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Research Article

Assessing the potentials of low impact materials for low energy housing provision in Nigeria

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ABSTRACT

Due to high energy consumption by building and a resultant increasing cost, it is imperative that a solution be sought after with the aim of achieving low energy housing delivery. This study aimed at assessing the availability, knowledge and importance of low impact building materials in the delivery of low energy housing. Low impact materials suitable for low energy housing delivery and how they are locally obtained in the study areas were identified, occupants' preference in the selection of low impact construction material for housing delivery were examined and the application of low impact material for low energy housing delivery in the study area were determined. The research focused mainly on three states in north central Nigeria namely; Niger, Kogi and FCT Abuja. Quantitative research method was used and weighted mean of responses were ranked in an ordinal manner from 236 respondents. The respondents were not aware of low impact materials as they were only aware and accustomed to using sandcrete blocks and burnt clay bricks. The outcome of the correlation established that the most preferred building material is the sandcrete block, showing a positive relationship with durability and structural performance as the influencers.

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1. INTRODUCTION

Due to the continuous increase in urban population in Nigeria, the need and importance of housing in society cannot be overemphasized. According to [1], affordable housing can be achieved through sustainability by incorporating environmentally friendly and community based principles through the choice of construction material. This will go a long way to reduce the negative impact residential buildings can have in the urban environment. All buildings which aim to reduce their impact on the environment could be called, at least, 'lower impact' but the term has come to mean those buildings using largely natural or organic materials. Such as, Compressed Earth Brick (CEB), Hydra Form (Interlocking Bricks), Timber, Clay, Lime, Rammed Earth, Cob, Straw, Hemp, Bamboo and Stone.

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Figure 1. **(a)** stabilized interlocking bricks, **(b)** straw (thatch), **(c)** Adobe, **(d)** Bamboo. Source: [7, 8].

Adequate housing delivery has been the target of many third world countries including Nigeria. The housing deficit of Nigeria falls at the range of 14 million housing units [2] and 17 million housing units. In a third world country like Nigeria, low energy and affordable housing have always been a far cry for an average Nigerian, despite all the strategies formulated by government to overcome shortage of houses by creating low energy and affordable housing scheme [3]. According to [4] it was revealed that 60% of the total housing expenditure goes for the purchase of building materials. Also one of the major challenges to poor housing delivery is high cost of building material, which is as a result of continuous importation of building and construction material from foreign countries.

This paper focused on assessing the availability, knowledge and importance of low impact building materials in the delivery of low energy housing, by identifying low impact materials suitable for low energy housing delivery and how they are locally obtained. It examined occupants' preference in the selection of low impact construction materials for housing delivery and determined the application of low impact materials for low energy housing delivery within three north central states namely; Niger State, Kogi State and FCT Abuja.

2. LITERATURE REVIEW

2.1 Provision of Low Energy Housing in Nigeria

According to [5] a low-energy new building is a building that is designed to achieve or to come close to the passive house standard and one where passive house or similar quality processes are followed to ensure that design energy use is realised in practice without compromising occupant comfort and satisfaction. In order to realise sustainable housing provision, the housing needs of the Nigerian population have to be put into proper focus and coordinated programmes. This need to be thoroughly worked out, with due consideration given to low impact materials available in Nigeria.

2.2 Low Impact Material in Nigeria

The introduction of modern technologies such as the concrete blocks and slabs during the industrial periods had relegated traditional components and methods to the background. Meanwhile, this new material did not provide same comfort as the traditional and locally sourced building material. Native dwellers rather have settled for the high taste of fashion, modernity, expressed of advancement and show of affluence and status in place of the sustainability that local and low impact material have to offer. Recently, more attention is been given to building material that can be very affordable and still deliver the same modern needs [6]. Hence, it is important to pigeonhole materials into five main groupings namely.

- Short term renewable origin (timber, wool, straw)
- Extracted or mined (earth, sand and gravel)
- Extracted and further processed (lime, cement, plaster, slate, stone, brick)
- Extracted and highly processed (steel, glass and plastics)
- Recycled or reclaimed (reused timber, brick, aggregate, steel, glass, insulation)

Some common low-impact building materials that can be sourced locally in Nigeria are shown in Figure 1 above.

