk ash (RHA). For each replacement level about 18 blocks samples were cast. Three sample blocks were crushed each at 1,3,7,14,21, and 28 days at different replacement levels using compressive testing machine. In this work of Oyetola and Abdullahi (2006), the tests conducted included chemical analysis of rice husk ash, particle size of sand, specific gravity test on RHA and sand, bulk density test on rice husk and sand, silt content test on sand, constituency tests, setting time test, free moisture content test and slump test as well as the determination of compressive strength and density. Mix design was carried out by absolute volume method to select most suitable materials of cement, RHA, sand and water, to produce blocks with desired properties.

The maximum value of the compressive strength of the blocks obtained in Minna was 0.97 N/mm^2, which does not comply with the minimum standard of 3.5 N/mm^2. Bulk density of RHA and sand were 530kg/ m^3 for compacted and 460 kg/m^3 for un-compacted RHA, while compacted densities of sand was 1600 kg/ m^3 and un-compacted density of sand was 1500 kg/ m^3. The difference in value is attributed due to the sample disturbance. It was found out that at 28 days hydration period, blocks made with 10% and 20% RHA replacement met the minimum stipulated compressive strength of 3.5 N/mm^2 as they were 4.1N/mm^2 and 3.65 N/mm^2 respectively. Although other replacement levels fell below standard of 3.5 N/mm^2, they were higher than local blocks produced in Minna, which had 0.97 N/mm^2, except for 50% replacement which had compressive strength of 0.59 N/mm^2 at 28 days.

Oyetola & Abdullahi (2006) concluded that blocks using RHA as partial replacement to OPC will be cheaper to produce and thus improve the quality of blocks in Minna. The use of sand and rice husk ash in this work deviates from the intent of this work which eliminates sand to reduce weight and uses sawdust and rice husk with OPC. Basic test on compressive strength are carried out. Many other tests as mentioned above are not used for the intended project. Furthermore, rice husk and sawdust are used in their natural state, not burned to ashes.

Sawdust, another agro-waste material, is a by-product of wood, produced from sawing of wood. Sawdust is those small pieces of wood that are left when one has been cutting wood. Akande (2001) has observed that large quantities of sawdust can be found in Nigeria around sawmills and wood based industries. Sawdust is largely seen as waste and so is not utilized. According to Ogunsanwo (2001), the non-utilization of the sawdust creates disposal problems, which are burdensome. Owonubi and Badejo (2000), therefore, observed that in order to dispose of the large sawdust hills around sawmills, saw millers resort to burning. The burning thus produces smoke and offensive gases like carbon dioxide and carbon monoxide, which are hazardous to human health and contribute to ozone layer depletion as well as environmental pollution.

Uses of Sawdust

Sawdust is a by-product of wood based actions. Since sawdust comes from wood and it is assumed to possess some of the properties of wood (Tiough, 2014). People have therefore tried to use sawdust in different ways and for various reasons, depending on the property of sawdust they want to utilize. This is in a bid to change it from waste to useful material. RMRDC (2002) and Badejo (2002) stated other uses of sawdust to include fuel for cooking, particle board production, ceiling boards, wall tiles, floor tiles and partitioning panels. Chemical uses include ethyl alcohol, yeast, oxalic acid rinse, just to mention a few.

Owonubi & Badejo (2000) have also stated that the volume of wood waste generated in Nigeria increases yearly, and according to Ogunsawo (2001) this large volume of sawdust generated however, creates disposal problems which are of great concern to all wood industries and governments. As activities of sawmills continue to increase with the increase in the number of saw mill industries and other wood based industries, quantities of sawdust will continue to increase. RMRDC (2003b), in a further research stated that as at 2003 Nigeria had 1325 sawmills located in different parts of the country. This gave a total installed capacity of sawmills industry in Nigeria as 11.7 million m^3 of wood, but that the actual production was about 3.8 million m^3. This they say represent the national capacity utilization of about 24.5%. This statistics shows an increase in the number of sawmills in Nigeria over what was earlier reported. It is noticed that sawdust production continues to increase at all times. This means that as long as there is wood in our forests and wood based industries and sawmilling continues to increase there will be increase in sawdust production, hence its availability.

