Appropriate Green Materials for Affordable Building Construction in Nigeria

Shogo Musbau Adeniyi, Sarajul Fikri Mohamed, Moronfoye Sikiru Ademola

Abstract*: *There are severe issues for the deficiency of affordable house for low-income earners in developing countries such as Nigeria. The high cost of conventional materials has been established to be one the major factors that heightened the cost of building in recent times. However the integration of green building materials that are relevant and sustainable for building construction in the present dispensation will provide excellent solutions to overcome high price of construction. The study was carried out on all the available green materials in north-central Nigeria. Surveyed instrument was prepared and distributed to building professional experts that are registered member of various professional bodies in the building sector. Four hundred questionnaires were distributed in the north-central zone. Three hundred five questionnaires that were filled correctly was used for the data analyses. Analysis of moments (AMOS) software through the structural equation model (SEM) was used to analysis and generated a model for the study. The result discloses that earth bricks, stone/rocks, timber, Bamboo, thatches, straw fibre, and rice husk are very relevant green materials that can be used to achieve affordable building construction. Therefore, the use and integration of green materials in building construction will produce low cost housing units

Keywords: affordable house, green materials, conventional materials, building construction, low cost.

I. INTRODUCTION

In the current time, it is no longer news that developing countries are facing an increase hosing deficit for the citizen due high cost of conventional materials that are majorly used for the construction building. The building industry has varieties of materials for construction; hence the price of building largely depends on the type of materials used. The promotion of relevant green materials (GMs) will go a long way in the mitigation of the cost of building. GMs are materials that are found with vegetation environment, and they are natural materials that required little or no process before it could be used. According to Mehta & Sharma (2014), the use of green materials and its products stimulates the preservation of deteriorating non-renewable materials". Additionally, re-introducing green building materials into building developments will assist in reducing the ecological influences related to the abstraction, conveyance, treatment, assembly, fixing, recycle, reusing, and discarding of building sector of materials sourcing. Green materials are also available in variety thus, the need to assess the relevant and sustainable ones among them and recommending its total or a combination with conventional materials will go a long way in the delivery of affordable and sustainable accommodation for the middling people of the country.

Revised Manuscript Received on November 15, 2019.
***** Correspondence Author
Shogo Musbau Adeniyi*, Department of Quantity Surveying, Federal Polytechnic Offa. Kwara State, Nigeria. Email: sogo4qs@gmail.com
Sarajul Fikri Mohamed, Department of Quantity Surveying, Universiti Tecknologi Malaysia. Email: sarajul@utm.my
Moronfoye Sikiru Ademola, Department of Quantity Surveying, Federal Polytechnic Offa. Kwara State, Nigeria. Email: smoskad@gmail.com

II. GREEN MATERIALS

Most study reveals that any materials that consist of a fraction of positive ecofriendly distinctive quality are merely referred to as green materials (Fithian & Sheets, 2009). Green materials also mean natural resources, and its adoption for construction work in order to serve as an alternative to conventional materials and protect our environment is inevitable. The environmental benefits of building green, according to Phatak (2015), include; safety of environments and biodiversity, enhanced air and water value, reduce surplus flowing into watercourses, and the preservation of natural capitals. The use of green materials can also result in lower cost of operation since they typically require little or no further process before being used for constructions. Therefore, the use of GMs will reduce expenses to its lowest and the influence of green skill invention on the state of economy perceived from the viewpoints of price redeemable/efficiency is colossal.
The following are the promising green materials that may be restored as building materials.

i. Earth brick
ii. Bamboo
iii. Timber
iv. Thatches
v. Fibre

A. Earth bricks

Earth material has been used ever since man existing, most the first building in the universes was made of earth walls with thatched roof. In the study carried out by Oshike, (2015), it was revealed that since man begins the act of shelter construction, the earth has been the main material for wall constructions and earlier to the foreign arrival into the west coast of Africa, the earth was the primary construction resources in the area. Oshike further stated that It was used efficiently in the different climatic regions the adopted technique rest on the kind of earth, practical know-how ,and equipment as well as indigenous societies and customs of the public Zami, (2008), further

stressed that the earth materials for building construction by human has been in use since the existence of people in the whole world, mainly due to its resourcefulness and general availability. Thus earth remains the first material that is used on-site as a construction material that saves full cost, time, energy, environmental contamination, and carriage rate. Papayianni (2017) confirmed that earth structures had been used continuously in building from early days to the present time.

