SCHOOL OF ENVIRONMENTAL TECHNOLOGY,
FEDERAL UNIVERSITY OF TECHNOLOGY
MINNA, NIGER STATE, NIGERIA

4th INTERNATIONAL CONFERENCE (SETIC2022)

BOOK OF PROCEEDINGS

MAIN THEME:

SUSTAINABLE DEVELOPMENT AND RESILIENCE OF THE BUILT ENVIRONMENT IN THE ERA OF PANDEMIC

6th - 8th February, 2023

VENUE: NITDA Centre, Federal University of Technology, Minna, Niger State, Nigeria

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Vice-Chancellor
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School of Environmental Technology International Conference (SETIC 2022)

6th – 8th Februay, 2023

Federal University of Technology Minna, Niger State, Nigeria

BOOK OF PROCEEDINGS

EDITOR IN CHIEF
B. J. Olawuyi

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PREFACE

The 4th edition of School of Environmental Technology International Conference (SETIC2022) is organised by School of Environmental Technology, Federal University of Technology Minna, Nigeria. In collaboration with Massey University New Zealand, University of Namibia, Namibia, Department of Architectural Technology, Najran University, Saudi Arabia, Deapartment of Civil Engineering, Stellenbosch University, Stellenbosch, South Africa and the Global Sustainable Futures, UK.

The main theme for this year conference is "**Sustainable Development and Resilience of the Built Environment in the Era of Pandemic**" and is of interest to everyone going by the fact that housing is a necessity following only after food and clothing while living in crowded places and poor sanitation is a concern and possible cause of spread of diseases and occurrence of epidemic/pandemic. This promotes and encourage innovative and novelty for emerging property management strategies in a pandemic era; modern geospatial tools for epidemiology; architecture, resilience and healthy buildings in pandemic era; planning for sustainable resilient neighbourhoods and cities in COVID-19 era; sustainable and resilient cities; sustainable cost management of built environment projects in the era of covid-19; wellbeing and resilience of the built environment.

The responses from participants for this conference are overwhelming, well attended, and successful. The operation mode was virtual for all participants with presentations in mode Our participants are from various Universities and other sector across the globe, from countries like United Kingdom, New Zealand, Saudi Arabia, South Africa, Namibia, Ethiopia and Nigeria just to mention a few. Hence, this conference provides a good platform for professionals, academicians and researchers to widen their knowledge and approach on latest advances in research and innovation. Papers presented in this conference cover a wide spectrum of science, engineering and social sciences.

Finally, a note of thanks must go to SETIC 2022 Local Organizing Committee (LOC) for their remarkable dedication in making this conference a success. We hope the event will prove to be an inspiring experience to all committee members and participants.

ACKNOWLEDGEMENTS

The effort put together in achieving the success of SETIC 2022 is predicated on the feat of the previous three edition of School of Environmental Technology International Conference held in 2016, 2018 and 2021, respectively. The support and goodwill from Vice-Chancellor of Federal University of Technology, Dean School of Environmental Technology, Dr. Renuka Thakore, Dr Dodo Y. A., Prof. James O.B. Rotimi and many other highly motivated people are highly appreciated.

It is also my privilege and honour to welcome you all, on behalf of the Local Organizing Committee (LOC) to the 4th edition of the Biennial School of Environmental International Conference (SETIC2022). This Conference which was earlier schedule for April, 2022 is holding now (6th to 8th th February, 2023) due to the prolonged ASUU-FGN crisis which made our public Universities in Nigeria to be closed for over Eight Months. Our experience in the 3rd edition held in 2021 after the COVID-19 Pandemic has thought us on new ways of doing things with the Virtual Conferencing offering us a wider coverage, it is our hope that SETIC2022 will be an improvement on the Participants experience of opportunity available for global networking and interaction at Conferences via the Virtual mode of presentation.

The conference provides an international forum for researchers and professionals in the built environment and allied professions to address fundamental problems, challenges and prospects of **Sustainable Development and Resilience of the Built Environment in the Era of Pandemic**. The conference is a platform where recognized best practices, theories and concepts are shared and discussed amongst academics, practitioners and researchers. This 2022 edition of SETIC has listed in the program a Round Table Talk on on Housing Affordability Beyond COVID-19 with selected Speakers from across the globe available to do justice on the topic of discussion. Distinguished Conference participants, permit me to warmly welcome our Keynote:

- Dr. Ibrahim Idris, *Director Public health, State Ministry of Health, Niger State, Nigeria;*
- Dr. A.A. Bilau, *Lecturer and expert in Disaster Risk Management, Department of Building, Federal University of Technology, Minna, Nigeria and;*
- Dr. Yakubu Aminu Dodo, *Ass. Prof. Architecture Engineering Department, Faculty of Engineering, Najran University, Najran, Saudi Arabia;*

And the lead Discussants for the Round Table Talk:

- Prof. James O.B. Rotimi, *Professor of Construction Economics & Management, School of Built Environment, College of Sciences, Massey University of New Zealand;*
- Prof. O.A. Kemiki, *Professor of Estate Management and Valuation, Federal University of Technology, Minna, Nigeria;*
- Dr. Renuka Thakore, *Founder, Institute for Global Sustainable Futures, Progress through Partnership, UK;*
- Dr. Guillermo Delgado, *Senior Lecturer, Architecture and Acting Director, Institute of Land, Livelihoods and Housing (ILlH), Namibia University of Science and Technology, Namibia;*
- Prof. Adewumi John Babafemi, *Associate Professor and Head of Construction Materials and Unit; Stellenbosch University, Stellenbosch, South Africa*;
- Dr. Yakubu Aminu Dodo, *Ass. Prof. Architecture Engineering Department, Faculty of Engineering, Najran University, Najran, Saudi Arabia.*

for accepting to share from their knowledge, wealth of experience and be available to interact with participants on varied issues on "**Sustainable Development and Resilience of the Built Environment in the Era of Pandemic**".

As reflected on the Conference program, the Conference activities will be Virtual for all presenters to run in four parallel sessions on the Zoon platform. With a total of Seventy (70) articles captured in the Conference Proceedings covering the six subthemes of the Conference, I have no doubt that we are all in for an impactful experience at SETIC2022 as we brainstorm, exchange ideas, share knowledge and participate in evolving more approach to sustainable housing and land management drives.