Many studies have also been carried out on the use of sawdust in building materials. Turgut and Algin (2007) in their study on "limestone dust and wood sawdust as brick materials" undertook a parametric experimental study to investigate the potential use of wood sawdust waste (WSW) and Limestone Powder Waste (LPW) combination to produce a low-cost and light weight composite as a building material. Some of the physical and mechanical properties of concrete mixes having high levels of WSW and LPW, like compressive strength, flexural strength, unit weight, ultrasonic pulse velocity (UPV) and water absorption values were investigated. It was then found that the values of the physical and mechanical properties investigated satisfy the relevant international standards. This parametric experimental study revealed that the effect of high level replacement of WSW with LPW does not exhibit a sudden brittle fracture even beyond the failure loads. It shows high energy absorption capacity, dramatically reduces the unit weight and introduces a smoother surface compared to the current concrete bricks in the market. This experiment reveals that the mixture of WSW and LPW has potential to be used for walls, wooden boards substitute, economically alternative to the concrete blocks, ceiling panels and sound barrier panels. One of the aims of this study was to utilize the abundant waste materials of sawdust and limestone powder which cause serious environmental problems and health hazards.

Zziwa, Kizito, Banana, Kamboggoza, Kambuga & Sseremba (2006), established that 18-20% of log volume in Uganda is sawdust. They also noted that sawdust is one of the major-under-utilized by-products from sawmilling operations in Uganda. They therefore suggest that finding an appropriate use of sawdust would help to offset production costs and increase the profitability of saw milling operations in Uganda's plantation forests. This suggestion will help Nigerian saw millers too, if economic use of sawdust is found. This project therefore seeks to explore ways of finding economic use of sawdust in Nigeria and the world, in building materials.

In a study carried out by Zziwa, Kizito, Banana, Kaboggoza, Kambugu & Sseremba (2006), on the production of composite bricks from sawdust using Portland cement as binder, whose specific objectives were:

(i) To make composite bricks using varying sawdust to cement ratios and

(ii) (ii) Determine the density, mass and compressive strength of the composite, 48 bricks of cement to sawdust mix ratios of 3:2 and 2:1 by volume were produced. The bricks sizes were 50mm x 50mm x 50mm (small) and 100mm x 100mm x 100mm (big). The sawdust particles were between 2.5 – 3.5mm in diameter. The sawdust was soaked in water for 24 hours to reduce the amount of water soluble sugars and tannins. This was then dried to 5% moisture content. The structural integrity of the brick was assessed by dropping the bricks from a height of 1m. Mass was measured using a weighing balance, while density was calculated from mass and volume of the bricks. A universal testing machine was used to test for compressive strength values which were found to be 1.61 Nmm^2 and 1.986 Nmm^2 for composite of 3:2 and 2:1 respectively. The compressive strength value of 100mm x 100mm x 100mm composite with sawdust to cement ratios of 3:2 and 2:1 was found to be 1.778 Nmm^2 and 2.21Nmm^2 respectively. The statistical tool used was analysis of variance (ANOVA) which indicated significant difference ($P<0.05$) in strength values of the two composites.

Zziwa, *et al;* (2006) therefore concluded that use of wood/cement composite bricks can reduce overall weight of the construction, since their densities and weight are generally low. They however found the composite bricks unfit for paving and medium heavy load construction. Zziwa, Kizito *et al;* however recommended that due to the light weight of the composites, they can be imparted with decorative mosaics and can be used for interior wall panelling and decoration, where minimum wetting is experienced. These bricks are unfit to be used externally due to dimensional instability during wetting. The study contributed to the improvement of the environment in Uganda through reduction of waste. Zziwa, *et al;* (2006) however, has laid a good base for this work where similar things are done.

Compressive Strength of Bricks and Blocks

According to Kerali (2001) the compressive strength of blocks is perhaps one of its most important engineering properties. According to Kerali (2001), it is on the basis of the value of the strength of a block that its mechanical and other valuable qualities are judged. Since the tensile strength of a block or concrete is 90% lower than its compressive strength, it is important to determine compressive strength of bricks/blocks. Kerali (2001) therefore states that the most likely valuable indicators of the strength of bonding achieved within the block is the difference between wet and dry compressive strength. The smaller the gap between the two, the higher the bond strength is expected to be.

The Nigerian Industrial Standard (NIS, 2004) recommended both the mix ratio for blocks as well as the compressive strength expected, based on the compaction method. NIS (2004) recommended the mix ratio of one part of cement to six parts of sand, i.e ratio 1:6 for block making. The ratio shall be either by volume or weight batching, while mix and moulding could be either mechanical or manual. NIS (2004) also divided the blocks into two groups – load bearing blocks and non-load bearing blocks. The load bearing blocks are of size 450mm x 225mm x 225mm, while the non-load bearing blocks are of size 450mm x 225mm x 150mm. The stipulated minimum strength, taking an average of five blocks, for load bearing is 3.45 N/mm^2 if machine vibrated blocks, but 2.5N/mm^2 if it is manually compacted blocks. Stipulated minimum strength, also taking an average of five blocks for non-load bearing blocks is 2.5N/mm^2 for machine vibrated blocks and 1.8 N/mm^2 for manually compacted blocks.