2.3 Energy Use in Buildings

To achieve a material where the energy needed in the dynamics of that material is low, one needs to understand how this energy is derived in its various components. A building's lifecycle energy comprises its embodied and operational energy [9–14]. Numerous authors such as [13 –15] have categorized embodied energy of buildings into three components namely; Initial embodied energy (IEE), Recurrent embodied energy (REE), Demolition embodied energy (DEE).

2.3.1 Initial Embodied Energy (IEE)

This is the energy consumed in the production process of a product, from the extraction of raw materials and processing of natural resources to the manufacturing and transport of products to building construction sites. It also includes the energy that is directly associated with the construction activities. IEE is thus all the energy that is consumed in the pre-use phase of the building's lifecycle [15].

2.3.2 Recurrent Embodied Energy (REE)

This refers to the energy required to maintain, repair, and/or refurbish the buildings during their service life. REE is a function of how a building is used by its occupants, the maintenance demands of the occupants, the service life of the building, and the life span and quality of the materials and components [13].

2.3.3 Demolition Embodied Energy (DEE)

This is the energy consumed to destroy the building at the end of its lifecycle, recycle and re-use some components, and dispose of others by transporting the debris and waste to landfills or incinerators [14].

2.4 Operational Energy in Residential Buildings

Among the parameters for assessing sustainable buildings is operation energy. It is described as the energy used in keeping the indoor environment within the acceptable range and other human activities [16]. Operational energy can vary depending on the level of luxury essential to occupants, the predominant climatic environments as well as the operational plan [17]. Meanwhile, the energy expended by the occupants is referred to as delivered energy [18], while the energy embodied in resources found in nature: chemical energy embodied in fossil fuels (coal, oil, and natural gas) is known as primary energy.

2.5 Embodied Carbon Emission

According to [19] 8.1 Gt of carbon dioxides is added to the global system as a result of high impact buildings. The global system experiences a harsh impact as a result of high emission of carbon dioxide [20]. The Durban, South Africa, International Union of Architect (UIA) conference held in 2014 by the Architecture profession, jointly projected 2050 as year from which building will experience zero carbon emission. Developed countries are known to generate the greatest emission, however the greatest impact is felt in developing countries. CO_2, hydrocarbons, Nitrogen Oxides (NO_x) Sulphur dioxide (SO_2), Carbon-monoxide (CO) are known as industrial flue gas responsible for greenhouse effect [21]. Energy used during construction and utilization process is largely responsible for CO_2 in building [20]. Energy utilization and CO_2 emission to our natural environment can be largely traced to procurement and operation of majorly residential building. From the analysis made by [22] approximately 40% global energy utilization, 60% global electricity usage and 30% global GHG emission are traced to buildings.

3. RESEARCH METHODOLOGY

3.1 The Research Method

The research method adopted in this research process is quantitative research method with comparative research approach. According to [23] comparative analysis is conducted mainly to explain and gain a better understanding of the causal processes involved in the creation of an event, feature or relationship usually by bringing together variations in the explanatory variable or variables.

3.2 The Survey Design

Primary data was collected with the aid of a structured questionnaire as the research instrument to determine users' preference as regards the use of low impact materials. To achieve the objectives of this study, a structured questionnaire comprising range of skills established in the literature was designed to determine users' preference in relation to the application of low impact materials. The questionnaire was piloted several times in order to validate and improve the survey.

3.3 The Instrument

The survey questions were crafted in simple and straightforward English that is easy to understand to prevent the participants from giving up midway through the survey. It uses two types of closed-ended questions, namely the Checklist and Likert item/scale. The predetermined replies were made comprehensive to capture most materials shared by previous researchers who had done similar study.

3.4 Sampling

The target population of the study are general occupants of residential buildings and professionals of the built environment. The sample for the survey span across three regions of North Central Nigeria; namely, Niger State, Kogi State and FCT Abuja. For Niger State the regions of Bosso and Gidan Kwano were surveyed in Bosso Local Government Area, for Kogi state, Lokoja was surveyed and for FCT Abuja, Bwari, Wuse, Amac, Asokoro, Jahi and Garki areas were surveyed. The survey questionnaire was distributed using a convenience sampling method to reach both the professionals and non-professionals in the building industry. Several avenues were employed to send out questionnaires such as emails, personal messages and others posted on social media channels. The respondents were encouraged to share the questionnaires among their network so as to enable the questionnaire to reach beyond the immediate social and professional network of the respondents. This helped to increase the number of respondents as well as enhanced the external validity of the study. This is in accordance with survey strategies employed by [24].