Earth materials significantly vary in colour and quality from the good red clay to the brownish type as shown in figure 1. (Fradinho & Nedelcu, 2017) further states that with the introduction of the adobe brick, an accomplished shape brick unit of weather dried mud, originated into actuality with advanced development stages.

Figure 1 Earth bricks of different colour and shape. Source: the author

Bredenoord (2017) concludes that earth-block knowledge is developing in many countries, well supported, and its enhancement produces prospects for the local production of raw materials, which is useful and economy as building materials that can be assessed locally in the housing construction industry.

B. Bamboo

Bamboo is available in Nigeria at all season of the year, its majorly used in the construction of building as prop to provide support for some element of building at construction stage, it is also used as scaffolding in high rise building. The recent study has shown that bamboo can be used to replace steel reinforcement in ground beam, lintel and short beam, according to Kayode & Olusegun, (2013), civil engineers has found out in their study that bamboo tensile strength is same to that of mild steel at its matured age and has an average of 1400kg/cm^2 to 2,800kg/cm^2.

Bamboo is available in Nigeria at all season of the year, its majorly used in the construction of building as prop to provide support for some element of building at construction stage, it is also used as scaffolding in high rise building. The recent study has shown that bamboo can be used to replace steel reinforcement in ground beam, lintel and short beam see figure 2. According to Kayode & Olusegun, (2013), civil engineers has found out in their study that bamboo tensile strength is same to that of mild steel at its matured age and has an average of 1400kg/cm^2 to 2,800kg/cm^2.

Figure 2: Stocks of Bamboo and its arrangement in a concrete beam. Source: engineering society.com

Internationally bamboo is used to produce mass housing for the people; according to Bredenoord (2017), bamboo was developed in Costa Rica as new hi-tech method to averting deforestation and serves as alternative to wood. Two hundred hectares of bamboo farm was cultivated due it cost advantages and seismic sound building materials.

C Timber

Timber is a material found in the forest and used around the world for construction activities. According to Ramage et al. (2017), they are natural materials from forest products that are readily available for small and big structures works.

Alex (2017) defined timber as one of the rare natural construction resources, which has many benefits such as non –toxic material, not enclose chemical and harmless to handle, and frequently use in house production. The hardwood is natural artifact of the earth material which is endlessly utilized and recycled on-site (see figure 3). Manufacture et al. (2017) confirms that it is wholly eco-friendly and can be easily recycled in other projects and at the end of its lifespan use as energy. Ramage et al. (2017) reveal that as a natural material, timber displays an essential distinction of its properties through samples of similar kinds due to its interface of features at the molecular and macro measures.

Dean, 2010), in a study discovered that timber is grown and produce locally in north Scotland as a sustainable and durable building material that is renewable, with little energy to process the tree to usable timber. The best timber used in northern part of Nigeria is originated from the matured male palm tree; they are rigid and heavy as well as unaffected by termite attack (Fradinho, 2017). According to Ramage et al., (2017) said that lumber achieve very well where strength (or strain) to weight is more significant than entire strength (or strain), specifically architectural and engineering projects can take benefit of this correlation, however, timber buildings may be substantially dissimilar from steel or concrete erections in physical and spatial design.

Figure 3: Timber in stocks in various sizes

D Thatches

The people have been using thatch for thousands of years to create durable roofs for their home, and if properly installed, is one of the most beautiful and practical forms of roofing available today. Thatch retains a tensile strength while used for roof, Fradinho & Nedelcu (2017), observed that the thatches are one of the oldest of all building materials known, thatch building uses matted or baled straw from wheat, oats, barley, rye, rice, and others.

Thatches, for example, shown in figure 4 is now commonly found and used in farm settlement buildings, museums, sit out bar of a big star hotel, and residential building across Nigeria.

