Education

Characteristics of earth bricks produced with partial replacement of laterite with plastic, ceramic tiles and glass for sustainable management of the environment

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Abstract

Solid waste material like glass, ceramic tiles and plastic form a major component of solid waste in Nigeria and other countries. The 3R-Method – Reuse, Recycle and Redo can be adopted after its usage. A large percentage is disposed to the land fill which constitutes environmental pollution.

To safeguard the environment, many efforts are being made for the recycling of different types of solid waste with the aim of utilizing them as construction materials. This research discusses the characteristic of earth brick produced with 100% laterite and produced by partially replacing laterite at 0%, 5%, 10%, 15% and 20% separately with plastic, crushed ceramic tiles and crushed glass materials for sustainable management of the environmental waste.

A total of 180 earth brick of size 115mm x 215mm x 115mm were produced.

The compressive strength of earth brick with 100% laterite at 28 days was 1.89 N/mm^2, which was not far from the compressive strength with 5 % replacement of crushed glass and ceramics having values of 1.86 N/mm^2 and 1.75 N/mm^2 respectively and that with plastic replacement at 5% which had a maximum value of 0.95 N/mm^2 after 28 days.

From the result It was deduced that there was a reduction in compressive strength of plastic, crushed glass and ceramic as their percentage increased, but for plastic as the number of days for air curing increased the compressive strength reduced for all percentage replacement unlike for crushed glass and ceramics where as the number of days for air curing increased from 7 days to 28 days the compressive strength also increased.

It can be recommended that bricks with up to 5% replacement of glass and ceramic which had compressive strength of approximate 2.0 N/mm^2 can be used for earth brick industry with a view to reduce the environmental waste.

Keywords: laterite, solid waste material, crushed glass and ceramics, plastic, compressive strength

1. Introduction

According to Yusuf, 2009, the cost of cement has continued to rise causing a subsequent rise in cost of building and construction materials at large. The need for locally manufactured building materials can hardly be overemphasized because there is an imbalance within the demands for housing and expensive conventional building materials coupled with the depletion of traditional building materials. To address this situation, attention has been focused on low-cost alternative building materials.

It has been found that certain waste materials produced by different industrial processes can be very useful in construction; they can provide the required properties, strength and safety (Dousova, 2017) [7]. These materials, if released into the environment and atmosphere, can severely harm human health and create pollution. Therefore, the best way to protect the environment and human health from such waste materials is to reuse them in construction, because these are waste materials, hence, there is no cost for manufacture which invariably will lead to reduction in cost of construction.

According to Adoga, 2008 [1], laterite is a highly weathered material rich in secondary oxides of Iron. It is nearly devoid of base and primary Aluminum Silicates but, may contain large amount of quartz and kaolinite which are soil types rich in Iron and Aluminum, formed in tropical regions. Nearly all laterites are rusty red in color because of iron oxide they develop by intensive and long-lasting weathering of the underlying parent rock (Kamseu *et al.*, 2007) [8].

Laterites can either be soft and easily broken into smaller pieces or firm and physically resistant (Mu'azu, 2009) [9].

According to Romualdo *et al.*, 2005 [10] the possibilities of using the granite sawing waste as alternative ceramic materials in the production of ceramic bricks and tile. Samples were uniaxially pressed and then fired at 850°C. Results for tests on ceramic compositions showed that samples with (10-30) % granite waste had physical and mineralogical characteristics similar to those of conventional ceramic raw materials. Ceramic composition with the addition of those waste produced water absorption lower than 3%, it was proven that recycling sludge in the production of ceramic bricks and tiles was feasible.

In Nigeria, most industrial and domestic activities are associated with significant amounts of non-biodegradable solid waste, which include a wide range of waste plastic and ceramics. As a result, the proliferation of solid waste has become one of the major environmental concerns in the world. The generation and disposal of waste is an intrinsic part of any developing or industrial society. According to Akinwale, 2005 [2], waste increases in a geometrical progression while collection and disposal increases at an arithmetical progression.

In the last decade, ceramics have been explored and used to manufacture products such as table, roofing tiles, clay pipe and bricks. According to Coletti *et al.*, 2016 [6], several issues related to the ceramics in the current era. The main issue that worries the industries, environment, and the researcher is the impact of the ceramic waste and its products on the environment.

According to Coletti, 2016 [6], waste ceramics have high potential to be an alternative brick material, leading to a reduction in the environmental impact.

According to Christian, 2003 in his paper titled "Glass concrete", recognizing the need for the concrete industry to comply with the fundamental goals of sustainable development will reduce its impact of waste glass on the environment. The use of crushed glass as a concrete aggregate would reduce the amount of solid waste doomed for landfill disposal.