The Nigeria National Building Code (NBC, 2007), section 10.3.14.4 stipulates that the lowest strength of an individual sandcrete block should be 1.75 N/mm^2 (250 psi) while the average strength of 6 sandcrete blocks should be 2.00N/mm^2 (300psi). The National Building Code (2007) section 10.3.14.3 also recommends a mix ratio of 1:6 (cement to sand).

Brozovsky and Zach (2007) have stated that compressive strength of bricks can be tested in three ways-professional assessment, destructive tests, and non-destructive testing. Professional Assessment means marking brick strength from experience of products made at the same time for other constructions. However, this method suffers the problem of undervaluation or overvaluation of the compressive strength. Brozovsky and Zach (2007) also noted that destructive testing has to do with the crushing of brick samples while non-destructive testing, which includes - Waitzmann hammer (thrust hardness test), drop hardness test, point chisel test and ultrasonic pulse method does not need crushing of the composites. These methods are however, mostly used for concrete. However this work concerns itself with the destructive method where specimens are crushed using machines.

Gap

From the review of literature it was discovered that researchers did not bother to combine rice husk and sawdust into a composite material. It was also discovered that the use of rice husk was concentrated on its ashes. This study therefore utilized rice husk and sawdust in their natural forms as building units to test their performance. The study also used ordinary Portland cement as binder because of its availability as compared to resin or other binders.

Statement of the Problem

Rice husk and sawdust abound in our localities and they are counted as waste materials. However, this study now seeks for ways of using rice husk and sawdust as aggregates for brick production so as to :- (1) reduce environmental problems caused by the waste, (2) ease disposal problem of the waste, (3) improve noise and thermal insulation of buildings, (4) reduce cost of buildings, (5) reduce weight of buildings through the reduction of weight of materials and units, (6) use locally available raw materials and (7) also diversify the economy through use of these waste materials. The study therefore utilized rice husk and sawdust in their natural forms as building units to test their performance. The study also used ordinary Portland cement as binder because of its availability as compared to resin or other binders, and also because it ensures for higher dimensional stability of wood products. From the review of literature too it was discovered that researchers have not bothered to combine rice husk and sawdust into a composite material. This study will therefore mix rice husk and sawdust into a composite to produce bricks which are tested for compressive strength.

Purpose of the Study

The main purpose of the study is to produce walling materials (bricks) using rice husk and sawdust as aggregates. Specifically, the study is intended to determine

1. The mix ratio of binder to aggregate that will produce optimal compressive strength in composite bricks using different curing methods.
2. The optimal wet and dry compressive strength of composite bricks of different mix ratios using different curing methods.
3. The curing method that will produce the optimal compressive strength in composite bricks using different mix ratios.

Research Questions

The following questions were formulated to guide the study.

1. What is the mix ratio of binder to aggregate that will produce optimal compressive strength in composite bricks using different curing methods?
2. What is the optimal wet and dry compressive strength of composite bricks of different mix ratios using different curing methods?

3. What is the curing method that will produce the optimal compressive strength in composite bricks using different mix ratios?

METHODOLOGY

This section describes the methods, procedures, material and instruments that were used in carrying out this research. It is presented under the following headings:- Design of the Study, Area of the Study, Population for the Study, Equipment and tools, Materials, Research and Development procedure, Method of Data Analysis.

Design of the Study

A Research and Development (R&D) design was adopted for the study. Research and development design is relevant in this study because the study aims at identifying new knowledge in the production of bricks using rice husk and sawdust. According to Answers.Com (2010) the objectives of academic and institutional research and development is to obtain new knowledge, which may or may not be applied to practical uses; while the objectives of industrial research and development is to obtain new knowledge, applicable to the company's business needs, that eventually will result in new or improved products, processes, systems, or services that can increase the company's sales and profits. In research and development (R&D) design, the researcher undertakes creative work on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and uses this stock of knowledge to develop new applications (Wikipedia, 2009) accessed Nov.,13, 2009). In research and development resources are used for the deliberate discovery of new information and ways of doing things, together with the application of that information in inventing new products or processes, (International Economics Glossary: R. 2009).

In the design of this study, compressive strength of the bricks produced using the rice husk and saw dust as aggregate were determined. The control variables were taken as method of curing, mix proportions, processing time and water quantity. In this case the effect of varying aggregate type, quantity, matrix content, and processing methods on the properties of bricks were monitored.

Area of the Study

The study was carried out in Benue State. Benue state is one of the states in the north central parts of Nigeria. It is situated along the Benue valley. The state has two major rivers, namely river Benue and river Katsina Ala, along with other smaller rivers and streams. The people are predominantly farmers. The laboratory facilities at the Federal University of Agriculture, Makurdi were used to carry out the study.