E Fibre

One of the industrial wastes transformed into building materials are wood fibre. It is a moderate modern insulation brought into limelight in the last two decades (Klarić, et-al. 2015).

The wood fibre was generated from current technique of converting wooden leftovers from little and factories waste into lagging lodging. It is also a biodegradable and recyclable substantive material that fascinates carbon dioxide from the atmosphere in a maintainable system. Klarić, et-al. (2015) stated the importance of wood fibre in its variety of functions which includes inflexible protection, shield for timber structure such frames, trusses, and flooring, as well as elastic fortification for studs and roof rafters. There is another industrial waste such as molasses, fly ash, rice husk, bagasse, etc. A survey market price of these materials is present in table 1.0

Figure 4: Thatches in stock with the address of the supplier. Source: the author

Table 1.0 Green materials price survey

S/N	Green Materials	Availability	Cost (N)	Remarks
1	Earth bricks; size 200x100x100mm	Largely available	62.00/unit	Durable, thermal insulation
2	Bamboo 6-meter len.	Largely Available	N300.00/len	Durable
3	Stone/rock	Available	N2500/ton	Durable
4	Timber; 25mmx300mmx3600mm 50mmx150mmx3600mm 50mmx75mmx3600mm	 Available	 N800.00/len N600.00/len N300.00/len	 Durable Durable Durable
5	Thatches	Available in different types	N166.66/bounce	Durable
6	Fibres; Particle board 1200mm x 2400mm	Largely Available	N 1,000.00/unit	Durable

III. APPROACH METHOD AND DATA ANALYSIS

In the process of conducting this research, the study instrument was designed and distributed among the building professionals that are duly registered with their various bodies in north-central Nigeria. Out of the four hundred (400) questionnaires distributed in the six different states, 305 of the forms retrieve were suitable and used for the evaluation of data. The information from respondents was first entered into special package for social science (SPSS 22) for analysis, and structural equation model (SEM) statistical tool was furthermore adopted to assess a confirmatory factor analysis taking into consideration all the required fitness index parameters.

A. Fitness Index

The results of the analysis are compared with all the relevant fitness Index to reveal in what way the resulted model fit (Zainudin, 2012). Wan Afthanorhan (2014) noted that "there are numerous Fitness Indices in SEM that show in what way the model fit. It is recommended that the parameter of model fitness index is used through at least one of the fitness index category of SEM model fit categories of absolute fit, Incremental fit and parsimonious fit as pronounced by Wan Afthanorhan, (2014) in table 2.0

Table 2: Fitness indices

Name of category	Name of index	Index name	Level of acceptance
Absolute Fit	GFI	Goodness of fit index	> 0.90
	Chisq.	Discrepancy chi square	P > 0.05
	RMSEA	Root mean square of error approximation	< 0.08
Increment Fit	AGFI	Adjusted Goodness of Fit	> 0.90
	CFI	Comparative Fit Index	> 0.90
	TLI	Tucker-Lewis Index	> 0.90
	NFI	Normed Fit Index	> 0.90
Parsimonious Fit	Chisq/df	Chi-Square/Degree of freedom	< 5.00

Source: Zainudin, (2012)

B. Relevant Green Material Measurement Model Fit

The GMs construct consists of three sub-categories, viz, Earth Materials, Natural Fibres, and Industrial and Building Wastes. Each of the sub-constructs has a number of items or indicators. The indicators are together thirteen observed variables, as listed in Section B of the survey's questionnaire. The indicators are sub-divided into the sub-constructs as follows: Earth Materials (4 items), Natural Fibres (5 items), and Industrial and Building Wastes (4 items), respectively. Figure 5 presents the initial measurement model for the improved information constructs derived from AMOS analysis. Table 3 lists the

observed variable indicators for the initial measurement model for Improved Information construct.