3.5 Data Analysis

To achieve the set objectives, comparative analysis with the use of ordinal scale for ranking based on weighted mean and weighted scores and a bivariate correlation were used to analyze the responses gotten from the survey. Descriptive analysis was used to summarize respondents' demographic data while inferential statistics were used to achieve the problems itemized in the objectives.

3.5.1 Validity and Reliability

Prior to the analyses, a reliability test using Cronbach alpha was undertaken as obtained from SPSS 25. Content and construct validity were used to obtain the reliability and validity of the measurement items used in the study. According to [25] content validity is the extent to which a scale measures a concept that it is intended to measure. Construct validity shows how well a test or experiment measures up to its claims [26]. For multiple scales, Cronbach alpha measures internal consistency and indicates the consistency of responses [27]. The Cronbach alpha based standardized items obtained is 0.75 (Table 1) which means that the data is reliable.

3.5.2 Descriptive Statistics

Descriptive statistics was used to establish occupants' demographics in form of tables as well as the availability of low impact materials in the study area. According to [28] descriptive statistics is the process that analyzes quantitatively summarized data. Specifically, the weighted scores and the weighted mean of each statement were computed and ranked using the ordinal scale (Table 2). Ordinal ranking makes use of ordinal numbers such as 1,2,3,4, to rank a set of items based on a casual relation in an ascending or descending order.

3.5.3 Inferential Statistics

Inferential statistics was employed to make inferences about a population based on data that was gathered from the sample of the study. Correlation was used to derive inferences based on the relationship between the variables from the sample population. The correlation coefficient in this study was achieved using SPSS 25.

4. RESULTS, FINDINGS AND DISCUSSION

A total of 236 respondents were recoded from the 250 questionnaires administered. This shows a response rate of 94.4% [30]. Had a 77% response rate in a study on the built environment. Based on gender, males have a greater outcome with a frequency of 163 respondents as against females with 73 respondents as shown in Table 3. The increase in the male populace is as the result of the dominance of males in the building industry.

According to Table 4 and Table 5, self-employed, regular salaried and students came up with the highest frequencies having a combined percentage of 90.9%, having 79.2% of the respondents' income which falls below N100,000. This is barely enough to build a decent house with the current economic situation.

The Nigerian Government places the minimum wage of every worker at N30, 000 which is very low yet 26.7% of the respondents earn below N20, 000. This agrees with the assessment of World Bank which generally places Nigeria at the low middle class income level as of 2020.

Considering the nature of the study, it is important to validate the understanding of the concept of low energy material through the level of education. 87.7% of the respondents have post-secondary qualification which means that data obtained is from a well-educated sampled populace (Table 6).

Due to the nature of this research, some aspects were covered strictly by professionals. Table 7 shows the distribu-

Table 1. Summary of the reliability statistics for the questionnaire survey

Cronbach's Alpha	Cronbach's Alpha based on standardized items	Number of questions	Number of Items
0.708	0.750	17	68

Table 2. Interpretation of Mean Scores for Individual Statements (adapted from [29] p.245)

Range of mean	Quantitative description	Qualitative description
4.21 to 5.00	5	Strongly agree
3.41 to 4.20	4	Agree
2.61 to 3.40	3	Neutral
1.81 to 2.60	2	Disagree
1 to 1.80	1	Strongly disagree

Table 3. Distribution of respondents based on gender

Gender	Frequency	Percentage
Male	163	69.1
Female	73	30.9
Total	236	100

Table 4. Distribution of respondents based on occupation

Occupation	Frequency	Percentage
Self-employed/business	48	20.3
Regular salaried (private)	65	27.5
Regular salaried (government)	40	16.9
Casual/daily wage worker	07	3.0
Student	63	26.7
Housewife	01	0.4
Unemployment	08	3.4
Retired	04	1.7
Total	236	100

Table 5. Distribution of respondents based on income

Income	Frequency	Percentage
Below ₦20,000	63	26.7
₦20,000–₦50,000	42	17.8
₦51,000–₦80,000	45	19.1
₦81,000–₦100,000	37	15.7
N100,000 and above	49	20.8
Total	236	100