Population of the Study (Specimens)

Four hundred and thirty two (432) Composite bricks comprising of Ordinary Portland Cement, Rice Husk and Sawdust were produced for testing. The composite bricks were produced using the mix ratios of 1:3:3; 1:2:4; 1:4:2; 2:1:1; 2:1:2; 2:2:1; 3:1:1; 3:2:1 and 3:1:2 of Ordinary Portland Cement to Rice Husk to Sawdust (OPC : RH : SD). Twenty four bricks samples of the composite bricks of each mix ratio were produced and cured using sun drying method, and similarly twenty four composite brick samples from each ratio were also produced and cured using the room drying curing method.

Equipment, Tools and Materials

Equipment and tools that were used for this research included California Bearing Ratio testing machine, which was used to test for the compressive strength of the specimen produced; head pans and wheel barrows, which were used to batch and convey materials to mixing platforms and to the moulds; shovels and scoop were used to mix the aggregate and binder, while wooden moulds were used to mould specimen into desired sizes. A 2.4kg rammer was used to compact the specimen in the moulds. Spring balance was used to weigh the bricks, while vernier calipers were used to take the measurements of the specimens that were used to check dimensional stability. Other equipment include graduated beaker in which water was poured for submersion of bricks to check for percentage water absorption, while a watering can was used to sprinkle water on the specimen during curing. Finally, sacks (bags) were used to collect the sawdust and rice husk from dump sites to the laboratory for inspection. Most of these equipment and tools were sourced from Federal University of Agriculture, Makurdi.

The materials used for this study include Ordinary Portland Cement (OPC) Rice Husk (RH) Sawdust (SD), and portable water that was used for mixing. Ordinary Portland cement is common and can be found in the market anywhere. Rice Husk was sourced from the rice mills in Makurdi. It is in great quantities and causes evacuation problems for rice millers. It is therefore readily available. Sawdust was sourced from the saw mills at the wood dealers markets. It is also available in great quantities.

The materials of rice husk and sawdust were used because they are of renewable sources. They were used to alleviate the evacuation problems and environmental hazards caused by their burning. The materials were also thought suitable because of their lightness and their sound and heat insulation properties.

RESEARCH AND DEVELOPMENT PROCEDURE

Research procedure consists of– preparation of materials, mixing, moulding, curing, testing and analysis.

Preparation of Materials

The rice husk and sawdust were collected in sacks of 50kg each. The materials were visually inspected and identified contaminants removed. The sawdust and rice husk were then sieved through a 5mm sieve to get materials of uniform grain size so as to also reduce pore size in the final bricks. Sawdust was then soaked in jars of water for 24hours so as to reduce the amount of lignin, tannins and cellulose which inhibit hydration necessary for cement setting. The sawdust was then spread on platform in the sun to dry the moisture contained therein. They were then batched (measured and mixed) by volume.

Mix Ratio

The mixture ratios used were 1:6 and 1:8 (cement to aggregate) as recommended by the Nigerian Industrial Standard (NIS 2004) and

National Building Code (NBC 2007) respectively, for concrete blocks. While the composite bricks were produced using the mix ratios of 1:3:3; 1:2:4; 1:4:2; 2:1:1; 2:1:2; 2:2:1; 3:1:1; 3:2:1 and 3:1:2 of Cement: Rice Husk: Sawdust.

The matrix and the aggregates were measured by volume according to the stated mix ratios. The scoop and measuring cylinder were used in measuring the quantity of materials to batch. However, as for composite bricks, the two aggregates of rice husks and sawdust were first mixed thoroughly before ordinary Portland Cement was added to mix with it to blend, after which water was added and then again mixed, using shovels. The composite bricks also had a greyish appearance. The mixing in each case was done till a uniform consistency was achieved. Then the moulding began.

Moulding, Casting of Samples or Specimens

The materials of rice husk and sawdust after having been mixed thoroughly with binder and water were put in the wooden mould of 100 mm x 100 mm x 100 mm. The specimens were manually moulded and casted. Shovels, head pans, wheelbarrow and metal scoops were used to mix and move the material. Also four hundred and thirty two bricks specimens were produced for composite bricks using the mix ratios of 1:3:3; 1:2:4; 1:4:2; 2:1:1; 2:1:2; 2:2:1; 3:1:1; 3:2:1 and 3:1:2 where forty eight brick samples were again produced in respect of each mix ratio.

Curing

Curing refers to the treatment of the samples in order for them to attain maximum strength. In this study two curing methods were used – namely the sun drying curing method and the room drying curing method. The sun drying curing method required the brick specimens to be dried in the sun while the room drying curing method required the brick specimens to be dried in the room or covered shade. The idea was to find out if there was difference in the attainment of strength either through fast drying in the sun or through gradual drying in the shade.