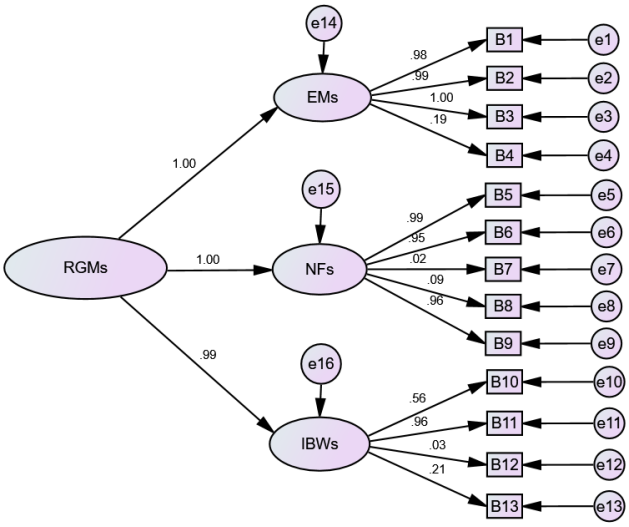

Figure 5: Initial measurement model for relevant GMs

Table 3: Indicators for the initial measurement model for relevant GMs construct

Constructs	Codes	Indicators
Availability of GMs	B1	Earth bricks
	B2	Stone/rocks
	B3	Timber
	B4	Lime
	B5	Bamboo
	B6	Thatches and grass
	B7	Coconut fibre
	B8	Palm kernel shell
	B9	Straw fibre
	B10	Fly ash
	B11	Rice husk
	B12	Cow dung
	B13	Bagasse fibre

Figure 5 shows the CFA results of fitness indices and factor loading for every item. Few of the fitness indices have achieved the acceptable range of respective indices; such that the (ChiSq / df=0.000 <3.00), (RMSEA=0.339 > 0.08), and the (GFI = 0.731, AGFI 0.618, CFI 0.691, TLI 0.623 and NFI 0.85 all < 0.90). This made the model fail the uni-dimensionality assessment. In order to achieve the uni-dimensionality of the model, the low factor loadings were deleted. Figure 5 demonstrates the modification measurement model for Relevant GMs construct that fits the acceptable range of index after the undervalued items were deleted. High MI values were treated, in which one of the paired redundant items was eliminated to obtain discriminant validity. The modification measurement model shows that all the error covariance values are less than 15, which is within the acceptable range for MI. The construct validity attained, in which the Fitness Indices for the construct (as shown in Figure 6) are within the required level. The values of Fitness Indices for final measurement model are: P-value=0.045, RMSEA=0.060, GFI=0.974, AGFI=0.959, CFI=0.933, TLI=0.922, NFI=0.846 and ChiSq/df= 1.62. Table 4 displays the Indicators for the modification measurement model for Relevant GMs construct.

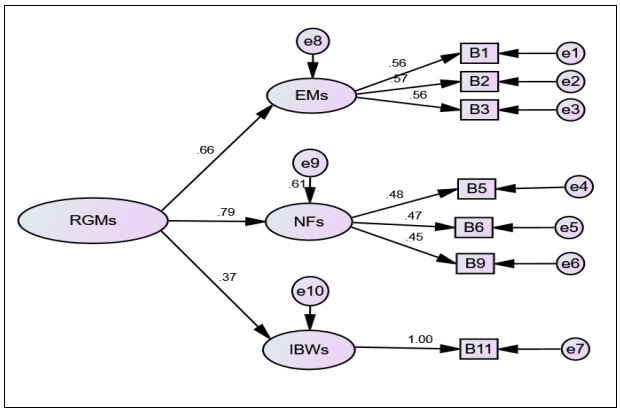

Figure 6: modified measurement model for Relevant GMs construct

Table 4: Indicators for the modification measurement model for Relevant Green Materials construct

Constructs	Code	Indicators
Relevant Green Materials	B1	Earth bricks
	B2	Stone/rocks
	B3	Timber
	B5	Bamboo
	B6	Thatches
	B9	Straw fibre
	B11	Rice husk

The model has passed the reliability assessment, in which the value of CR ≥ 0.6 is achieved. The convergent validity of the sub-constructs is significant with a value of AVE ≥ 0.5. The results of AVE and CR, which assessed the convergent validity and composite reliability of the Relevant GMs Construct model, are reported as shown in Table 5. With all the acceptable values described. Therefore, this modification measurement model for the Relevant GMs construct is fit for inclusion in the SEM structural model for further analysis.