I implore us all to enjoy every moment of the deliberations and ensure we maximize the great opportunity offered by the Conference to network for better research and career development as we also make new friends.

I also on behalf of myself and the LOC express our appreciation to the Dean, School of Environmental Technology and the entire Staff of the School for giving us the opportunity to steer the ship for SETIC2022. To the Reviewers and various Committees that served with us, I say thank you for helping us through despite the pressure of work.

Thanks, and God bless you all.

Olawuyi, B.J. (PhD)
Chairman, LOC
SETIC2022

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6th February, 2023

TO WHOM IT MAY CONCERN

I wish to state that all the papers published in SETIC2022 Conference Proceedings have passed through the peer review process which involved an initial review of abstracts, review of full papers by minimum of two referees, forwarding of reviewers' comments to authors, submission of revised papers by authors and subsequent evaluation of submitted papers by the Scientific Committee to determine content quality.

It is the policy of the School of Environmental Technology International Conference (SETIC) that for papers to be accepted for inclusion in the conference proceedings it must have undergone the review process and passed the academic integrity test. All papers are only published based on the recommendation of the Reviewers and the Scientific Committee of SETIC

Babatunde James OLAWUYI
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Prof. Junaid, A	Planning for Sustainable Resilient Neighbourhoods and Cities in Pandemic Era
Dr. Opaluwa, Y.D.	Modern Geospatial Tools for Epidemiology
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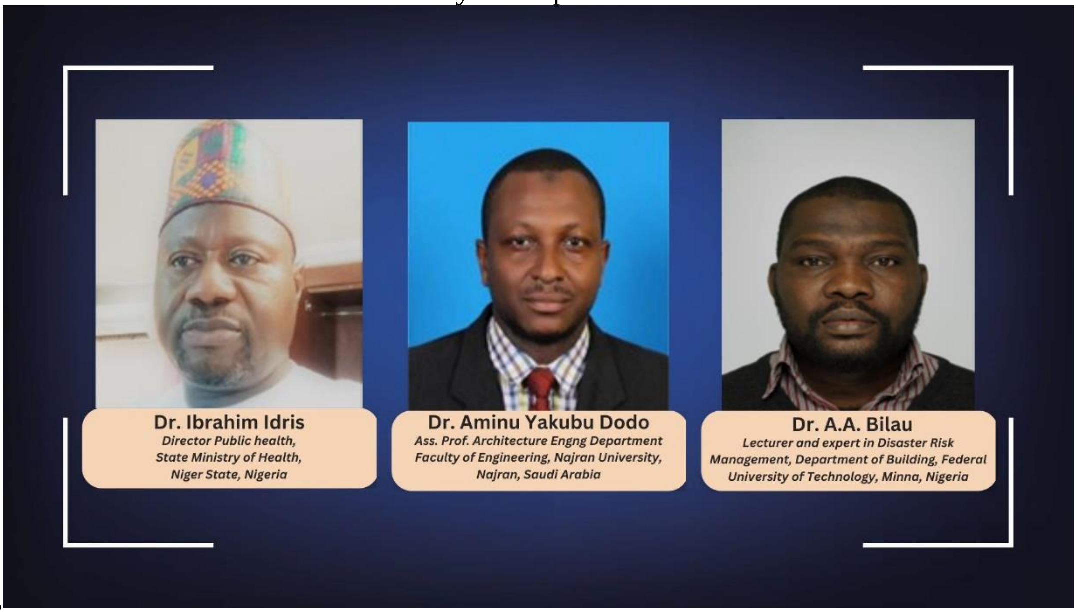
Acknowledgement To Keynote Speakers and Lead Discussants

SETIC 2022 organisers wishes to thank our keynote speakers, and Guest speakers for accepting to create time to share from their rich wealth of knowledge and interact with delegates and participants on varied issues being examined at this year's conference. A brief profile of each keynote speaker is provided here, this would allow for future interaction and networking with them.

Keynote Speakers



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Development of Scheffe's Regression Model to Predict the Compressive Strength of Concrete Using Metakaolin as Partial Replacement of Cement

Jegede, A.[1a], Adejumo, T. W.[1b], Oritola, S. F.[1c], Shehu, M.[1d], Omojah, A.[1e] & Mahmud, M. B.[2]

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Abstract
Kaolinite clay, that Nigeria has been proven to have about 3 billion tonnes scattered across all the geo-political zone, can be used to produce Metakaolin through a simple calcinations process. Metakaolin may be used as a cement replacing material in concrete, to reduce cement consumption, to increase strength and the rate of strength gain, to decrease permeability and to improve durability. In this study, it served as a fifth component of concrete blend as it replaces between 0% to 20% of cement. The other four ingredients were water, cement, fine aggregates (sand), coarse aggregates(granite). Scheffe's simplex theory was used for the five-mix design in a {5,2} experimental design which resulted in an additional ten mix ratios. For the purpose of testing and verification, additional fifteen mix ratios were made. The thirty concrete mix ratios were subjected to laboratory experiment to determine the 28days compressive strengths. The results of the first fifteen compressive strengths (model mixes) were used for the calibration of the model constant coefficients, while those from the second compressive strength (control mixes) were used for the model verification. A mathematical scheffe's regression model was derived from the experimental results, which was used to predict the compressive strength of concrete. The regression model was subjected to a t-test with 5% significance, which ascertain the model to be adequate with an R^2 value of 0.9417. The study reveal that Metakaolin can replace up to 20% of cement without compromising 28-day compressive strength.

Keyword: *Concrete, Cement, Metakaolin, Strength, Model, Kaolinite*

Introduction

Concrete is one of the most widely used construction materials in the world, with 2.8 billion tons placed worldwide each year (Schneider *et al.*, 2011). It is attractive in many applications because it offers considerable strength at a relatively low cost. Concrete can generally be produced of locally available constituents. It can be cast into a wide variety of structural configurations, and requires minimal maintenance during service (Najimi *et al.*, 2012). Portland cement industry is responsible for approximately 8% of global CO_2 emission (Report, C. H., 2018). Partial replacement of Portland cement by one or more additives to obtain blended cements not only provides reduction in CO_2 emission and energy saving in cement production but also supplies more durable cementitious system to the construction industry.