Table 6. Distribution of respondents based on education level

Educational level	Frequency	Percentage
Qur'anic education	04	1.7
Primary education	02	0.8
Secondary school	23	9.7
Post-secondary qualification	157	66.5
Post-graduate qualification	50	21.2
Total	236	100

Table 7. Distribution of respondents that are built environment professionals

Built environmental professional	Frequency	Percentage
Architect	27	27.0
Quantity surveyor	16	16.0
Town planner	13	13.0
Builder	14	14.0
Developer	5	5.0
Estate Valuer/surveyor	12	12.0
Civil Engineer	5	5.0
Land surveyor	3	3.0
Project manager	5	5.0
Total	100	100

Table 8. Years of professional practice of professional respondents

Professional practice (years)	Frequency	Percentage
0–5	50	50
6–10	27	27
11–15	11	11
16–20	04	04
Above 20	08	08
Total	100	100

tion of 100 professional respondents into the various fields of the built environment with architects (27%) been the highest as they are the ones closest to the clients to influence decisions as regards choice of materials as well as they are the original designers of the houses.

The majority of the professionals have between 0-5 years (50%) which shows a young influx of professionals with 12% at 16 and above years (Table 8). This distribution creates a balance of older experience as well as a young workforce who can implement the adoption of low impact materials for low energy housing delivery.

The result from Table 11 shows the knowledge of how available low impact materials are in the study area. However, the respondents are majorly conversant with sandcrete block which ranks 1st with a weighted mean of 4.64. This agrees with similar studies conducted in Ethiopia by [31] with cement been the widely known and used material. It

Table 9. Professional membership of professional respondents

Professional body membership	Frequency	Percentage
Nil	22	22
NIA (Nigerian Institute of Architects)	23	23
NIOB (Nigerian Institute of Builders)	11	11
NIQS (Nigerian Institute of quantity surveyors)	12	12
NIS (Nigerian Institute of Surveyors)	02	02
NIESV (Nigerian Institute of Estate Surveyors and valuers)	11	11
NICE (Nigerian Institute of civil Engineers)	06	06
CIPMN(Chartered Institute of Project Managers of Nigeria)	04	04
NITP (Nigerian Institute of Town Planners)	09	09
Total	100	100

Table 10. Materials used by the respondents in building construction

Materials used or specified	Frequency	Percentage used	Rank
Straw (thatch from grasses, rice husk)	70	29.7	6th
Mud bricks	105	44.5	3rd
Stone	88	37.3	4th
Bamboo	20	8.5	8th
Timber	168	71.2	2nd
Interlocking bricks	41	17.4	7th
Burnt clay bricks	80	33.9	5th
Sand crete blocks	218	92.4	1st

further showed that the low impact materials such as mud-bricks, straw, interlocking bricks and bamboo rank 4th, 6th, 7th and 8th respectively are not well known in comparison with sandcrete blocks. Stone and timber rank 2nd and 3rd and respectively [32]. Stated that bamboo is commonly found in the rain forests regions in Nigeria which agrees to it ranking as the least known material in the north central region. Sandcrete block ranked 1st as the most used material from Tables 10 and 12 respectively. This shows that these areas use high impact materials more due to the high content of cement in the sandcrete blocks [22]. Observed from findings that the cement and steel in the usage of sandcrete block alongside with reinforcements amount for 44% from cradle-to-grave energy and 57% of the material energy. This places sandcrete block on a high energy profile. However, mud bricks, timber, stone, bamboo, straw and interlocking bricks which ranks lower compared to sandcrete blocks from both tables in terms of usage have lower embodied energy and embodied carbon emission. According to ICE,

Table 11. Knowledge of the availability of low impact materials in the study

Low impact materials	Weighted score	Weighted mean	Decision rule	Rank
Straw (thatch from grasses)	818	3.47	Quite knowledgeable	6th
Mud bricks	945	4.00	Quite knowledgeable	4th
Stone	979	4.15	Quite knowledgeable	2nd
Bamboo	699	2.96	Barely knowledgeable	8th
Timber	971	4.11	Quite knowledgeable	3rd
Interlocking bricks	750	3.18	Barely knowledgeable	7th
Burnt clay bricks	931	3.94	Quite knowledgeable	5th
Sand crete blocks	1095	4.64	Highly knowledgeable	1st

