EVALUATING PHYSICAL CHARACTERISTICS OF BRICKS PRODUCED USING FLY ASH FOR SUSTAINABLE CONSTRUCTION INDUSTRY IN NIGERIA

Lawal Hussaini MUSA*[1], Ibrahim Zuntu ADAMU[1], Yusuf ABDULLAHI[2]

[1]Department of Building Technology, School of Environmental Studies, Nuhu Bamalli Polytechnic, Zaria, Nigeria
[2]Department of Quantity Surveying, School of Environmental Studies, Nuhu Bamalli Polytechnic, Zaria, Nigeria

Abstract: Building construction is one of the most resource-intensive sectors, as well as creating a high impact on the environment. The traditional clay bricks are not eco-friendly, because of the embodied carbon in them due to the high primary energy used. Consequently, this study evaluates physical characteristics of bricks produced using fly ash. The methods of this research involve using laboratory tests of the physical properties of the fly ash. The study found that Class F fly ash particles are generally finer compared to class C fly ash. It was concluded that the bricks made from Fly Ash are relatively consistent in quality and shape when tested, lightweight, have lower thermal conductivity, thermal insulations, relatively good strength material, good fire resistance and can be moulded at room temperature. The study recommends creating awareness on the use of fly ash for brick production as it promotes acceptance among potential customers in the construction industry.

Keywords: Construction, Fly- Ash, Industry, Physical-Characteristics.

1. INTRODUCTION

Fly Ash is an environmental waste pozzolan substance containing aluminous and siliceous material that forms cement in the presence of water (Lufan et al. 2022; Amos et al. 2020; Munoz et al. 2020; Daly et al. 2020; Slimanou et al. 2019). Fly ash is eco-friendly as they are made of waste materials that come from the combustion of coal in thermal power plants (Lufan et al. 2022; Amos et al. 2020). Studies highlighted that the traditional clay bricks are not eco-friendly, the embodied carbon in them due to the high primary energy used is very high and contributes to irreversible damage to agriculture (Slimanou et al. 2019; Gokarakonka et al. 2018).

Numerous studies revealed that, when mixed with lime and water, fly ash forms a compound like Portland cement and when used in mixed concrete improves the strength and makes it easier to pump (Lufan et al. 2022; Amos et al. 2020; Munoz et al. 2020; Daly et al. 2020; Slimanou et al. 2019).
Studies highlighted that environmental waste fly ash was used in different weight percentage ratios of 10%, 20% and 100% to substitute clay. The increase of the fly ash content in the brick-making process proved to significantly reduce the environmental load among the selected impact categories (Amos et al, 2020; Munoz et al. 2020; Daly et al. 2020; Gokarakonka et al. 2018).

Many studies further revealed a significant prospect of substituting fly ash in bricks productions, pavement and road construction project that deals with large concrete in the construction industry (Lufan et al. 2022; Amos et al. 2020; Munoz et al. 2020; Daly et. al. 2020; Slimanou et al. 2019; Gokarakonka et al. 2018).

Production of bricks with Fly Ash offers Prospect such as durability, relatively economical, availability, thermal insulations, relatively high strength, fire resistance, heterogeneous, and can be moulded at room temperature (Lufan et al, 2022; Companhoa et al. 2021; Amos et al. 2020; Munoz et al, 2020; Daly et al. 2020; Slimanou et. al.

2019). Studies exploring circular economy practices in the context of the brick industry have been lacking in amplitude (Lufan et al. 2022; Companhao et al. 2021; Amos et al. 2020; Munoz et al. 2020; Daly et al. 2020; Slimanou et al. 2019). Slimanou et al. (2019), and Gokarakonka et al. (2018) highlighted that traditional clay bricks are not eco-friendly, the embodied carbon in them due to the high primary energy used is very high and contributes to irreversible damage to agriculture and the environment. Resource efficiency in the construction industry coupled with the rising demand for bricks to meet the housing needs in developing countries can lead to a cleaner environment and greener agricultural land (Amos et al, 2020, Munoz et al. 2020, Daly et al. 2020, Slimanou et al. 2019, Gokarakonka et al. 2018). However, Pollution caused by clay bricks is extremely detrimental and leads to topsoil loss which can cause irreversible damage to the environment and even affect food security in the long run (Lufan et al. 2022; Companhao et al. 2021; Amos et al, 2020; Munoz et al; 2020; Daly et al. 2020; Edeh et al. 2020; Slimanou et al. 2019; Gokarakonka et al, 2018).