Supplementary cementitious materials (SCMs) are finely ground solid materials that are used to replace part of cement in a concrete mixture. These materials react chemically with hydrating cement to form a modified paste microstructure. In addition to their positive environmental impact, SMCs may improve concrete workability, mechanical properties, and durability.

Metakaolin (MK) is produced by controlled thermal treatment of kaolin. Different researchers have introduced different optimum temperature (600–850 ° C) and period (1–12h) for heating kaolin to obtain MK with a high pozzolanic index. Therefore, MK can replace cement in concrete because of it pozzolanic properties (Elavarasan *et al.*, 2020). When used in concrete, metakaolin undergoes a pozzolanic reaction and refines the microstructure of the hydrated cement paste. Due to the small particle size and high surface area, MK reacts quickly and reduces the diffusion coefficient compared with plain Portland cement (Basheer *et al.*, 2002). Research suggests that Silica fumes and MK have similar influences on the chloride ingress resistance of concrete. Typical replacement levels for MK range from 5% to 10% (Holland *et al.*, 2016).

Modeling involves setting up mathematical formulations of physical or other systems. Such formulations are constructed for the assessment of the objective function after the hindsight of observed operating variables. Hence or otherwise, model could be constructed for a proper observation of response from the integration of the factors through controlled experimentations followed by schematic design where such simplex lattice approach of the type of Scheffe (1958) optimization theory could be employed. Entirely different physical systems may correspond to the same mathematical model so that they can be solved by the methods. This study seeks to develop a mathematical regression model known as the Scheffe's model to predict the compressive strength of concrete when cement is partially replaced Metakaolin (MK).

2.0 Materials and Methods

2.1 Materials

The materials used to achieve the aim of this study include the following;

i Kaolin clay

The kaolin clay was gotten from Kuta and synthesis into Metakaolin (MK) at the material lab, Bosso campus of the Federal University of Technology Minna

ii Ordinary Portland cement (OPC)

The Ordinary Portland cement of Dangote brand was obtained from an open Market and conforms to BS 12, (1996).

iii Coarse aggregates

The coarse aggregates obtained from a quarry in Maikunkele, Bosso Local Government Area, Niger State, grading of the aggregate was carried out to BS 882, (1992)

iv Fine aggregates

The fine aggregate was obtained from a river behind the boy's hostel Gidan Kwano Campus, Federal University of Technology Minna. The grading of the aggregate was carried out to BS 812, (1985)

v Potable water

The potable water used was obtained from the University water mains free from impurities.

2.2 Method

i Scheffe's simplex theory

A lattice is purely an abstract space to achieve the desired strength of concrete. The major factor lies on the adequate proportioning of ingredients needed to make concrete. The simplex approach considers a number of components, *q*, and a degree of polynomial, *m*. The sum of all the *ith* components is not greater than 1. Hence,

$$X_1 + X_2 + \cdots + X_{q-1} + X_q = 1 \quad (that\ is\ 100\%) \tag{1}$$

$$\sum_{i=1}^{q} x_i = 1 \tag{2}$$

with $0 \leq x \leq 1$. The factor space becomes S_{q-1}. According to (Scheffe, 1958), the {*q*, *m*}

simplex lattice design is a symmetrical arrangement of points within the experimental region in a suitable polynomial equation representing the response surface in the simplex region.

The number of points $C_m^{(q+m-1)}$ has (m+1) equally spaced values of $X_i = 0, \frac{1}{m}, \frac{2}{m}, \ldots \frac{m}{m}$.

$$N = \frac{(q+m-1)!}{m!\,(q-1)!} \tag{3}$$

For a polynomial of degree *m* with *q* component variables where Equation (3. 2) holds, the general form is:

$$Y \ = \ b0 \ + \sum b_i\, x_i \ + \sum b_{ij}\, x_i x_j \ + \sum b_{ijk}\, x_i x_j\, x_k \ + \ \ldots . + \sum b_{i1,i2..in}\, x_{i1} x_{i2}\, x_{in} \tag{4}$$

Where $1 \le i \le q$, $1 \le i \le j \le q$, $1 \le i \le j \le k \le q$, and b_0 is the constant coefficient.

x is the pseudo component for constituents *i*, *j*, and *k*.

When $\{q,m\} = \{5,2\}$, Equation (3.5) becomes:

$$Y = \ \beta_1 x_1 + \ \beta_2 x_2 + \beta_3 x_3 + \ \beta_4 x_4 + \ \beta_5 x_5 + \beta_{12} x_1 x_2 \ + \ \beta_{13} x_1 x_3 + \ \beta_{14} x_1 x_4 \ + \ \beta_{15} x_1 x_5 + \ \beta_{23} x_2 x_3 + \ \beta_{24} x_2 x_4 + \ \beta_{25} x_2 x_5 + \ \beta_{34} x_3 x_4 + \ \beta_{35} x_3 x_5 + \ \beta_{45} x_4 x_5 \tag{5}$$

$$Y = \sum_{i=1}^{s} \beta_i\, x_i + \sum_{1 \le i \le j \le 5} \beta_{ij}\, x_i \tag{6}$$

Where the response, Y is a dependent variable (compressive strength of concrete). Equation (5) is the general equation for a $\{5, 2\}$ polynomial, and it has 15 terms, which conforms to Scheffe's theory in Equation (3)

Let Y_i denote response to pure components, and Y_{ij} denote response to mixture components in *i* and *j*. If $x_i=1$ and $x_j= 0$, since $j \neq i$, then.

$$Y_i = \ \beta_i \tag{7}$$

This means that;

$$\sum_{i=1}^{s} \beta_i\, x_i = \sum_{i=1}^{s} Y_i\, x_i \tag{8}$$

Hence, from Equation (3.14)

$$Y_1 = \ \beta_1\, , \ Y_2 = \ \beta_{2,} \ Y_3 = \ \beta_3, \ Y_4 = \ \beta_4 and \ Y_5 = \ \beta_5 \tag{9}$$

According to Scheffe (1958),

$$\beta_{ij} \ = 4Y_{ij} \ - 2\, Y_i \ - 2\, Y_j \tag{10}$$

1.1.1 Concrete mix design

The Department of Environment (DoE, 1988) mix design was adopted for the preparation of the concrete due to its versatility and applications in different concrete structures such as buildings, roads and bridges. Five different mix proportions were produced by replacing cement with Metakaolin (MK) from 0 to 20% respectively. The following results were obtained;

