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Inhibitors to Earth-based Materials Adoption in Urban Housing Construction: The View of Design Experts

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ABSTRACT: Earth-based materials are eco-friendly and harmless to the environment but have been neglected and relegated, and preference is given to non-sustainable and expensive conventional materials owing to certain factors. Existing studies in the Nigerian context did not consider the factors hindering the use of earthen materials in urban low-cost housing production. This study presents the outcome of examining the inhibitors to the adoption of earth-based materials in urban housing construction from the perspective of design experts in a developing country like Nigeria. Thus, it fills the critical literature gap in the Nigerian context. A well-structured quantitative questionnaire was utilised to collect data from construction design experts using the snowball sampling technique via electronic means. With a reliability index of 0.899, The gathered data were analysed using frequencies, percentages, Mean score, normalisation value technique, Mann-Whitney U test, overlap analysis, and exploratory factor analysis (EFA). It was found that the major barriers to the use of earth materials in urban housing production are (i) image and aesthetic barriers, (ii) Knowledge and resistance barriers, (iii) technology and data barriers, (iv) strength and maintenance barriers, and (v) demand and demographic barriers. More training and workshops were advocated to increase knowledge of the environmental and economic benefits of these materials among stakeholders to influence their interest and the market for earthen materials' acceptability and usage in housing production in urban areas.

KEYWORDS: Environmental performance; earth-based materials; sustainable construction; eco-friendly materials; barriers; urban housing construction

1. Introduction

The construction industry is responsible for driving infrastructure and economic growth and development. The need to meet the socio-physical needs and infrastructure of the ever-growing citizenries drives house-building provisions by the state. Urbanisation and Rural-urban drift have caused rapid population growth in the cities, and this puts pressure on the few available houses and contributes to the housing problems faced by nations, hence, the urban housing crisis [1]. Also, housing deficits are among the factors responsible for the high cost of buildings (Ibid). Conventional building materials and approaches have been relied upon in the quest to meet the housing needs of the citizenry. These materials are injurious to the environment and, by extension, the economy, as well as lead to unsustainable development [2, 3]. The traditional conventional building construction procedures utilise eco-harsh, eco-friendly, unsustainable products that are inimical to the environment [4]. Conventional buildings consume and deplete natural resources, degrade the environment, emit a lot of CO_2, and are the leading energy users in the globe [5]. In mature construction markets like the UK, there is pressure to meet the housing needs and, at the same time, make frantic efforts to minimise greenhouse gas emissions. One of the ways of mitigating GHG emissions is the use of earth-based materials with lower embodied carbon [6].

Earth-based materials are alternative building materials that have been advocated by researchers to be a suitable replacement for imported building materials used in substructure and superstructure works [7]. The United Nations conference made a case for the development and adaptation of local building materials in building techniques for local conditions [8, 1]. Earth-based materials such as adobe (laterite) blocks, Rammed Earth, Compressed earth bricks, natural Clay and mud, and Bricks and tile are regarded as green, sustainable, or environmentally friendly building materials that are recyclable, consume low energy, non-toxic during production and usage [9]. The need to pursue a sustainability agenda has put pressure on the demand for eco-friendly materials in order to resolve the global issues on the environment. Thus, materials with lower embodied energy and compatibility with the climatic conditions of the place are considered [10, 7]. Earth-based materials such as mud brick and rammed Earth are used to produce cheap houses and have continued to find use in advanced construction markets of the world. For example, in France is "Pise de terre", in South America is "Adobe" [11], and in Africa, particularly in Mali, is "Djenne's Mosque" [11]. Earth-based materials are ecologically responsible and contribute significantly to mitigating the effects of harmful gaseous emissions responsible for greenhouse effects, inequality in the ecosystem, global warming, and others. These materials are known as “friends of the environment” as their impact on the environment is zero [13].