In all four hundred and thirty two (432) cube specimens were produced. Out of that number, half of it, that is two hundred and sixteen (216) cube specimens were labelled (A) and dried in the sun while the other half labelled (B) and was air dried in the room.

In using the sun drying method, the specimens labelled (A) were initially cast and placed under the shade to dry while water was sprinkled on them 8 hourly, for seven days using watering can, before they were transferred to the sun. The watering was to provide water so that cement would develop strength, before the harsh drying in the sun. The specimens were then dried in the sun for twenty one (21) days without further watering. The other half labelled B was dried in the room using room drying curing method. In room drying curing method, the specimens were air dried without the sprinkling of water. The samples were however covered with cellophane immediately after they were removed from the mould. The cellophane was covered on them for seven days, to conserve moisture necessary for cement to attain strength. After the seven days the samples were left to air dry in the room for twenty one days. They were also sent for tests at the stipulated days.

Testing

Tests were carried out to determine the compressive strength of the bricks as well as determine their percentage water absorption. Testing of the samples was done at 7th, 14th, 21st and 28th days of production and curing. The specimens were tested for compressive strength using the California Bearing Ratio compressive testing machine. Both the dry and saturated testing was done. For dry testing, the bricks were weighed and tested, while for saturated (wet) testing, the bricks were immersed in water for 4 hours, then removed and wiped of any traces of moisture. The bricks were then weighed and tested in accordance with Nigerian Standards for sandcrete blocks (NIS, 2004) and National Building Code (2007).

Three specimens from each mix proportion were crushed in the California Bearing Ration (CBR) (a compressive testing machine) to determine their dry compressive strength and also three specimens from each mix proportion were tested for compressive strength in the wet state. Similarly three specimens from each mix proportion, cured using open air drying in the shade, as the second curing methods were tested to ascertain their compressive strengths. Furthermore, three bricks from each mix proportion were submerged in water to check for percentage water absorption and dimensional stability. There was no sampling since all the specimens produced were used

In testing for compression, the brick cubes were placed between metal plates and placed between the centres of the plates of the compressive testing machine. The load was then applied axially and without shock till failure occurred. The maximum or failure loads of the bricks were then recorded. The crushing strength is calculated by the formula:

$$\text{Crushing strength (N/mm}^2\text{)} = \frac{\text{Maximum load at failure (N)}}{\text{Cross} - \text{sectional Area of brick (mm}^2\text{)}}$$

Source: Nigerian Industrial Standards (2004)

The average of the results of which was taken as the crushing strength of the blocks/bricks.

Test for Water Absorption was also carried out. The dry mass (M_1) was obtained by measuring the weight of the brick using the spring balance. In testing for water absorption, the dried blocks/bricks were then immersed completely in clean water at a temperature of 27 ±2°C for 4hours. The specimen was then removed and wiped off of any trace of water with a damp cloth and then weighed again (M_2). The weighing was done and completed within 3 minutes after removal from water.

Density was calculated from the data acquired from the compressive strength tests and the physical measurements of weight and size of the blocks. Dimensional stability was also determined by the differential length measurement obtained through the comparison of physical measurement of length carried out on the bricks before and after submersion in the water

Method of Data Analysis

The data collected was analysed using the mean as a statistical tool.

Results

The results for the study were obtained from the answers from the research questions.

Research Question 1

What is the mix ratio of binder to aggregate that will produce optimal compressive strength in composite bricks, using different curing methods?

Data for providing answers to research question 1 are presented in Table 1

Table 1: Mean compressive strengths of composite bricks of different mix ratios cured under different curing methods in 28 days

Curing method	Mix ratio	$\overline{X}_1$ Dry strength N/mm²	$\overline{X}_2$ Wet strength N/mm²	$\overline{X}g$ N/mm²
Sun	1:3:3	0.01	0.01	0.01
	1:2:4	0.01	0.01	0.01
	1:4:2	0.00	0.00	0.00
	2:1:1	0.01	0.01	0.01
	2:1:2	0.03	0.02	0.025
	2:2:1	0.03	0.01	0.02
	3:1:1	0.01	0.004	0.007
	3:2:1	0.02	0.01	0.015
	3:1:2	0.02	0.02	0.02
Room	1:3:3	0.01	0.01	0.01
	1:2:4	0.01	0.01	0.01
	1:4:2	0.00	0.00	0.00
	2:1:1	0.01	0.01	0.01
	2:1:2	0.02	0.02	0.02
	2:2:1	0.02	0.01	0.015
	3:1:1	0.01	0.01	0.01
	3:2:1	0.02	0.01	0.015
	3:1:2	0.02	0.02	0.02