In order to satisfy the requirement of a 5, 2 Scheffe's model, the following five mix ratios of Water: Cement: MK: FA: CA were generated from a five-mix design in 3.3.2:

$$A1 \ = \ [0.50, 1.00, 0.00, 1.65, 2.78], \ A2 \ = \ [0.48, 0.95, 0.05, 1.54, 2.64], \ A3 \ = [0.46, 0.90, 0.10, 1.46, 2.50], \ A4 \ = \ [0.52, 0.85, 0.15, 1.69, 2.91]\,, A5 \ = [0.54, 0.80, 0.20, 1.77, 3.05 \tag{2.2.1}$$

The corresponding pseudo components are:

$$X1 \ = \ [1, 0, 0, 0, 0], X2 \ = \ [0, 1, 0, 0, 0], X3 \ = \ [0, 0, 1, 0, 0], X4 \ = \ [0, 0, 0, 1, 0], X5 \ = \ [0, 0, 0, 0, 1] \tag{2.2.2}$$

Substituting X_i and S_i into equation 3.23 and transposing the values of A matrix were obtained as

$$[S] = \begin{bmatrix} 0.50 & 0.48 & 0.46 & 0.52 & 0.54 \\ 1.00 & 0.95 & 0.90 & 0.85 & 0.80 \\ 0.00 & 0.05 & 0.10 & 0.15 & 0.20 \\ 1.65 & 1.54 & 1.46 & 1.69 & 1.77 \\ 2.78 & 2.64 & 2.50 & 2.91 & 3.05 \end{bmatrix} \quad (2.2.3)$$

With the binary points or centre points

$$X12 = [0.5, 0.5, 0, 0, 0], X13 = [0.5, 0, 0.5, 0, 0], X14 = [0.5, 0, 0, 0.5, 0], X15 = [0.5, 0, 0, 0, 0.5]$$

$$X23 = [0, 0.5, 0.5, 0, 0], X24 = [0, 0.5, 0, 0.5, 0], X25 = [0, 0.5, 0, 0, 0.5], X34 = [0, 0, 0.5, 0.5, 0]$$

$$X35 = [0, 0, 0.5, 0, 0.5], X45 = [0, 0, 0, 0.5, 0.5 \quad (2.2.4)$$

According to Scheffe (1958),

$$S_{ij} = XS_i \quad (2.2.5)$$

Substituting,

$$\begin{bmatrix} S_{12} \\ S_{13} \\ S_{14} \\ S_{15} \\ S_{23} \end{bmatrix} = \begin{bmatrix} 0.5 & 0.5 & 0.0 & 0.0 & 0.0 \\ 0.5 & 0.0 & 0.5 & 0.0 & 0.0 \\ 0.5 & 0.0 & 0.0 & 0.5 & 0.0 \\ 0.5 & 0.0 & 0.0 & 0.0 & 0.5 \\ 0.0 & 0.5 & 0.5 & 0.0 & 0.0 \end{bmatrix} \begin{bmatrix} 0.50 \\ 0.48 \\ 0.46 \\ 0.52 \\ 0.54 \end{bmatrix} \quad (2.2.6)$$

This process was repeated for S_{24}, S_{25}, S_{34}, S_{35} and S_{45}. Similarly, the process was repeated for an additional 15 control points that will be used for the verification of the formulated model.

***Table 1**: Actual and pseudo mix ratios of the model*

	Actual Components					**Resp.**	**Pseudo Components**				
S	W	C	MK	FA	CA	(Y_{exp})	X_1	X_2	X_3	X_4	X_5
N_1	0.50	1.00	0	1.65	2.78	Y_1	1	0	0	0	0
N_2	0.48	0.95	0.05	1.54	2.64	Y_2	0	1	0	0	0
N_3	0.46	0.90	0.10	1.46	2.50	Y_3	0	0	1	0	0
N_4	0.52	0.85	0.15	1.69	2.91	Y_4	0	0	0	1	0
N_5	0.54	0.80	0.20	1.77	3.05	Y_5	0	0	0	0	1
N_{12}	0.49	0.975	0.025	1.595	2.71	Y_{12}	0.5	0.5	0	0	0
N_{13}	0.48	0.950	0.05	1.555	2.64	Y_{13}	0.5	0	0.5	0	0
N_{14}	0.51	0.925	0.070	1.67	2.845	Y_{14}	0.5	0	0	0.5	0
N_{15}	0.52	0.90	0.10	1.70	2.915	Y_{15}	0.5	0	0	0	0.5
N_{23}	0.47	0.925	0.075	1.50	2.57	Y_{23}	0	0.5	0.5	0	0
N_{24}	0.50	0.90	0.1	1.615	2.775	Y_{24}	0	0.5	0	0.5	0
N_{25}	0.51	0.875	0.125	1.655	2.845	Y_{25}	0	0.5	0	0	0.5
N_{34}	0.49	0.875	0.125	1.575	2.705	Y_{34}	0	0	0.5	0.5	0
N_{35}	0.50	0.850	0.15	1.615	2.775	Y_{35}	0	0	0.5	0	0.5
N_{45}	0.53	0.825	0.175	1.73	2.98	Y_{45}	0	0	0	0.5	0.5