Table 12. Level of usage of the mentioned materials as a walling material

Low impact materials	Weighted score	Weighted mean	Decision rule	Rank
Straw (thatch from grasses)	543	2.30	Not used	8th
Mud bricks	793	3.36	Barely used	4th
Stone	785	3.32	Barely used	5th
Bamboo	581	2.46	Not used	7th
Timber	837	3.55	Often used	3rd
Interlocking bricks	655	2.78	Barely used	6th
Burnt clay bricks	869	3.68	Often used	2nd
Sand crete blocks	1121	4.75	Most used	1st

Table 13. Locations where materials can be obtained

Material	Source in the study area
Straw (thatch from grasses)	Dried grasses and husks from rice farming, typical to FCT Abuja and Niger State
Mud bricks	Readily available in local areas of the study areas which entails digging the earth
Stone	Quarrying activities are seen in locations like Dutsen Kura, Maikunkele all in Niger State.
Bamboo	Pocket of bamboo clumps is found in Niger, Taraba, Plateau and Abuja (Atanda, 2015)
Timber	Timber is scarcely found in Abuja and Niger state been in the Sudan Savannah, but can be obtained in Kogi State as it is a derived Savanah (a transition from rain forest to savannah)
Interlocking bricks	It is not widely used as its practice in Nigeria is still at the early stage.
Burnt clay bricks	Produced in Niger state along Minna- paikoro road chanchaga.
Sand crete blocks	Readily available in all block industries in the towns of the study area

Table 14. Respondents preferred choice material for construction

Low impact materials	Weighted score	Weighted mean	Decision rule	Rank
Straw (thatch from grasses)	448	1.90	Not preferred	8th
Mud bricks	569	2.41	Not preferred	7th
Stone	724	3.07	Neutral	5th
Bamboo	612	2.59	Not preferred	6th
Timber	837	3.55	Preferred	3rd
Interlocking bricks	765	3.24	Neutral	4th
Burnt clay bricks	880	3.73	Preferred	2nd
Sand crete blocks	965	4.09	Preferred	1st

steel and cement have high carbon emission of 2.7 CO_2/kg and 1.0 CO_2/kg. Timber, bricks, straw and stone on the other hand have carbon emissions of 0.3 CO_2/kg, 0.2 CO_2/kg, 0.1 CO_2/kg and 0.1 CO_2/kg respectively.

Table 15. Factors that influenced respondents' choice of preferred materials

Preference	Frequency	Percentage	Rank
Buildability	38	16.1	4th
Aesthetics	36	15.3	5th
Structural performance	44	18.6	2nd
Sustainability	07	3.0	7th
Reduced total cost of building	42	17.8	3rd
Durability	52	22.0	1st
Readily available	09	3.8	6th
Accessibility	07	3.0	7th
Lack of knowledge about other materials	01	0.4	9th

Table 16. Factors that influenced respondents' choice of preferred materials

Low impact materials	WS	WM	Decision rule	Rank
Straw is easy to maintain	201	2.09	Disagree	8th
Mud bricks is easy to maintain once plastered	289	3.01	Neutral	6th
Stone is the easiest to maintain	322	3.35	Neutral	4th
Bamboo is does not need added treatment for its maintenance	270	2.81	Neutral	7th
Timber can only be maintained if treated against pest	351	3.66	Agree	2nd
Interlocking bricks can be easily maintained if the technical skill in construction is high	323	3.36	Neutral	3rd
Burnt clay bricks can be maintained easily just the way it is	321	3.34	Neutral	5th
Sandcrete blocks can be easily maintained.	412	4.29	Strongly agree	1st

Occupants preference as seen from Table 14 shows that sandcrete blocks, burnt clay bricks and timber are the preferred materials for building construction with a ranking of 1st, 2nd and 3rd respectively. This finding agrees with [33], who stated that the most common buildings both residential and public in urban centres in Nigeria are built typical with sandcrete blocks, concrete and timber. This further buttresses the fact that the occupants most preferred material has a negative impact to the environment and a need to switch to low impact materials. Low impact materials such as mud bricks, bamboo and straw were not preferred at all and they ranked 6th, 7th and 8th respectively. The occupants were neutral to interlocking blocks as well as stone which ranked 4th and 5th respectively.