The use of these materials in housing production for the economically disadvantage earners in society has dropped in the last decades owing to advances in technology and client sophistication [14]. Furthermore, according to [12], the use of laterite has been relegated to the background, and the few ones that exist in rural areas are less recognised. Furthermore, owing to the bias and stigma attached to earthen materials, which links them to people experiencing poverty in society, these materials face acceptability problems [1]. These have made owning a house in the cities expensive and uneconomical for most of the citizenry in developing countries like Nigeria. Despite the efforts of the public and private sectors to meet the demand of low-income earners in Nigeria, the use of technology and overreliance on imported conventional building materials have made the delivery of house building expensive and less economical for low-income earners [15]. The advantages of Earthen materials over conventional materials include being 100% natural, affordable, readily available in substantial quantities, zero waste, detoxifying role, fire resistance, humidity control, very low carbon footprint, low cost of excavation and easy workability [1, 14]. Thus, there is an increasing call for the use of these alternative building materials in the production of residential houses [15].

It is evident from the literature that the interest and use of earthen materials for housing construction have declined in both advanced and emerging construction markets [16–18]. This is despite the severe shortage of affordable housing and the high cost of conventional buildings.

In the local context, there are few studies, and they mostly adopted simple descriptive statistics in their methods, among other issues [15, 19–21]. Furthermore, none of the studies carried out in Nigeria covered the south-south region of Nigeria. For example, in the southwest, there are [20, 22], in the northern region [9, 19, 24]. The study by [21] only covered Port Harcourt, which is just a city in the six states that make up south-south Nigeria. In addition, none of these cited studies emphasised the barriers to the adoption of earthen materials in housing construction in urban areas, especially in the production of low-cost housing. Furthermore, the emphasis has not been given to the views of design experts in the construction industry, whose responsibility is primarily the designing of buildings and the selection of materials for housing production. Based on the preceding knowledge, this study assesses the inhibitors to the adoption of earth-based materials in urban housing construction in developing countries, using Nigeria as a case in point. The outcome of this study will help the government and other players in the construction market to understand the key issues surrounding the use of Earth for building construction in urban areas and map out strategies for mitigating them. In addition, to leverage the Environmental and economic benefits of these materials, the factors hindering their usage in urban housing need to be identified and mitigated. Earthen materials are readily available in the locality in their natural form, thus, making them cheap and economical for housing production. In the long run, they can be reused and recycled, thus putting them into a continuous use that does not put pressure on nature's resources. Environmentally, they are equally pollution-free and minimise the quantity of cement used in buildings, and this has a reduced impact on CO_2 emissions, thus offering protection to the environment and a safe and healthy living space for occupants [14]. A "universal access to adequate housing" and "maximising the use of local materials in construction" are well captured in SDG 11.

2. Barriers to the Adoption of Earth-Based Materials in Construction

Local experts have observed that the demand for earthen construction is growing in developed countries such as the UK, USA, France, etc, and this is driven by the need to build houses that are sustainable and have low embodied carbon [25, 26]. The use of earthen materials in urban construction is evident in some developing countries of Egypt, Bangladesh, Pakistan, and India, but their proportion is insignificant compared to non-earthen buildings [25]. This is an indication of an "unsaturated and untapped sustainability market" in developing countries worldwide. In India, the use of earthen materials for housing development has declined, and this has contributed to the housing shortage experienced in the country [17]. A critical factor responsible for this decline in the use of Earth is 'image'. The widespread reduction in the acceptance of earth houses is that it is ink to poverty. The pressure from industrialised building materials has also contributed to the decrease in the use of local and traditional materials and techniques, as they are unable to compete favourably with these imported and advanced building materials. However, the low interest in these materials does not make them lose their potential, as earth-based houses are expected to come back to the limelight in future because of the cost savings potential over concrete [17]. Previous study [18] reported the perception of end-users and experts in the construction sector in the United States on the barriers to the use of earth base materials and methods (EBMM) in mainstream construction and found that the major barriers to the implementation of EBMM are high labour intensity of the construction process, lack of experienced contractors and professionals as well as unexpected costs, difficulty in getting the permit for building earthen structure, problems of insuring earthen house by insurance companies and high maintenance requirement. Another study confirmed that earthen housing has declined relative to housing made from non-earth base materials [27]. This situation was blamed on changes in demographic variables and negative perceptions of earth materials, especially in developing nations of the world. Furthermore, the lack of current information on the trends and distribution of earthen housing has hindered effective research and policy for earthen housing. Earth is a sustainable material that supports the circular economy, but its use in the construction sector is limited by factors such as Steering mechanisms, Processes, Economics, Client understanding and Underpinning knowledge [28]. The steep decline in the use of vernacular earthen structures is because of the lack of standardisation of earth-based materials, rapid development, lifestyle changes and high level of adoption of energy-intensive modern construction materials [29].