***Table2:** Actual and pseudo mix ratios of control observation points*

Actual Components	**Resp.**	**Pseudo Components**

S	W	C	MK	FA	CA	(Y_{exp})	X_1	X_2	X_3	X_4	X_5
C_1	0.514	0.895	0.105	1.678	2.871	Y_1	0.3	0	0	0.7	0
C_2	0.478	0.945	0.055	1.538	2.626	Y_2	0.2	0.5	0.3	0	0
C_3	0.476	0.940	0.06	1.536	2.612	Y_3	0.4	0	0.6	0	0
C_4	0.50	0.90	0.10	1.622	2.776	Y_4	0.2	0.2	0.2	0.2	0.2
C_5	0.49	0.935	0.065	1.587	2.708	Y_5	0.3	0.3	0.2	0.2	0
C_{12}	0.488	0.970	0.03	1.584	2.696	Y_{12}	0.4	0.6	0	0	0
C_{13}	0.486	0.915	0.085	1.565	2.68	Y_{13}	0.1	0.4	0.3	0.1	0.1
C_{14}	0.472	0.93	0.070	1.517	2.584	Y_{14}	0.3	0	0.7	0	0
C_{15}	0.464	0.91	0.09	1.476	2.528	Y_{15}	0	0.2	0.8	0	0
C_{23}	0.504	0.92	0.08	1.642	2.805	Y_{23}	0.3	0.4	0	0	0.3
C_{24}	0.496	0.99	0.01	1.631	2.752	Y_{24}	0.9	0	0.1	0	0
C_{25}	0.49	0.905	0.095	1.577	2.707	Y_{25}	0	0.5	0.2	0.2	0.1
C_{34}	0.496	0.97	0.03	1.624	2.751	Y_{34}	0.7	0.1	0.1	0.1	0
C_{35}	0.508	0.94	0.06	1.666	2.832	Y_{35}	0.6	0	0	0.4	0
C_{45}	0.496	0.91	0.09	1.61	2.749	Y_{45}	0.3	0.1	0.3	0.1	0.2

3.0 Results and Discussion

3.1 Compressive Strength of Concrete

Three replicate concrete cubes were cast for each of the thirty mix ratios using $150mm$ moulds. The cubes were removed after 24 hours from the mould and were soaked in water to cure for 28 days. The cubes were removed on the 28^{th} day and subjected to crushing with the help of a uniaxial compressive strength machine. The compressive strength was determined with Equation (3.36)

$$F_c = \frac{P}{A} \tag{3.1.1}$$

Where;

Fc = compressive strength of concrete, P = the applied compressive load at failure (kN)

A = the cross-sectional area of the specimen (mm^2)

For the average loads of mix, A, B and C with a constant cube cross sectional area of 22500mm^2, the compressive strength for the various sample points was presented in Figure 1.

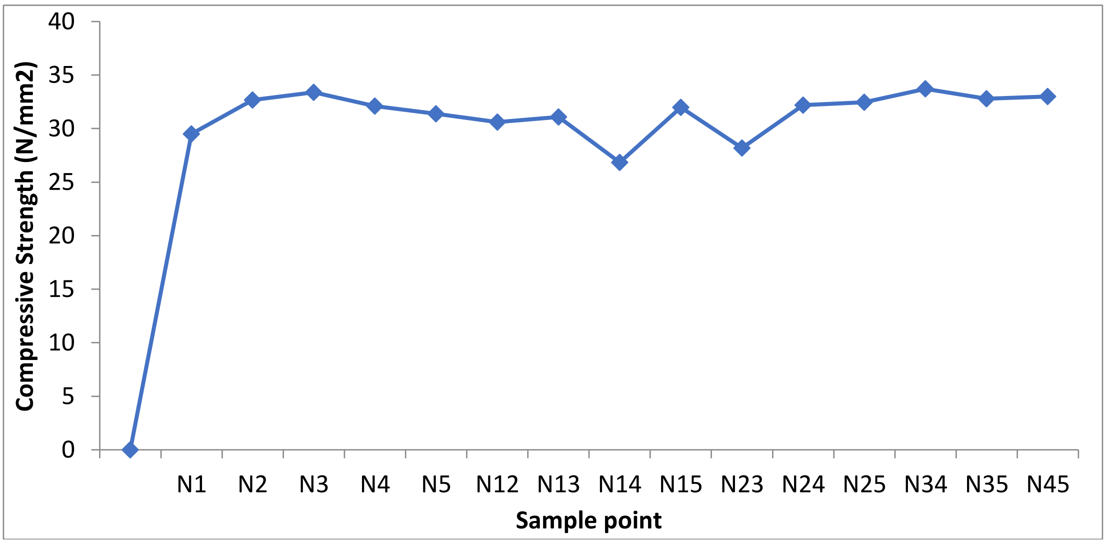

Figure 1: Compressive Strength of Cubes

3.2 Scheffe's model for 28 days compressive strength

The coefficients of polynomials from Table 3.1.1 substituted into the

Equation (2.2.1.14) and Equation (2.2.1.15) are:

$$\beta_1 = 29.51, \quad \beta_2 = 32.66, \quad \beta_3 = 33.39, \quad \beta_4 = 32.11, \quad \beta_5 = 31.40$$

Recall from equation 3.18 that, $\beta_{ij} = 4\,Y_{ij} - 2\,Y_i - 2\,Y_j$

$$\beta_{12} = 4\,Y_{12} - 2\,Y_1 - 2\,Y_2$$

$$\beta_{12} = 4(30.6) - 2(29.51) - 2(32.66) = -1.94$$

Similarly, $\beta_{13} = -1.4$, $\beta_{14} = -15.84$, $\beta_{15} = 6.1$, $\beta_{23} = -19.3$, $\beta_{24} = 0.74$,

$\beta_{25} = 1.72$, $\beta_{34} = 3.84$, $\beta_{35} = 1.62$, $\beta_{24} = 4.94$

Substituting the above coefficients into equation (2.2.1.10)

$$Y = 29.51x_1 + 32.66x_2 + 33.99x_3 + 32.11x_4 + 31.40x_5 - 1.94x_1x_2 - 1.4x_1x_3 - 15.84x_1x_4 + 6.1x_1x_5 - 19.3x_2x_3 + 0.74x_2x_4 + 1.72x_2x_5 + 3.84x_3x_4 + 1.62x_3x_5 + 4.94x_4x_5 \qquad (3.2.1)$$

Equation (1) above is the mathematical model to predict the 28 days compressive strength of concrete using MK to replace 0-20% of cement.