Traditionally, plastics are very stable and not readily degraded in the ambient environment. As a result, environmental pollution from synthetic plastics has been recognized as a major problem.

Plastic waste materials consist of surplus, obsolete, broken, old plastic furniture, different household plastic materials, equipment's, anti-static packaging materials and devices made of plastic. These polymer wastes are almost non-degradable in the natural environment even after a long period of exposure.

2. Materials and Method

2.1 Materials

The materials and equipment that were used in this study includes;

a) Laterite

Laterite samples were taken from College of Animal Science (COLANIM) farm at the Federal University of Agriculture Abeokuta, Ogun State, Nigeria.

Fig 1: Laterite

b) Recycled plastic

Samples of the waste granulated plastic particles were collected from a plastic collection company near Ojota dumpsite in Lagos, Lagos State Nigeria. The samples were thoroughly cleaned before use to ensure that the debris and other forms of impurities that could alter or influence the hydration and bonding of cement water paste are removed.

Fig 2: Recycled plastic

c) Crushed glass

Waste Glass Powder was obtained from different glass which was formed by grinding. Grinding was done by hammer milling machine which was made for grinding. The different glass vessels, window glasses, cool-drinks bottles, etc. were the materials picked from surroundings and transported to the engineering workshop for breaking into smaller pieces by the use of mechanical activities. The samples were thoroughly cleaned before use to ensure that the debris and other forms of impurities that could alter or influence the hydration and bonding of cement water paste were removed.

Fig 3: Crushed glass

d) Ceramic Tiles

The waste and unwanted ceramics were obtained from a tile shop at Oke-yeke Abeokuta. A Sample of the collected ceramic is shown in figure 4. The figure shows the crushed ceramics after crushing. Ceramic waste was obtained in form of large pieces which required crushing. This waste was generated during the on-loading and off-loading of ceramic tiles.

Fig 4: Ceramic tiles

e) Cement

CEM 1- 42.5R grade limestone Portland cement was used in order to stabilize the soil.

2.2 Method

a) Test of Materials

Tests carried out on the concrete constituents include particle size distribution, moisture content, specific gravity, compaction test, Atterberg Limits, compressive test.

b) Specific gravity

The specific gravity of the quarry dust and the expanded polystyrene were carried out according to the standard of (ASTM D 854-00) standard test for specific gravity of soil solids by water pycnometer. The specific gravity was calculated using the equation below;
Specific gravity,

$$Gs = \omega o \omega o + (\omega a - \omega b) \quad \text{eqn 1}$$

where,
ωo = weight of sample of oven-dry soil
ωa = weight of pycnometer filled with water + sample
ωb = weight of pycnometer filled with water

c) Plasticity Index (PI)

This is a measure of the plasticity of a soil the plasticity index is the size of the range of water content where the soil exhibits properties. It is the difference between the liquid limit and plastic limit (PI = LL - PL). Soil with a high PI tend to be clayey with those with lower PI tend to be silt.

d) Compaction Test

Proctor compaction test
This test covers the determination of the dry density of soil passing through 4.75mm test sieve. It was compacted in such a specific manner over a range of moisture content. The compaction type will be that of the modified AASHTO.

e) Natural moisture content

This is to determine the amount of moisture present in the sample before the sample is contaminated. The moisture content of soil was calculated as percentage of the ratio of the mass of water of dry soil.

The Moisture content value =

$$\text{Moisture content value} = \frac{M2-W1}{M3-M1} \text{x}100 \text{.........equation 2}$$

Where,
M1 = mass of empty specimen container (g)
M2 = mass of empty specimen container plus moist soil (g)
M3= mass of empty specimen container plus dried soil (g)

f) Compressive Strength Test

The 180 Nos of concrete bricks 115mm x 215mm x 115mm were produced in accordance with (BS 1924 – 1990 part 1 & 2), air cured and tested at 7, 14, 21, and 28 using Compressive Testing machine at Federal Civil Engineering building University of Agriculture.
The compressive strength was calculated using the equation below.

$$\sigma c = F/A \quad \text{.............................equation 3}$$

Where:
σc = Compressive strength (N/mm^2)
F = Failure load (N)
A = Area of concrete cube-face (mm^2)

Fig 5: Compressive strength test of brick

g) Earth Brick Molding

The Hydraform brick making machine MODEL M8DE MFD 2014 was used for making brick samples used for this research. After the laterite had been mixed with plastic, crushed glass and ceramics at the required percentage and water added to the aggregate, the upper arm of the machine was raised with the aid of a hydraulic gear revealing the form chamber, the mixture from mixed batch by weight was carefully poured into the chamber. Compression was carried out by both of the lower and upper arm with a pressure of 2200Psi (150bar) after which the upper arm was again lifted and the lower arm raised to lift the molded brick out of the chamber.