Table 5: Validity and reliability assessment for Relevant GMs measurement model

Constructs	Sub-constructs	Items	Factor Loading (≥ 0.5)	AVE (≥ 0.5)	CR (≥ 0.6)
Relevant GMs	Earth Materials	B1	0.56	0.95	1.21
		B2	0.57		
		B3	0.56		
		B4	Deleted		
	Natural Fibres	B5	0.48	0.65	0.88
		B6	0.47		
		B7	Deleted		
		B8	Deleted		
		B9	0.45		
	Industrial and	B10	Deleted	1.	
		B11	1.00		

	building waste	B12	Deleted	00	0
		B13	Deleted		.89

IV. CONCLUSION

The delivery of affordable building to the average citizen of many developing countries remains a mirage; thus, this formed the main reason for carrying out this study, to establish or reactivates significant green materials that can be used to replace conventional material in the construction of building. The extensive literature review and survey of relevant GM pinpoints various green materials and reveals that the adoption of GMs can result to lower cost of operation since they typically require little or no further process before being used for construction works (Phatak 2015). The result of this study reveals that the most significant GMs available for low-cost building construction in Nigeria are earth bricks, stone/rocks, timber, bamboo, thatches straw fibre, and rice husk. (Nwoke & Ugwuishiwu 2011, Adegun & Adedeji 2017) Similarly, found out that earth bricks and bamboos are very suitable and have been put into used in the construction of building in Nigeria. In conclusion the integration of appropriate green materials for construction of building will reduce price drastically and make housing affordable to the lower-income earners in the society.

ACKNOLEGDEMENT

The researcher wishes to appreciate the ministry of education (MOE) Malaysia through research university grant (RUG) grand project number Py/2017/01501 and government of Nigeria through TETFUND for monetary supports in accompanying the investigation drudgery.

REFERENCES

1. G. Mehta, A. Mehta, and B. Sharma, "Selection of Materials for Green Construction : A Review," vol. 11, no. 6, pp. 80–83, 2014.
2. C. Fithian and A. Sheets, "Green Building Materials Determining the True Definition of Green Green Building Materials," pp. 1–13, 2009.
3. U. J. Phatak, "GREEN BUILDING MATERIALS – A Way," vol. 4, no. 4, pp. 244–249, 2015.
4. E. E. Oshike, "Building with earth in Nigeria: A review of the past and present efforts to enhance future housing developments," vol. 4, no. 1, pp. 646–660, 2015.
5. M. Zami, "Using earth as a building material for sustainable low cost housing in Zimbabwe," *Built Hum. Environ. Rev.*, vol. 1, pp. 40–55, 2008.
6. I. Papayianni and V. Pachta, "Earth Block Houses of Historic Centers. A Sustainable Upgrading with Compatible Repair Materials," *Procedia Environ. Sci.*, vol. 38, pp. 274–282, 2017.
7. J. Fradinho and D. Nedelcu, "Vernacular Architecture of Northern Nigeria in the Light of Sustainability," 2017.
8. J. Bredenoord, "Sustainable Building Materials for Low-cost Housing and the Challenges Facing their Technological Developments: Examples and Lessons Regarding Bamboo, Earth-Block Technologies, Building Blocks of Recycled Materials, and Improved Concrete Panels," *J. Archit. Eng. Technol.*, vol. 06, no. 01, pp. 1–10, 2017.
9. O. Kayode and A. E. Olusegun, "Local Building Materials : a Tool Towards Effective Low-Income Housing in Nigeria Department of Architecture Rufus Giwa Polytechnic , Owo , Nigeria," vol. 18, no. 4, pp. 492–497, 2013.
10. M. H. Ramage *et al.*, "The wood from the trees: The use of timber in construction," *Renew. Sustain. Energy Rev.*, vol. 68, no. October 2016, pp. 333–359, 2017.
11. R. Manufacture, T. Distance, L. Cycle, and C. Flooring, "Cost Effective Green Flooring Options Eco Friendly Flooring Materials Sorted by Cost."
12. S. Dean, "Using Local Timber - Contributing to Sustainable Construction. Guidance for North Scotland," no. March, 2010.
13. S. Klarić, A. Novalic, Z. Hujdur, I. Aybek, and A. Dautovic, "Advantages of Natural Renewable Materials in the Building Sector," *3rd Int. Conf. "The Importance Place,"* no. December, pp. 445–463, 2015.
14. A. Zainudin, "The Second Order Confirmatory Factor Analysis," *A Handb. SEM*, no. March, pp. 163–181, 2012.
15. W. M. A. Wan Afthanorhan, "Modeling the Multiple Indirect Effects among Latent Constructs By Using Structural Equation Modeling : Volunteerism Program," *Int. J. Adv. Appl. Sci.*, vol. 3, no. 1, pp. 25–32, 2014.
16. O. A. Nwoke and B. O. Ugwuishiwu, "Local Bamboo and Earth Construction Potentials for Provision of Affordable Structures in Nigeria," *Int. J. Sustain. Constr. Eng. Technol.*, vol. 2, no. 2, pp. 17–31, 2011.
17. O. B. Adegun and Y. M. D. Adedeji, "Review of economic and environmental benefits of earthen materials for housing in Africa," *Front. Archit. Res.*, vol. 6, no. 4, pp. 519–528, 2017.