Figures from Table 15 indicates that the respondents considered factors that influenced firmness ahead of aesthetics when choosing their materials. Durability and structural performance were the most influencers ranking 1st and 2nd respectively. Reduced total cost of building came 3rd while buildability came 4th, which entails that the respondents do not mind spending a little more on the materials as long as durability, structural performance and buildability are seen in that material. This is the reason why sandcrete blocks and burnt clay bricks were the most preferred materials. Aesthetics came 5th as well as sustainability coming 7th. This shows the level of knowledge that can be found amongst the respondents as regards sustainability and low energy materials. However, the respondents were neutral to interlocking blocks (hydraforms) also known as CSEB (Compressed Stabilized Earth Blocks) and did not prefer bamboo. These two materials can achieve durability, structural performance, buildability factors as well as synergizing aesthetics and sustainability for low energy housing delivery [33]. Stated that hydraforms are easy to build, less expensive [34]. In a test on Hydraform blocks came up with a compressive strength value as high as 4.6 MPa which was higher than the recommended 1 MPa for masonry units for all the blocks in Mettu, Nopa and Hurumu regions in Ethiopia [35]. Established that bamboo is light weight, easy to transport [37]; stated that bamboo has a compressive strength of 23.8 MPa at the top for untreated ones and 36.60 MPa at the top for treated ones. Hydraform blocks and Bamboo are great alternatives to the sandcrete blocks which are as well durable and also have a good compressive strength for residential buildings.

The cost and energy expended in maintaining a building falls under recurrent embodied energy. This influences the total embodied energy of the building. It can be seen from the respondents' responses in Table 16 that sandcrete blocks can be easily maintained as it is the most used and widely known. The neutral response to bamboo, hydraform, bricks and stone shows lack of adequate knowledge of the maintenance culture of materials. This factor influenced the reason why sustainability ranked 7th in the influencers

Table 17. Correlation between factors that influenced respondents' choice of preferred materials and the preferred

Variables	Buildability	Aesthetics	Structural perform.	Sustainability	Reduced total cost of bld.	Durability	Lack of knowl.	Readily avail.	Accessibility
Straw	0.056	0.043	0.045	-0.099	0.198***	-0.237***	-0.063	-0.054	0.000
Significance	0.392	0.512	0.493	0.131	0.002	0.000	0.337	0.405	0.998
Mudbricks	0.097	0.079	-0.095	-0.020	0.159**	-0.152**	0.039	-0.157	0.031
Significance	0.136	0.224	0.148	0.765	0.014	0.020	0.553	0.016	0.633
Stone	-0.041	-0.067	0.114*	0.029	-0.185***	0.062	0.105	0.096	0.056
Significance	0.532	0.308	0.080	0.662	0.004	0.345	0.109	0.140	0.388
Bamboo	-0.019	0.217***	-0.082	-0.071	0.359***	-0.344***	-0.075	-0.058	-0.035
Significance	0.770	0.001	0.210	0.278	0.000	0.000	0.251	0.376	0.590
Timber	0.009	0.165**	-0.221	-0.013	0.199***	-0.078	-0.050	-0.068	-0.013
Significance	0.885	0.011	0.001	0.845	0.002	0.231	0.445	0.301	0.845
Interlocking	-0.024	-0.008	0.164**	0.098	-0.040	-0.164**	-0.064	-0.045	0.160**
Significance	0.709	0.907	0.012	0.134	0.546	0.011	0.326	0.494	0.014
Burnt clay	-0.052	-0.022	0.146**	0.077	-0.002	-0.139**	-0.093	-0.012	0.137**
Significance	0.429	0.742	0.025	0.240	0.978	0.033	0.154	0.849	0.035
Sandcrete	-0.005	-0.066	0.031	0.023	-0.330***	0.255***	0.067	0.115*	0.023
Significance	0.936	0.315	0.640	0.727	0.000	0.000	0.307	0.079	0.727

Table 18. Importance of low impact materials

Potentials/importance	WS	WM	Decision rule	Rank
A reduced total embodied energy of the building	403	4.20	Agree	1st
A reduced total embodied carbon emission	398	4.15	Agree	2nd
Reduces the cost of construction	395	4.11	Agree	3rd
Reduces the cost incurred in day to day heating and cooling processes.(operational energy)	390	4.06	Agree	4th
Reduces environmental pollution through reuse of materials	369	3.84	Agree	5th

of preferred materials. Bamboo needs treatment which does not only improves its life span as a result of improved maintenance, it increases it compressive strength [36]. Mud bricks are easy to maintain once plastered. However, [37], iterated that steel moulded bricks bounded with mud plaster and plastered with sandcrete, gives the least amount of cracks compared to those moulded with wooden moulds.