Fig 6: Mixing solid waste material with laterite

Fig 8: Brick production

Fig 7: Pouring waste brick material into hydrofoam brick making machine

Fig 9: Air curing of produced bricks

3. Results and Discussion

3.1 Physical Properties of Lateritic soil

Table 3.1: Index Properties of Lateritic Soil

Lateritic soil	
Natural moisture context	19.4%
Specific gravity	2.66
Liquid limit	51.00%
Plastic limit	36.0%
Plastic index	14.97%
Maximum dry density	1.6 (g/cm^3)
Optimum moisture content	24.4%

3.2 Compressive Strength

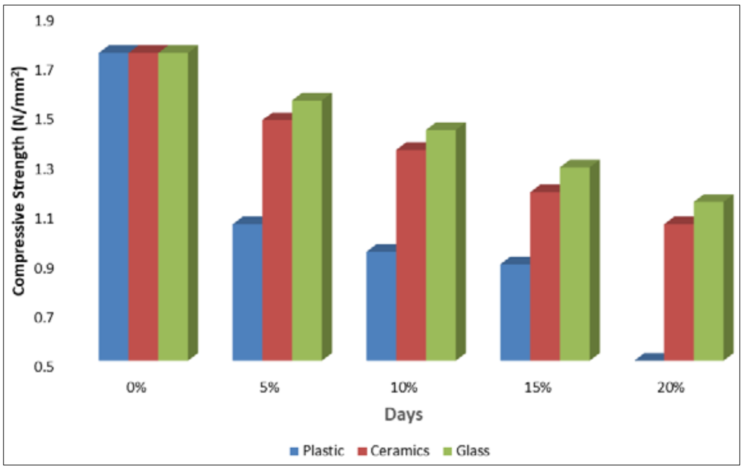

Fig 10: Seven days Compressive Strength of Laterite with plastic, ceramic and glass

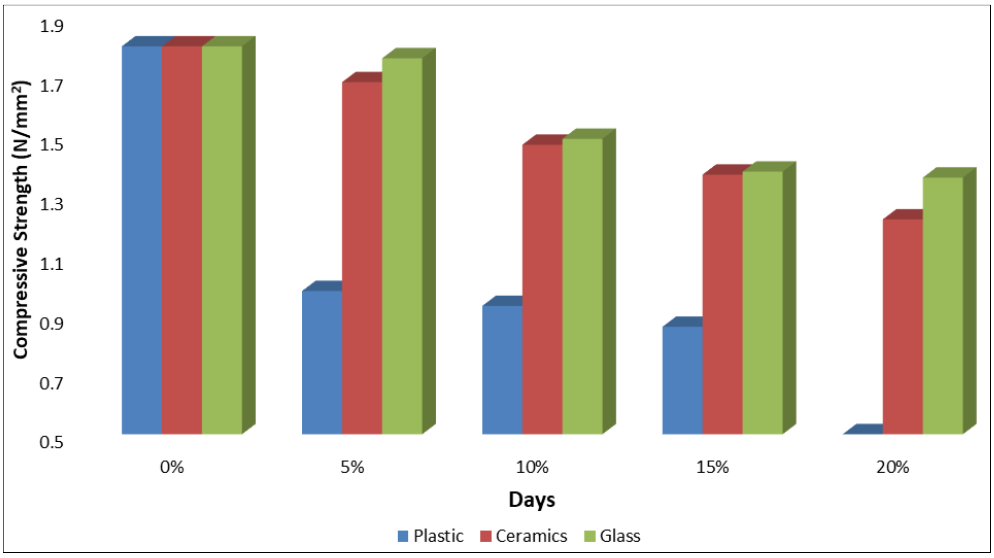

Fig 11: Fourteen days Compressive Strength of Laterite with plastic, ceramic and glass.