Table 3: *Experimental and predicted values of 28 days compressive strength for the model mix*

Sample Points	**Response**	**PSUEDO COMPONENTS**					**comp. strength**	**comp. strength**
	Y	**W/C**	**C**	**MK**	**F. A**	**C. A**	Yexp. (N/mm^2)	Ypred. (N/mm^2)
		X_1	X_2	X_3	X_4	X_5		
N1	Y1	1.0	0.0	0.0	0.0	0.0	29.51	29.51
N2	Y2	0.0	1.0	0.0	0.0	0.0	32.66	32.66
N3	Y3	0.0	0.0	1.0	0.0	0.0	33.99	33.39
N4	Y4	0.0	0.0	0.0	1.0	0.0	32.11	32.11
N5	Y5	0.0	0.0	0.0	0.0	1.0	31.40	31.40
N12	Y6	0.5	0.5	0.0	0.0	0.0	30.60	30.60
N13	Y7	0.5	0.0	0.5	0.0	0.0	31.40	31.10
N14	Y8	0.5	0.0	0.0	0.5	0.0	26.85	26.85
N15	Y9	0.5	0.0	0.0	0.0	0.5	31.98	31.98
N23	Y10	0.0	0.5	0.5	0.0	0.0	28.50	28.20
N24	Y11	0.0	0.5	0.0	0.5	0.0	32.57	32.20
N25	Y12	0.0	0.5	0.0	0.0	0.5	32.46	32.46
N34	Y13	0.0	0.0	0.5	0.5	0.0	34.42	33.71
N35	Y14	0.0	0.0	0.5	0.0	0.5	32.70	32.80
N45	Y15	0.0	0.0	0.0	0.5	0.5	32.99	32.99

Table 4*: Experimental and predicted values of 28 days compressive strength for the control mix*

Sample Points	**Response Y**	**PSUEDO COMPONENTS**					**comp. strength**	**comp. strength**
		W/C	**C**	**MK**	**F. A**	**C. A**	Yexp. (N/mm^2)	Ypred. (N/mm^2)
		X1	X2	X3	X4	X5		
C1	Y1	0.3	0.0	0.0	0.7	0.0	29.94	28.00
C2	Y2	0.2	0.5	0.3	0.0	0.0	29.37	29.26
C3	Y3	0.4	0.0	0.6	0.0	0.0	30.14	31.86
C4	Y4	0.2	0.2	0.2	0.2	0.2	30.38	31.15
C5	Y5	0.3	0.3	0.2	0.2	0.0	30.08	29.77
C12	Y6	0.4	0.6	0.0	0.0	0.0	28.55	30.93
C13	Y7	0.1	0.4	0.3	0.1	0.1	27.97	30.34
C14	Y8	0.3	0.0	0.7	0.0	0.0	29.25	32.35

C15	Y9	0.0	0.2	0.8	0.0	0.0	30.53	30.64
C23	Y10	0.3	0.4	0.0	0.0	0.3	29.85	31.86
C24	Y11	0.9	0.0	0.1	0.0	0.0	30.19	29.83
C25	Y12	0.0	0.5	0.2	0.2	0.1	27.06	31.24
C34	Y13	0.7	0.1	0.1	0.1	0.0	31.17	29.06
C35	Y14	0.6	0.0	0.0	0.4	0.0	27.19	26.75
C45	Y15	0.3	0.1	0.3	0.1	0.2	27.92	31.24

3.0 Conclusion

Results of this research work have been collected within the limits of experimental accuracy, upon which various deductions have been made, these deductions include; The compressive strength of concrete increases on the progressive replacement of cement with Metakaolin (MK)**.** Using Scheffe's (5, 2) polynomial equation, mix design mathematical model for a five component MK blended cement concrete was developed. The model could predict the compressive strength of MK blended concrete when the mix ratios are known and vice versa.

The predictions from the model were tested at 95% accuracy level using statistical Fisher test and found to be adequate. The maximum strength predicted by this model was 33.71 N/mm^{2}derived from a mix ratio of 0.490:0.875:0.125:1.575:2.705 for Water: Cement: MK: FA (Sharp sand): CA (Granite) respectively.

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Assessment of the Performance of Sandcrete Blocks Produced by Partially Replacing Sand with Coal Bottom Ash as a Fine Aggregate

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Abstract

This paper describes the results of an experimental investigation into the assessment of the performance of Sandcrete blocks produced by partially replacing sand with coal bottom ash as fine aggregate. The physical properties of coal bottom ash and sand were carried out in accordance with BS 1377-9 (1990). Sandcrete blocks were produced using hand mould in 0, 10, 20, 30, 40 and 50% replacement levels of sand with the coal bottom ash using cement-sand ratio of 1:6. They were cured at the ages of 7, 14, 21, 28 days and were then subjected to compressive strength tests. Sieve analysis test showed a very similar particle size distribution between sand and coal bottom ash. It was found out that the optimum replacement level was achieved at 20% and the 28-day compressive strength at this level was 3.11N/mm^2 which is greater than the minimum strength of 2.8N/mm^2 specified by BS 6073-2 (2008). Also, there was a decrease in the weight of the blocks with an increase in coal bottom ash content; this indicates the suitability of using coal bottom ash as a lightweight material in Sandcrete block production.

Keyword: Sand, Block, Coal Bottom Ash, Strength, Aggregate

1.0 Introduction

Sandcrete blocks have been the predominant walling material in both residential and commercial buildings in West Africa for over fifty years, (Onwuka *et al.*, 2013). They are used extensively due to the availability of raw materials used in its production (Yusuf *et al.*, 2017). Sandcrete blocks are produced with a mixture of cement and sand with a varying percentage of water. In Nigeria today, the production of sandcrete blocks requires a significant amount of river sand. This river sand is sourced constantly from various mines and this constant mining has an adverse effect as it leads to depletion of this material and the deterioration of the environment. The need to search for an alternative source of fine aggregate, which will be suitable for production of masonry blocks, forms the background of using coal bottom ash as an alternative to sand for this study.

Coal bottom ash is a residue, among others, obtained from the combustion of coal during thermal power generation. These residues are generally referred to as coal combustion products (CCPs). Other CCPs include fly ash, boiler slag, flue gas desulfurization (FGD) and gypsum (Kim and Lee, 2014). The properties of these materials were not studied or evaluated seriously and nearly all the CCPs were landfilled (Ramme-Tharaniyil, 2000). The landfilling of these CCPs were later found to pose a great risk to human health and the environment as it spreads hazardous components, contaminates adjacent soil and underground water (Khan and Ganesh, 2016). In the course of time, the cementitous and pozzolanic properties of fly ash were recognized and studied by several individuals and institutions. The products were tested to understand their physical properties, chemical properties and suitability as a construction material.