Thus, the Identification and assessment of fly ash as a substitute for clay in brick production will be more effective if physical characteristics are tested for economic sustainability for effective uptake and sustainability.

Attempts were not made (Amos et al. 2020; Munoz et al. 2020; Daly et al. 2020; Slimanou et al. 2019; Gokarakonka et al. 2018) to ascertain the physical characteristics of fly ash from Sokoto, Kogi, Benue cement factory in the state Nigeria for bricks production and for effective uptake and acceptance in Nigeria construction sector. However, previous studies were restricted to the identification of fly ash as a substitute for clay only (Lufan et al. 2022; Amos et al, 2020; Munoz et al, 2020; Daly et al. 2020; Slimanou et al. 2019; Gokarakonka et al. 2018). Thus, the Identification of FLY ASH as a substitute for clay in brick production are worthless without effectively evaluating the strength of physical characteristics of the Fly Ash bricks for brick production, This creates a gap in an effort towards effective uptake for using Fly Ash as a substitute to clay for bricks production in the Nigerian Construction industry. Therefore, research is necessary to be carried out to evaluate the strength of physical characteristics of Fly Ash from Sokoto, Obajana and Benue cement factories in Nigeria for brick production for proper uptake and acceptance.

Therefore, this study aims to evaluate the physical characteristics of Fly Ash from Sokoto, Kogi, and Benue cement factories in the state of Nigeria for brick production and effective uptake and acceptance.

MATERIALS AND METHODS

This section discussed materials and methods employed in this study. Thus, tests for the experiment were conducted in the laboratory of the Department of Civil Engineering Ahmadu Bello University Zaria, Department of Building Nuhu Bamalli Polytechnic, Zaria and NARICT Zaria. All tests were conducted in conformance with British standards. To achieve the study objectives, the researcher used experimental research design in determining the different petrophysical compositions of Fly Ash for brick production.

Materials

The samples of Class F and C fly ash were obtained in reasonable quantities at Sokoto cement factory, Kogi and Benue state Nigeria.

Apparatus/Materials used in Digestion process for chemical test of the fly ash are as follow: Beakers 50/25Ml, Conical flask, Volumetric flask, weighing balance, Fowl

paper, Masking tape, Pen marker, Solvent**HcL + hn03, Hot plate, Hand Glove, Nose mask, Lab coat, Fume Hood cupboard, distilled water, filter paper, Funnel, Samples Bottle, Washing bottle, Spatula, Syringe 5cc/10cc.

Methods

The methods of this research involve using laboratory tests of both physical and chemical properties of the fly ash as explained below.

Chemical Test

The sample of fly ash class F and C was taken to the chemical laboratory at the National Research Institute for Chemical Technology (NARICT) Zaria for a chemical test using an AAS machine. Principles of AAS Model AA 6800 Shimadzu 0.02-0.25 up to 0.5ml was aspirated to the nebulizer via nebulizer rubber to the burner, then flame photometer was also burning the aspirated drop of digested samples to vapour within the mobile phase of the AAS Machine. In the process detector also directly captured the concentration in the vapor in PPM as well and the beam of the cathode lamp also works with the detector. Proceeding to the system as it is saved to monitor for Data inserted as sample names and client names to print out the command of the result of chemical properties of the samples F& C Fly Ash.

Physical Test

A sampling fly ash (coal) class F and C. sample preparations, C Brick manufacturing: fly ash mixed manually in a pan with water in varying proportion – polythene sheet for drying and small moulding machine producing prism of average size; Length=100mm, W=100mm, H= 100mm will be used, water absorption capacity (W=M2-M1/M1 x 100), F. Ammonium nitrate corrosion resistance. The fly ash material was properly prepared and mixed with clean water and the specific gravity was approximately 50 to 100g of dried sample.



Plate 1. AAS Machine: used for testing chemical properties of Fly Ash.
Source: (2022) Laboratory test NARICT Zaria.