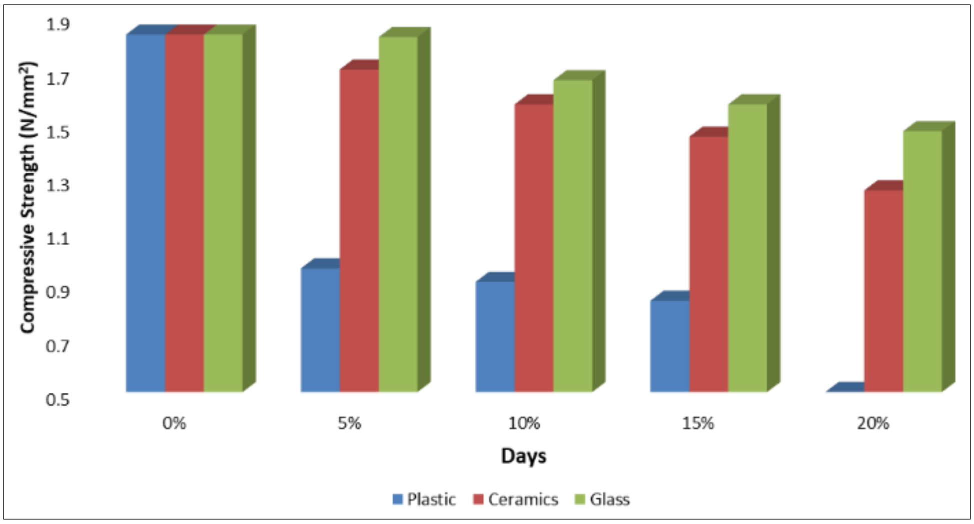

Fig 12: Twenty-One days Compressive Strength of Laterite with plastic, ceramic and glass

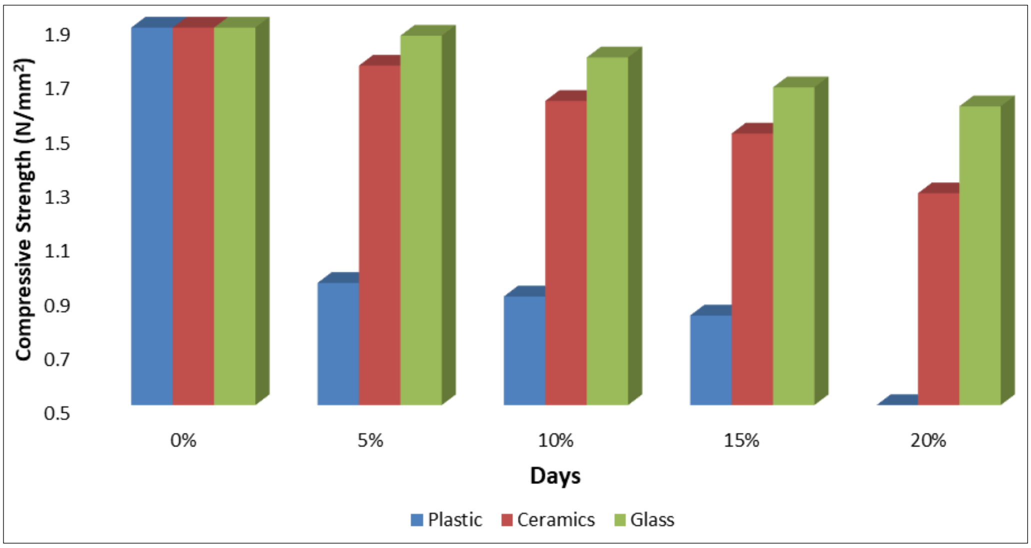

Fig 13: Twenty-Eight days Compressive Strength of Laterite with plastic, ceramic and glass.

It can be deduced that fig 10 to fig 13 show the trend at which laterite was partially replaced with plastic, ceramic and glass. The compressive strength result shows that plastic performed the least amongst the three solid waste material having compressive strength values far below the control of 1.89 N/mm^2.

Waste glass performed the best amongst the three solid waste material, followed by ceramics.

The optimum percentage replacement of laterite with plastic, ceramic and glass was 5% at all curing days from 7, 14, 21 and 28 days.

The optimum percentage replacement was 5% at 28 days for crushed glass having a compressive strength value of 1.86 N/mm^2.

4. Conclusion

From the research findings, the following conclusions can be made: the strength of bricks consisting of solid waste plastics, crushed glass, and ceramic which partially replaced laterite seemed to be lower than the control having laterite 100 % without any solid waste material.

Compressive strength of bricks at 5% replacement of glass and ceramics had the optimum compressive strength at 1.86 N/mm^2 and 1.75 N/mm^2 respectively at 28 days of open air curing which was slightly lower than the control strength of the earth brick having a value of 1.89 N/mm^2. This indicated that waste glass and ceramic particle can be used as a partial replacement of laterite up to 5% and can produce a good strength because the maximum strength obtained at 28 days strength for both samples were within the minimum strength requirement recommended for construction of low-rise buildings. Bricks produced by partially replacing laterite with plastics reduced as the days of curing increased from 1.05 N/mm^2 at 7 days to 0.95 N/mm^2 at 28 days but it followed the same trend that affirms the fact that laterite up to5 % was the best percentage replacement of laterite with solid waste at all days of curing.

Hence, the use of both ceramic and glass waste in construction industry, will allow sustainable development.

The advantages of been both economical and helpful in controlling the environmental pollution makes the use of solid waste in construction a very necessary alternative to building material.

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