Several experiments have also been done on application of coal bottom ash in construction. These works focused primarily on concrete production. A research work carried out by Khan and Ganesh (2016) on the effect of coal bottom ash on the mechanical and durability of concrete showed that with an increase in the amount of coal bottom ash, early age strength is less compared to control mix, but as age increases, they showed good improvement in strength due to pozzolanic reaction and concluded that 10% replacement of cement with coal bottom ash is economical and lesser amount of CO_2 is emitted. Kim and Lee (2011) investigated the effect of fine and coarse bottom ash on the compressive strength of concrete at 7- and 28-days age of curing. They observed that the compressive strengths were not significantly affected by the replacements of fine aggregate with bottom ash. The objective of this work is to investigate the effect of partial replacement of sand with coal bottom ash on the compressive strength and density of masonry blocks.

2.0 Methodology

2.1 Materials

The materials described below were used for this study.

2.1.1 Coal bottom ash

The Coal Bottom Ash (CBA) was acquired from Unicane Industries limited located at Jamata village along Lokoja expressway in Kogi state, Nigeria. The CBA was sieved, and the aggregate used were those that passed through sieve with aperture 4.75mm. The aggregate was clean, sharp, and free from clay, loam, dirt or organic matters (NIS 87:2004).

Plate I: Coal Bottom Ash

2.1.2 Fine aggregate

The aggregate was obtained from a river at Gidan Mangoro along Bida-Minna Road in Minna, Niger state. The fine aggregate was clean, sharp, and free from clay, loam and any organic or chemical matter (NIS 87:2004). It was also well graded to conform to the requirement in BS 882:1992, Aggregates from natural sources for concrete.

2.1.3 Cement

The cement used in this study is the Ordinary Portland Cement (OPC). The cement used was Dangote 3x cement produced in accordance with NIS 87:2004 Part 1, classified as CEM 1 of the standard and it was purchased from a cement depot at Gidan Kwano area, opposite the main gate of the Federal University of Technology, Minna, Niger State.

2.1.4 Water

The water used for mixing and curing the block samples was potable water obtained from the tap at civil engineering laboratory, Federal University of Technology, Minna, Niger State. It was properly examined to ensure that it was clean, fit for drinking and free from deleterious materials such as clay, silt, alkali, acids and organic materials.

2.2 Physical Properties

In this study, laboratory tests on the sand and coal bottom ash to determine their respective physical properties. The properties investigated include the particle size distribution, specific gravity, bulk density and moisture content. These investigations were done in accordance with BS 1377-9 (1990).

2.3 Block Manufacturing

Seventy-two (72) hollow blocks with the size of 450mm x 225mm x 150mm were produced manually with the mix ratio 1:6; cement: sand on volume basis. This was done in the civil engineering laboratory of Federal University of Technology, Minna. Sand used in the cement-sand mixture was replaced with coal bottom ash at 0, 10, 20, 30, 40 and 50% replacement level by weight. Water was added to the mixture while maintaining 0.5 water cement ratio. The blocks produced were then cured for 7, 14, 21 and 28 days respectively by spraying method.

2.4 Compressive Strength Test

Compressive strength test on the produced block samples were carried out. For each curing day, eighteen (18) numbers of the produced blocks were subjected to compressive strength test to determine the load that will lead to failure of the block samples. A manual compressive strength testing machine in the Laboratory of Building department, Federal University of Technology, Minna, Nigeria was used. For each replacement level, three (3) blocks were tested, and the average compressive strength was obtained by getting the average of the measurements for three blocks.

3.0 Results and Discussions

3.1 Physical Properties

Figure 1 shows the particle size distribution that was obtained from the sieve analysis test for sand and coal bottom ash. The result revealed that both CBA and sand have almost similar trend in the distribution of particle size at similar percentages. The percentage passing for selected sieves was lying between 10% to 80% for CBA and 0% to 90% for sand. This complied with the grading limit of fine aggregate in zone 4 in accordance with NIS 87:2004, therefore the aggregate is suitable for block making. However, the curve for the sand is steep, this indicates that the aggregate contains particle of almost same size which in turn means the soil is poorly graded.

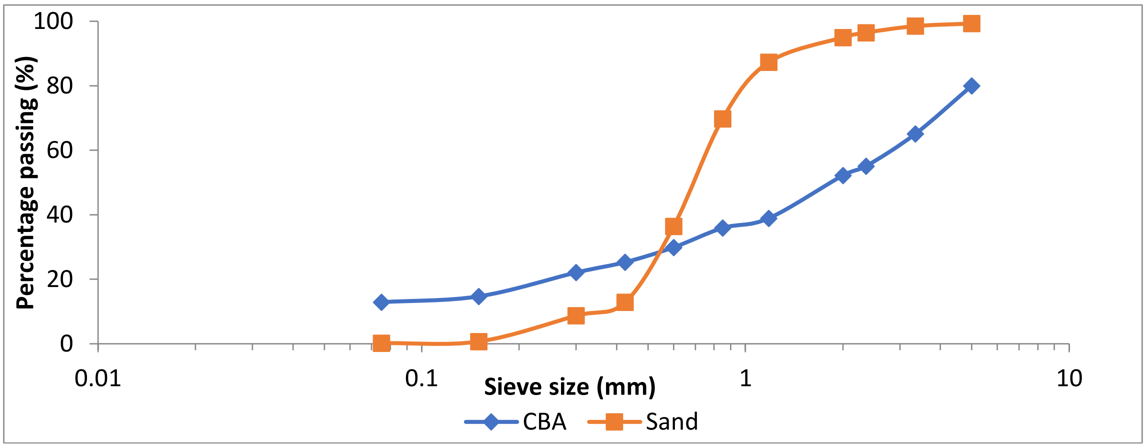

Figure 1: Particle size distribution of sand and coal bottom ash

The results of the physical properties of the sand and coal bottom ash are presented in Table 1 below. The specific gravity for coal bottom ash and sand were found to be 2.55 and 2.70 respectively and is presented in Table 1.

Table 1: Summary of the properties of sand and coal bottom ash (CBA) used in the study.

Physical Test	Sand	Coal bottom ash
Specific gravity	2.70	2.55
Bulk density (kg/m3)	1606.06	842.80
Moisture content (%)	5.04	23.83

The value obtained for sand falls within the limit of 2.6 and 2.7 for natural aggregates as prescribed by BS 812 part 109: 1990, while the value obtained for coal bottom ash just falls by 0.05 below the limit.

The mean bulk density of the sand was found to be 1606.06kg/m^3 which fall within the standard range of 1300 – 1800kg/m^3 in accordance with BS 812: Part 109 (1990). The mean bulk density of coal bottom ash was found to be 842.80kg/m^3. This shows that coal bottom ash is less dense than sand and is loosely packed. The density depends on how densely the aggregates are packed.