Keys

$\overline{X}_1$ = Mean dry compressive strength of composite bricks at 28 days curing period.
$\overline{X}_2$ = Mean wet compressive strength of composite bricks at 28 days curing period
$\overline{X}_g$ = Grand mean of both wet and dry compressive strength of the composite bricks at 28 days period.
N/mm^2 = Newtons per square millimeter

Table 1 shows the mean compressive strength of composite bricks (comprised of cement, rice husk and sawdust) of mix ratios 1:3:3, 1:2:4, 1:4:2, 2:1:1, 2:1:2, 2:2:1, 3:1:1, 3:2:1, 3:1:2, at 28 days curing period, using both sun and room curing methods. The mean compressive strengths of the different mix ratios of the composite bricks, cured using sun drying method are 0.01N/mm^2 for ratio 1:3:3, 0.01N/mm^2 for ratio 1:2:4, 0.00N/mm^2 for ratio 1:4:2, 0.01N/mm^2 for ratio 2:1:1 0.025 N/mm^2 for ratio 2:1:2, 0.02 N/mm^2 for ratio 2:2:1, 0.01N/mm^2 for ratio 3:1:1, 0.015N/mm^2 for ratio 3:2:1, 0.02N/mm^2 for ratio 3:1:2 respectively. The highest mean compressive strength of 0.025N/mm^2 is obtained using a mixture ratio of 2:1:2 of composite bricks, cured under the sun.

Similarly, the mean compressive strengths of different mix ratios of composite bricks cured using room drying method are 0.01N/mm^2 for ratio 1:3:3, 0.01N/mm^2 for ratio 1:2:4, 0.00N/mm^2 for ratio 1:4:2, 0.01N/mm^2 for ratio 2:1:1, 0.02N/mm^2 for ratio 2:1:2, 0.015N/mm^2 for ratio 2:2:1, 0.01N/mm^2 for ratio 3:1:1, 0.015N/mm^2 for ratio 3:2:1, and 0.02 N/mm^2 for ratio 3:1:2 respectively. The greatest mean compressive strength of the composite bricks, cured using room drying method, is observed to be 0.02N/mm^2. The 0.02N/mm^2 strength is derived using mixture ratios of 2:1:2 and 3:1:2.

It is observed that the composite bricks attained their highest mean compressive strength of 0.025 N/mm^2 at the mixture ratios of 2:1:2 when cured in the sun. It is also observed that the composite bricks that are cured in the room attained their highest mean compressive strength using mixture ratios of 2:1:2 and 3:1:2. From these observations it can be seen that one mix ratio has given the highest mean compressive strength of the composite brick when cured in the sun, while two mix ratios have also shown attainment of highest compressive strength when cured in the room. It is seen that since the mixture ratio of 2:1:2 has shown the highest strength when cured in the sun, and mixture ratio of 2:1:2 and 3:1:2 have shown highest strength when cured in the room, it can be seen that it is only the mixture ratio of 2:1:2 that is common to the two curing methods. Since it is the mixture ratio of 2:1:2 that has given the highest mean compressive strength in both curing methods, it can be concluded that the mix ratio of binder to aggregate that would give the optimal compressive strength of composite bricks using different curing methods is ratio 2:1:2 (i.e. 2 parts of cement: 1 part of rice husk:2 parts of sawdust).

Research Question 2

What is the optimal wet and dry compressive strength of composite bricks of different mix ratio cured using different methods?
Data for providing answers to research question 2 are presented in Table 2

Table 2: Mean Wet and Dry Compressive Strength of Composite Bricks of Different Mix Ratios Cured Using Sun and Room Drying Methods

State of bricks	Mix ratio	$\bar{X}_S$ strength N/mm²	$\bar{X}_R$ strength N/mm²	$\bar{X}g$ N/mm²
Dry	1:3:3	0.01	0.01	0.01
	1:2:4	0.01	0.01	0.01
	1:4:2	0.00	0.00	0.00
	2:1:1	0.01	0.01	0.01
	2:1:2	0.03	0.02	0.025
	2:2:1	0.03	0.02	0.025
	3:1:1	0.01	0.01	0.01
	3:2:1	0.02	0.02	0.02
	3:1:2	0.02	0.02	0.02
Wet	1:3:3	0.01	0.01	0.01
	1:2:4	0.01	0.01	0.01
	1:4:2	0.00	0.00	0.00
	2:1:1	0.01	0.01	0.01
	2:1:2	0.02	0.02	0.02
	2:2:1	0.01	0.01	0.01

	3:1:1	0.004	0.01	0.007
	3:2:1	0.01	0.01	0.01
	3:1:2	0.02	0.02	0.02

Key

$\bar{X}s$= mean compressive strength of composite bricks cured in the sun at 28 days curing period.