Plate 2. Sample of Fly Ash. **Source:** (2022) Sokoto cement factory



Plate 3. Fly Ash sample to be mixed with water for casting cubes
Source: (2022) Concrete Laborotory NBPZaria



Plate 4. Sample of Fly ash brick cast after 28 days of curing
Source: (2022) Concrete Laborotory NBPZaria



Plate 5. Machine Crushing of Fly Ash cubes at 1 & 3 days,
Source: (2022) Concrete Laborotory NBPZaria



Plate 6. Measuring scale for weighing fly ash bricks
Source: (2022) Concrete Laborotory ABU -Zaria



Plate 7: Machine Crushing of Fly Ash bricks at 7, 14 & 28 days. **Source:** (2022) Civil Eng. Concrete Laborotory ABU- Zaria.

RESULTS AND DISCUSSION

Tables 1 to 5 present the results obtained in the laboratory test of the physical characteristics of fly ash. However, the results indicate the physical characteristics test of fly ash cubes at 24 hours (1 day), 72 hours (3 days), then 7 days, 14 days and 28 days.

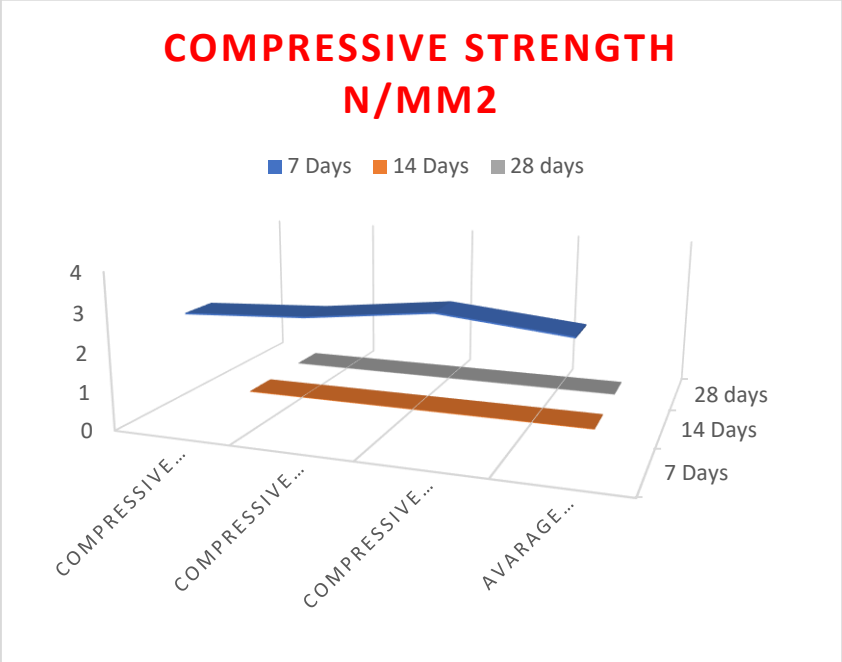

Table 1. Testing the Compressive Strength of Fly Ash

SN	Curing age	Weight of fly ash concrete cubes(kg)	Cross Sectional area (mm^2)	Failure load (kn)	Compressive strength (N/mm^2)
1	1day	0.5	100 x100	20	2.0
2	1day	0.5	100 x 100	15	1.5
3	1day	0.5	100 x 100	15	1.5

Source: Fieldwork NBP Zaria Laboratory test (2022)

Table 1. shows the results of the compressive strength test of fly ash cubes at 24 hours (1 day), the weight of the cubes was 0.5kg, with a cross-sectional area of 100 x 100mm^2, the cube's average failure load was 16.67kn while the average compressive strength was 1.7N/mm^2.