The average moisture content of sand as shown in Table 1 is 5.04% which falls between the ranges of 5 to 15% (BS 812: Part 109, 1990). The average moisture content of CBA obtained is 23.83%. This falls beyond the range stated by BS 812: Part 109, (1990). This implies that the CBA will absorb less amount of water from the mixture than the sand aggregate. The moisture content of a soil is dependent on the void ratio of the soil; thus, this value is indicative of the void spaces present in the soil and also the specific gravity.

3.2 Chemical Properties of CBA

The result of the chemical property of the coal bottom ash is presented in Table 2 below. From the investigation, the cumulative combination of SiO2 + Al2O3 + Fe2O3 for the CBA used in this study is 63.25%, making the CBA pass the minimum requirement of 50% for C class pozzolana. However, the CBA contains 38.81% of SiO2 and 10.79% of alkali making the CBA unsuitable be classified into any pozzolana class.

Table 2: Chemical properties of coal bottom ash used in the study.

Description	N Class (%)	F Class (%)	C Class (%)	CBA sample (%)
SiO_2	-	54.90	39.90	38.81
$SiO_2 + Al_2O_3 + Fe_2O_3$	70.00	70.00	50.00	63.25
SO_3	4.00	5.00	5.00	17.79
Water Content	3.00	3.00	3.00	23.83
Incandescent lost (LOI)	10.00	12.00	6.00	-
Alkali	1.50	1.50	1.5.00	10.79
Pozzolan activity with 7 days lime	56.25	56.25	-	-

3.3 Compressive Strength Test Results

The highest value of compressive strength was obtained for the block made with zero percentage of coal bottom ash (control sample). However, the result also shows that the 20% coal bottom ash replacement provides the greatest compressive strength among the blocks manufactured with the bottom ash. At this percentage, the 28-day compressive strength was 3.11N/mm2 which is greater than the minimum required value of 2.8N/mm2 (BS 6073: Part 2: 2008). The 10% replacement has shown a 28-day compressive strength of about 2.85N/mm2 which is also greater than the minimum required value. This shows that the optimum replacement level of coal bottom ash is 20% of sand. The compressive strength then decreased gradually at 30, 40 and 50% partial replacements.

The results for the average compressive strength test of the block samples are shown in Figure 2.

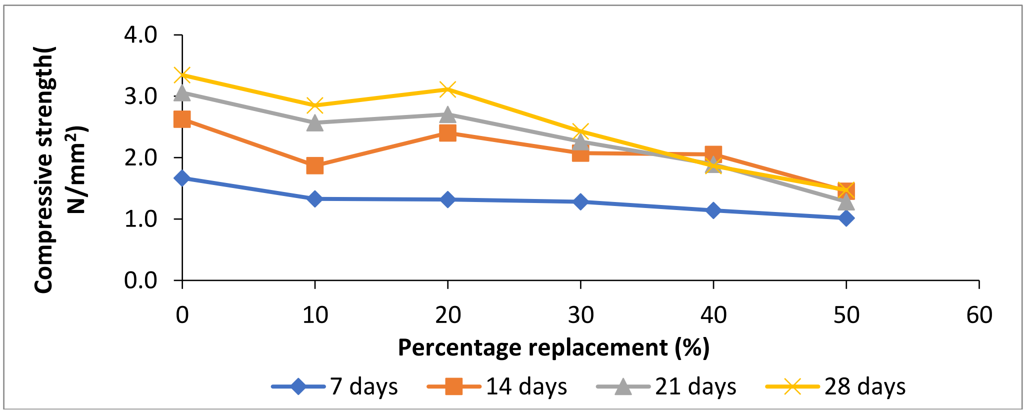

Figure 2: *Average compressive strength of sandcrete blocks for different coal bottom ash replacement levels.*

3.4 Dry density of block samples

The result shows a decrease in the density of the block samples with an increase in coal bottom ash replacement and curing age. This indicates that the coal bottom ash can be used as a lightweight material to produce blocks with acceptable strength. This will in turn reduce the weight of buildings.

The relationship between percentage replacement of sand with coal bottom ash and dry density of block sample is presented in Figure 3.

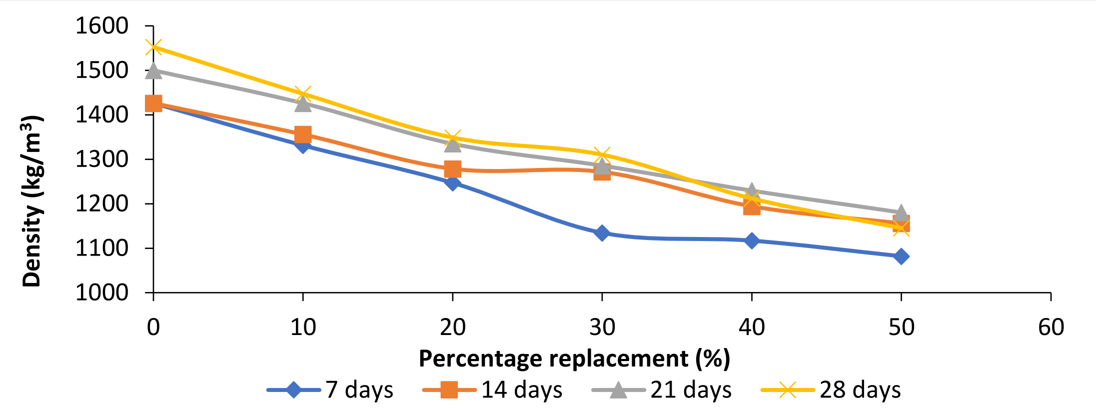

***Figure 3**: Relationship between dry density of block and percentage replacement of coal bottom ash*

4.0 Conclusion

The CBA used in this research contains 38.81% of SiO2 and 10.79% of alkali making it unsuitable be classified into any pozzolana class The block produced from coal bottom ash at 10 to 20% replacement level shows higher compressive strength than the required standard minimum value, this indicates that the block can be used to construct load bearing walls. In addition, the block produced from coal bottom ash is very much lighter than the blocks produced from sand, thus it can be used as a lightweight walling material.

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