AUTHORS PROFILE

Shogo Musbau Adeniyi is currently an assistant chief lecturer at the Federal Polytechnic, Offa, Kwara State, Nigeria. The author obtained his first degree in quantity surveying in 1997 at the Federal University of Technology Minna, Niger State Nigeria, and master's degree in construction management at the prestigious University of Lagos, Nigeria, in 2011. The research area is on Public-Private Partnership (PPP) and Green Materials for construction of affordable buildings. He is a registered member of Nigeria Institute of Quantity Surveyors (NIQS) and register quantity surveyor certified by the Quantity Surveyors Registration Board of Nigeria (QSRBN). Presently at the final laps of his Ph.D. in Quantity Surveying program at the Universiti Tecknologi Malaysia. He has about 20 years of working environment in academic and practical works in the construction industry

ASSOCIATE PROFESSOR Sr DR. SARAJUL FIKRI MOHAMED is an academic staff at the Department of Quantity Surveying, Faculty of Built Environment, Universiti Teknologi Malaysia, Johor Baharu, Johor where he specializes in Construction Management, Project Estimating and Construction Innovation. He obtained B.Sc. in Quantity Surveying from Universiti TeknologiMalaysia (UTM). In the year 2002, he completed his Master of Science in Construction Innovation and PhD in Construction Management in 2006 from Loughborough University, United Kingdom. His research areas include construction procurement, construction innovation and commercial management in construction. Prior to this, he worked as property and construction consultant at MDA Consulting UK. The examples of projects he was involved in are Stratford Western Relief Road (Warwickshire County Council), William Baker Building (University of De Montfort), Airfield Business Park Market Harborough (William Davis), and Sport Complex Building (Leicestershire County Council). He has more than 17 years working experiences in related field.

Sikiru Ademola Moronfoye is a Lecturer in the Department of Quantity Surveying, School of Environmental Studies, Federal Polytechnic, Offa, Kwara State, Nigeria. He holds B.Sc (Hons) Quantity Surveying from Ahmadu Bello University, Zaria, Nigeria and M.Sc (Construction Project Management) from University of The West of England, Bristol, United Kingdom. Sikiru. Ademola Moronfoye is a Corporate Member, The Nigerian Institute of Quantity Surveyors and also a Registered Quantity Surveyor with The Quantity Surveyors Registration Board of Nigeria. Mr Moronfoye research interests are in the area of Public Private Partnership, Employees motivation, Strategic Management, and Health and Safety in Environment. He has over twenty years teaching experience in Quantity Surveying and Construction Project Management with bias in subjects like Measurement of Engineering Services in Building, Construction Contracts and Procurements, and Research Methodology.