Table 2. Testing the Compressive Strength of Fly Ash

SN	Curing age	Weight of fly ash concrete cubes(kg)	Cross sectional area (mm^2)	Failure load (kn)	Compressive strength (N/mm^2)
1	3days	0.8	100 x100	20	2.0
2	3days	0.8	100 x 100	25	2.5
3	3days	0.8	100 x 100	23	2.3

Source: Fieldwork NBP Zaria Laboratory test (2022)

Table 2. shows the results of the compressive strength test of fly ash cubes at 72 hours (3 days), the weight of the cubes was 0.5kg, the cross-sectional area was 100 x 100mm^2, the

cube's average failure load was 22.67kn while the average compressive strength was 2.27N/mm^2

Table 3. Testing the Compressive Strength of Fly Ash

SN	Curıng age	Weıght of fly Ash concrete cubes(kg)	Cross sectıonal area (mm^2)	Faılure load (kn)	Compressıve strength (N/mm^2	Average compressıve strength (N/mm^2)
1	7days	1.60	100 x100	29.0	2.9	3.1
2	7days	1.60	100 x 100	31.0	3.05	3.1
3	7days	1.60	100 x 100	34.0	3.4	3.1
Average Compressive strength= 9.3/3 = 3.1 N/mm^2						

Source: Fieldwork ABU-Zaria Laboratory test (2022).

Table 3. Indicate the results of the compressive strength test of fly ash cubes at 7 days, the weight of cubes was 1.60kg, the cross-sectional area was 100 x 100mm^2, the cube's average failure load was 31.33kn while the average compressive strength was 3.1 N/mm^2.

Table 4. Testing the Compressive Strength of Fly Ash

SN	Curıng age	Weıght of fly ash concrete cubes(kg)	Cross sectıonal area (mm^2)	Faılure load (kn)	Compressıve strength (N/mm^2)
1	14days	1.65	100 x100	30	3.0
2	14days	1.68	100 x 100	31	3.05
3	14days	1.59	100 x 100	34	3.4

Source: Fieldwork ABU-Zaria Laboratory test (2022).

Table 4. Also, shows the results of the compressive strength test of fly ash cubes at 14 days, the average weight of cubes was 1.64kg, with a cross-sectional area of 100 x 100mm^2, the cube's average failure load was 31.67kn while the average compressive strength was 3.15N/mm^2. The results show there is no significant difference between 7 days and 14 days of curing.

Table 5. Testing the Compressive Strength of Fly Ash

SN	Curing age	Weight of fly ash concrete cubes(kg)	Cross sectional area (mm^2)	Failure load (Kn)	Compressive strength (N/mm^2)
1	28days	1.68	100 x100	47	4.7
2	28days	1.67	100 x 100	52	5.2
3	28days	1.77	100 x 100	55	5.5

Source: Fieldwork ABU-Zaria Laboratory test (2022)

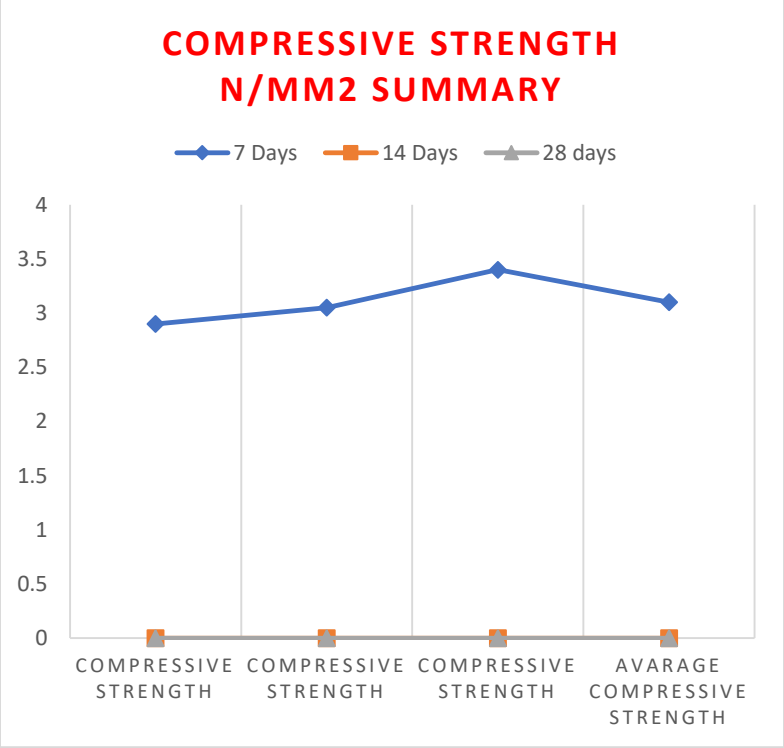

Table 1. shows the results of the compressive strength test of fly ash cubes at 28 days, the average weight of the cubes was 1.70kg, with a cross-sectional area of 100 x $100mm^2$, and the cube's average failure load was 51.33kn while the average compressive strength was $5.13N/mm^2$. Therefore, the physical characteristics: of fly ash Class F and C fly ash, used in this research brick production, can vary depending on the specific properties of the fly ash and the manufacturing processes involved. Here are some physical properties of the fly ash:

Class F Fly Ash Testing Result Discussion

Particle Size: Class F fly ash particles are generally finer compared to class C fly ash. They typically have a higher percentage of particles passing through a 45-micron sieve.

Fineness: Class F fly ash exhibits high fineness with a typical specific surface area ranging from 400 to 600 square meters per kilogram (m'2/kg). this high fineness contributes to improved workability and pozzolanic reactivity in brick production.

Colour: Class F fly ash is usually grey to dark grey in colour ranging from light grey to

dark grey. The exact colour can depend on the specific coal sources and combustion conditions.

Moisture contents: The moisture contents of Class F fly ash are typically low, often less than 3%. Low, moisture contents facilities handling and storage of the fly ash.

Class C Fly Ash Testing Results Discussion.

Particle size: Class C fly ash particles are generally coarser compared to class F fly ash. They typically have a lower percentage of particles passing through a 45-micron sieve.

Fineness: Class C fly ash exhibits moderate to high fineness, with a specific surface area ranging from 300 to 500'2/kg. the fineness contributes to its reactivity and pozzolanic properties during brick production.

Colour: Class C fly ash can vary in colour, ranging from grey to tan or brown depending on the coal source and combustions.

Moisture Contents: the moisture contents of Class C fly ash are like Class F fly ash, typically less than 3%.

Therefore, both the Class F and Class C fly ash can provide beneficial properties to brick production, such as improved workability, increased strength, and reduced water absorption. The specific physical characteristics can influence the processing and performance of fly ash bricks, hence it is essential to consider these factors when utilizing fly ash in bricks production.

CONCLUSION AND RECOMMENDATIONS

The results of the fly ash test obtained from Sokoto, Kogi, Benue cement factory in Nigeria were compared with BS codes of practice: BS 8110: 2000 Part structural use of concrete, BS 8002:2015, BS EN 206:2013, BS 1377: 1990 concrete specification, performance, production and conformity, BS 4729 clay and calcium silicate bricks of special shapes and sizes recommendations. Based on the results of the test of 28 days the strength of the fly ash cubes is within the standard, and this is corroborated with the findings of (Edeh *et. al.*, 2020) in their research on the effect of oil palm fibre ash on cement stabilized lateritic soil. BS 31000(2018)

Based on this research on fly ash class F & C samples obtained from Sokoto, Kogi, and Benue cement factories in Nigeria, the three different cement manufacturing companies, it's important to note that, the use of fly ash for brick production can vary depending on factors such as regional availability, transportation costs, local regulations, and market demand. Conducting a thorough cost-benefit analysis and assessing the specific market conditions would be necessary to determine the economic feasibility of incorporating fly ash into brick manufacturing in a particular location in Nigeria. Therefore, both the Class F and Class C fly ash can provide beneficial properties to brick production, such as improved workability, increased strength, and reduced water absorption. The specific physical characteristics can influence the processing and performance of fly ash bricks, hence it is essential to consider these factors when utilizing fly ash in bricks production. The environmental benefits of using fly ash in brick production can help reduce the environmental impact associated with the disposal of this waste material. By utilizing fly ash, brick production contributes to waste reduction and promotes a circular economy, which can have positive long-term economic benefits. However, raising awareness about the benefit of fly ash in brick production would promote acceptance among potential customers in the construction industry. The study recommends creating awareness on the use of fly ash for brick production as it promotes acceptance among potential customers in the construction industry.

AUTHOR CONTRIBUTION

The professional background of each author contributed to the collection from each site being part of the IBR research. Musa H. L. conceived the idea, while ADAMU Zuntu I., put together the article. Abdullahi Y. was involved in the data coding. Zuntu, A. I., and Abdullahi Y., performed the data analysis, and discussion of results and reviewed the article for final submission.

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