$\bar{X}_R$ = mean compressive strength of composite bricks cured in the room at 28 days curing period.

$\bar{X}g$ = Grand mean compressive strength of the two curing methods.

N/mm^2= Newtons per square millimeter

Table 2 shows the mean dry and wet compressive strengths of composite bricks of different mix ratios cured using sun and room drying curing methods. The mean compressive strengths are taken at 28 days curing period. The mean dry compressive strengths of composite bricks, cured in the sun, as shown in table 2 are 0.01N/mm^2, 0.01N/mm^2, 0.00N/mm^2, 0.01N/mm^2, 0.03N/mm^2, 0.03N/mm^2, 0.01N/mm^2, 0.02N/mm^2 and 0.02N/mm^2 for mixture ratio of 1:3:3, 1:2:4, 1:4:2, 2:1:1, 2:1:2, 2:2:1, 3:1:1, 3:2:1, and 3:1:2 respectively. The highest mean dry compressive strength of composite bricks of 0.03N/mm^2 is attained using mix ratios of 2:1:2 and 2:2:1. Similarly, the mean wet compressive strength of composite bricks, cured in the sun is shown in Table 2 as 0.01N/mm^2, 0.01N/mm^2, 0.00N/mm^2, 0.01N/mm^2, 0.02N/mm^2, 0.01N/mm^2, 0.004N/mm^2, 0.01N/mm^2, and 0.02N/mm^2 respectively for mixture ratio 1:3:3, 1:2:4, 1:4:2, 2:1:1, 2:1:2, 2:2:1, 3:1:1, 3:2:1, and 3:1:2. The highest mean wet strength was 0.02N/mm^2 attained at mix ratios 2:1:2 and 3:1:2.

From Table 2, again it can be seen that the mean dry compressive strengths of composite bricks, cured in the room, are 0.01N/mm^2 for ratio 1:3:3, 0.01N/mm^2 for ratio 1:2:4, 0.00N/mm^2 for ratio 1:4:2, 0.01 N/mm^2 for ratio 2:1:1, 0.02 N/mm^2 for ratio 2:1:2, 0.02N/mm^2 for ratio 2:2:1, 0.01N/mm^2 for ratio 3:1:1, 0.02N/mm^2 for ratio 3:2:1 and 0.02N/mm^2 for ratio 3:1:2 respectively. The greatest mean dry compressive strength attained is 0.025 N/mm^2, derived at ratio 2:1:2 and 2:2:1. Similarly, the mean wet compressive strengths of composite bricks cured in the rooms are 0.01N/mm^2 for ratio 1:3:3, 0.01 N/mm^2 for ratio 1:2:4, 0.00 N/mm^2 for ratio 1:4:2, 0.01N/mm^2 for ratio 2:1:1, 0.02N/mm^2 for ratio 2:1:2, 0.01N/mm^2 for ratio 2:2:1, 0.01N/mm^2 for ratio 3:1:1, 0.01N/mm^2 for ratio 3:2:1 and 0.02N/mm^2 for ratio 3:1:2. The greatest attained wet strength here is 0.02N/mm^2 achieved with mix ratios of 2:1:2 and 3:1:2.

The data in Table 2 further shows that the grand mean dry strength of the composite bricks are 0.01N/mm^2, 0.01N/mm^2, 0.00N/mm^2, 0.01N/mm^2, 0.025N/mm^2, 0.025 N/mm^2, 0.01N/mm^2, 0.02N/mm^2 and 0.02N/mm^2 for mix ratios of 1:3:3, 1:2:4, 1:4:2, 2:1:1, 2:1:2, 2:2:1, 3:1:1, 3:2:1 and 3:1:2 respectively. This shows the highest strength of 0.025N/mm^{2}derived at mix ratios of 2:1:2 and 2:2:1. In like manner, the grand mean wet strength of the composite bricks of the various mix ratios is 0.01N/mm^2, 0.01N/mm^2, 0.00N/mm^2, 0.01N/mm^2, 0.02N/mm^2, 0.01N/mm^2, 0.007N/mm^2, 0.01N/mm^2 and 0.02N/mm^2. The highest wet compressive strength of 0.02N/mm^2 is derived using mix ratios 2:1:2 and 3:1:2. The optimal wet compressive strength of composite bricks therefore is 0.02N/mm^2 derived using mix ratios 2:1:2 and 3:1:2. The optimal dry compressive strength of composite bricks is 0.025N/mm^2 also derived at the mixture ratios of 2:1:2 and 2:2:1. It is also observed that the common mix ratio that attains greatest strength in the two curing methods is ratio 2:1:2. This means that mix ratio 2:1:2 would produce the optimal strength in composite bricks.