From the table of correlation in Table 17, buttresses the fact that the users' preferred choice of building material been sandcrete have a relationship with topped ranked influencers been durability and structural performance. An alpha level of coefficient of correlation (r) for relationship within the bivariate data is placed at 0.01 and the level of significance (p) is placed at 0.05. There exists a positive relationship between sandcrete block and durability based with a r value of 0.225. This relationship is statistically significant. It means that the major reason for choosing sandcrete block is due to its durability, with high cost been the real cost. Reduced total cost showed a negative relationship with sandcrete blocks with a r value of -0.330. This shows that there is a relationship between cost and sandcrete blocks but a high cost is needed to achieve it.

Burnt clay bricks ranked 2nd from the weighted mean and it showed a positive relationship with structural performance (r=0.146) and a negative relationship with durability (r=-0.139) with both showing statistical significance. Both burnt clay bricks and sandcrete block have a higher impact compared to bamboo and hydraform. Bamboo showed a positive relationship with aesthetics (r=0.217) and reduced total building cost (r=0.359), both outcomes are statistically significant. It showed a relationship between durability but a negative one. This means that the bamboo is a material that is durable, cost effective and aesthetically pleasing. Hydraform showed a positive relationship with structural performance (r=0.164) and accessibility (r=0.160). This means structurally it is ok. It is easily accessible as it is produced on site. It however showed a negative relationship with durability (r=-0.139). The correlation that bamboo and hydraform has shown with structural performance and durability shows that it can serve as an adequate alternative to sandcrete blocks and burnt clay which have a higher impact on the environment.

When the importance and advantages of low energy materials are established, application becomes possible as it will be

Table 19. Respondent's agreement to the strategies of infusing low impact materials to building

Statements	WS	WM	Decision rule	Rank
Public awareness as regards the benefits of these materials	393	4.09	Agree	3rd
Training of specialists in the construction of low energy materials	422	4.40	Strongly agree	1st
Creating and implementing policies that will improve its usage	413	4.30	Strongly agree	2nd
Creating a maximum standard for embodied energy to a range of housing types	386	4.02	Agree	4th

Number of professional respondents=96; WS: Weighted score; WM: Weighted mean.

Table 20. Respondent's agreement to barriers preventing the integration of low energy materials

Statements	WS	WM	Decision rule	Rank
Lack of awareness by the users	389	4.05	Agree	1st
Mindset of seeing low energy materials as an indicator of been poor	361	3.76	Agree	5th
Occupants low income class	330	3.44	Agree	7th
The poor outlook of the finished product	351	3.67	Agree	6th
The life span of the material	368	3.83	Agree	4th
Clients preferred choice as regards the materials	372	3.88	Agree	2nd
Lack of database on the impact placed by high impact materials on the environment	372	3.88	Agree	2nd

Number of respondents=96; WS: Weighted score; WM: Weighted mean.

Table 21. Respondent's level of agreement to strategies for improving the awareness of low energy materials

Statements	WS	WM	Decision rule	Rank
Public enlightenment on the impact of high energy materials.	411	4.28	Strongly agree	3rd
A constant use of these materials by the building professionals and developers.	419	4.36	Strongly agree	2nd
Societal Enlightenment as against the mindset that low impact materials is for the poor who cannot afford expensive high energy materials.	408	4.25	Strongly agree	4th
Integrating the use of low impact materials in the curriculum of Architecture Engineering and Construction (AEC) education	424	4.42	Strongly agree	1st

Number of professional respondents=96; WS: Weighted score; WM: Weighted mean.

easily accepted. Table 18 showed the professional respondents' response with regards to level of agreement with respect to importance of low energy materials. All statements were agreed to which shows that the respondents are well aware of the benefits of these materials. [31] agrees that low impact materials reduce total embodied energy and total embodied carbon emission and reduces environmental pollution through reuse and recycling of materials. [38] agrees that low impact materials result in sustainable homes which is relevant to reduce cost of construction as well as reduce operational energy.