Research Question 3

What is the curing method that will produce the optimal compressive strength in composite bricks using different mix ratios?
Data for providing answers to research question 3 are presented in Table 1

Observations of Table 1 show that the grand mean compressive strength of the composite bricks, cured in the sun are 0.01N/mm^2, 0.01N/mm^2, 0.00N/mm^2, 0.01N/mm^2, 0.025N/mm^2, 0.02N/mm^2, 0.007N/mm^2, 0.015N/mm^2 and 0.02N/mm^2 for mixture ratios of 1:3:3, 1:2:4, 1:4:2, 2:1:1, 2:1:2, 2:2:1, 3:1:1, 3:2:1 and 3:1:2 respectively. The highest strength attained by composite bricks when cured in the sun therefore is 0.025N/mm^2, derived at mix ratios of 2:1:2. Table 1 also shows the compressive strengths of composite bricks cured in the room, with grand means of 0.01N/mm^2, 0.01N/mm^2, 0.00N/mm^2, 0.01N/mm^2, 0.02N/mm^2, 0.015N/mm^2, 0.01N/mm^2 0.015N/mm^2, and 0.02N/mm^2 for the respective mix ratios. The highest strength attained by the composite bricks cured in the room is 0.02N/mm^2. It is attained using mix ratios of 2:1:2 and 3:1:2.

These observations have shown that the highest compressive strength attained by the composite bricks when cured in the sun is 0.025N/mm^2. Similarly, the highest strength attained by the same bricks when cured in the room is also 0.02N/mm^2. This means that the sun curing method produced highest compressive strength in respect of composite bricks.

DISCUSSION OF FINDINGS

The findings on composite (Cement: Rice husk: Sawdust) bricks shows that the highest mean dry compressive strength of composite bricks was 0.025 N/mm^2 derived at the mix ratio of 2:1:2 and 2:2:1. The highest mean wet compressive strength of composite bricks was found to be 0.02 N/mm^2 using the mix ratio of 2:1:2 and 3:1:2. This also means that both curing methods produced optimal compressive strength.

In search of literature for this study, no literature was seen by this researcher where rice husk was combined with sawdust to produce bricks or concrete. Since no similar study using similar constituents of composite is seen, this study cannot be compared. However the compressive strength derived is less than the stipulated standard for sandcrete bricks and blocks as stated by NIS (2004) and NBC (2007). The composite bricks have not attained similar compressive strength to sandcrete blocks because sand which is the major constituent of sandcrete blocks is more dense, less compressible and stronger than both rice husk and sawdust. Curing of sandcrete blocks also differs slightly from the curing of the bricks in the study as sandcrete blocks once moulded are placed directly under the sun and watered periodically.

IMPLICATIONS OF THE STUDY

This study set out to see if it would be possible to meaningfully utilize rice husk and sawdust for building purposes. This was with the aim of providing local materials for building, alleviating evacuation problems for rice and saw millers, reducing degradation of the soil, reducing health hazard, as well as provision of heat insulation materials which would have added to energy efficiency in the house. However the results of this study have serious implications.

Furthermore, the mixture of these materials – rice husk and sawdust into a composite has even resulted to lower strength. This again shows that these materials cannot be used in this un-burnt form to produce bricks than can be of structural relevance. Other additives may therefore be used with it. However, embarking on this research is a show of sensitivity to the need of the community, which is ethical and also imperative from a delivery perspective.

CONCLUSION

From the findings of this study, the following conclusions were reached. The highest mean compressive strength of composite bricks attained was 0.025 N/mm^2. This was attained using the mixture ratio of 2:1:2 (cement: rice husk: sawdust) and using the two curing methods. This optimal compressive strength attained by the composite bricks is also less than the recommended minimum strength of sandcrete bricks to be used for walling. The bricks therefore cannot be used for load bearing walls.

RECOMMENDATIONS

Based on the findings of this study, the following recommendations are made:

1. The possibility of using rice husk in its natural form (un-burnt) should also be explored so that the heaps of wastes around the country will be reduced.
2. Rice husk and sawdust are light materials, therefore they should be used with other materials like sand and clay to reduce the weight of walling materials and also provide both sound and thermal insulation to the house, especially in the tropical region.
3. Since termites do not attack rice husks and sawdust when heaped on milling sites, they should therefore be used to reduce cases of termite attack on buildings.
4. Efforts should be made by government and individuals to utilize Rice husk and sawdust, to generate power or as complement to cement just as other countries have done.
5. Evacuation of waste products in our country is a problem. Heaps of rice husk and sawdust are seen at various milling sites. Government should therefore build industries to convert this waste to useful items thereby converting waste to wealth.

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