Table 19 shows agreement by the respondents to all the strategies that will infuse low energy materials into the building industry. Training specialists in the construction of low energy materials ranks top as agreed by [31]. This means that the professionals have interest in sustainable construction practices. Policies should be created and implemented by professional bodies backed with the power of the government [39]. Agrees as they suggested government creates a conducive environment that will improve the usage of low energy materials. The public are not left out and as such they should be an enlightenment towards the benefits and use of low energy materials.

Barriers inhibit the progress of any phenomena in a given space. As advantageous as low energy materials are, their use can be hindered. Table 20 shows all possible statements that can prevent the adoption of low energy materials fully for housing delivery. Topping the list is lack of awareness by the end users. These are the clients and they need to be aware of the existence of these materials. Clients preferred choice as established in objective two shows that durability is their prime focus. It also shows that though occupant's income level inhibits the integration of low energy materials, it is not a simile strong inhibitor as long as the client is knowledgeable and satisfied with the output.

As established from Table 20, lack of awareness is the strongest inhibitor to the integration of low energy materials in housing delivery. Table 21 shows strategies to improve awareness. Adding the knowledge of low energy materials to the curriculum of Architecture Engineering and Construction (AEC) education ranks first [39]. Agrees to this and a review of the AEC curriculum be done. The professionals and developers can help by constantly using low energy materials in construction while ensuring that the public understands the impact high energy materials have on the society. Societal enlightenment against stigma attached to the use of low energy materials has been poor ranked 4th but still has a significant impact.

5. RECOMMENDATIONS AND CONCLUSION

5.1 Recommendations

From the study, the following recommendations will be of great help which are categorized. Strategies that can result in the integration of low impact materials for low energy housing delivery include;

- Public awareness as regards the benefits of these materials
- Training of specialists in the construction and use of low energy materials
- Creating and implementing policies that will improve its usage by professional bodies and the government
- Creating a maximum standard for embodied energy to a range of housing types.
- The outlook of the finished product should be improved upon to look aesthetically pleasing
- The compressive strength of the materials should be improved so as to improve durability, structural performance and life span of the material.
- The public should be enlightened on maintenance policies and strategies that will make the use of these materials sustainable
- High impact materials should be reused or recycled to reduce the embodied carbon emission as well as embodied energy emitted.

Strategies to improving awareness amongst the masses of the existence and application of low impact materials include;

- Public enlightenment on the impact of high energy materials.
- A constant use of these materials by the building professionals and developers.
- Societal enlightenment as against the mindset that low impact materials is for the poor who cannot afford expensive high energy materials.
- Integrating the use of low impact materials in the curriculum of Architecture Engineering and Construction (AEC) education.

5.2 CONCLUSION

The aim of this study focused on assessing the availability, knowledge and importance of low impact building materials in the delivery of low energy housing. In achieving this aim, a threefold objective was set each tied to a research question. The first objective identified low impact materials suitable for low energy housing delivery and how they are locally obtained in the study areas. It was discovered that the occupants in the study area are more conversant with the use of sandcrete blocks and timber in their construction practices. The second objective focused on examining the occupants' preference in the selection of low impact construction materials for housing delivery. Nine variables were considered as influencers in the choice of the most preferred material. Sandcrete blocks and burnt clay bricks came out as the most preferred material with durability and structural performance been the major influencers. Although some of the unknown materials like bamboo and hydraform with good durability and structural performance were not chosen because of lack of knowledge. The third objective focused on determining the application of low impact material for low energy housing delivery in the study areas. The importance of low impact materials was established with strategies that can integrate low impact materials into low energy housing delivery as well as strategies that can improve the awareness of these materials established. Inhibitors to the application of low impact materials were also discovered. Conclusively, low impact materials have the potential to reduce the negative impact on the environment caused by high impact materials as well reducing the embodied energy of the building and operational energy. This is a sustainable construction practice and as such its knowledge and importance should be widely known as well as its application.

DATA AVAILABILITY STATEMENT

The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

FINANCIAL DISCLOSURE

The authors declared that this study has received no financial support.

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