Previous study [29] adopted a Delphi technique and summarised the fourteen major inhibitors and drawbacks to the use of earthen materials in the construction of a building. Some of the inhibitors include the absence of knowledge among stakeholders, wrong perception, lack of use of technology, low technical performances, aesthetics considerations, absence of building codes and policies, legislation considerations, and non-existence of policies for reducing energy-intensive materials, among others. These factors make the production of earth-based housing to be unpopular among construction professionals. Thus, in the UK nowadays, Earth as a building material is under-exploited in the construction of houses [30]. Construction practitioners' perception of the barriers to the use of earth construction materials in the circular economy context in the UK [31]. The authors categorised the barriers to the use of earth materials into five groups: economic barriers, organisational barriers, sociological barriers, political barriers and technical barriers.

In Nigeria, the factors that affect the acceptability and unpopularity of bricks made from the Earth are perceived structural shortcomings, lack of skilled labour for bricklaying, lack of standards of material and workmanship, environmental adaptability issues, accessibility, supply shortfalls, poor marketing by brick manufacturers and the perception of local materials as inferior [21]. In the Ghanian construction industry, previous study reported that despite the obvious benefits such as cool room temperature, readily available and affordability of the earth materials, and cultural heritage, the major challenges of earth base houses are high and frequent maintenance requirements, low strength, easy wearing and erosion, and require a high number of labours [16]. The improvement of locally made or available materials will help to improve their use in the construction of houses in urban areas. In the study [32], it was found that the key barriers to the use of earth products like burnt clay brick for housing development are perceived as high cost, low demand for the materials, non-compatibility with other materials, inappropriate use in construction, unpredictable production and problems of transportation. Earth materials have one or more problems that hinder their use in housing production in urban areas, and these have been duly acknowledged by several studies in developing nations such as Uganda and Algeria [33–34]. Building made of the Earth has a short lifespan, and it is vulnerable to termite attached, lacks standardisation, has low structural strength, and is readily eroded by rains and other weather elements [34]. These factors contribute to the limitation of the use of the Earth in housing construction.

3. Research Methodology

This study adopted a well-structured questionnaire in the collection of quantifiable data from design experts in the construction industry to meet the study's aim. The questionnaire is appropriate for large audiences covering wider areas, as in the case of this study, which covered the south-south geopolitical zone (housing six states) of Nigeria. It is economical and time-saving and is common among social researchers [35]. Experienced construction design experts who practice in states such as Bayelsa, Akwa Ibom, Cross River, Edo, Rivers, and Delta states were sampled. These states make up the south-south geopolitical zone of Nigeria. These experts are Engineers and Architects involved in making design decisions and selection of materials in house building projects, and since these experts are scattered across the study area, the questionnaire becomes appropriate to reach the participants [4].

Following an extensive literature review, the questionnaire was developed and designed to consist of two sections. The first section collected data on the demographic information of the participants and served as a quality check to data obtained from the second section. The second section garnered responses on the barriers to earth-based materials adoption in urban housing construction. The respondents were required to rank the selected barriers based on the extent of their agreement on how they have hindered the use of earthen materials in housing construction in urban areas. The questionnaire was based on a 5-point Likert scale ranging from 1 to 5, where (1 = lowest scale; 5 = the highest scale). Aside from the criteria of residing and working in the study areas, the participants were required to be experienced in construction, knowledgeable on green/sustainable building materials and construction, and have at least five years of practice experience. This informed the use of the non-probabilistic snow sampling technique since there is no separate database of experts with these attributes; as such, a firm sample size could not be determined. The snowball sampling technique thrives on referrals from respondents to respondents, and it can increase the response rate [36].

The electronic questionnaire developed in Google form was used in the data collection and was administered to the first set of participants identified via a preliminary survey of the study area and from the researchers' own cycle. Google Forms is easy to design and flexible to use in data collection, making data analysis less cumbersome. Electronic questionnaire in Google form makes data collection faster, especially from wider audiences separated by substantial distance. According to [37], "the electronic questionnaire is 'eco-friendly' as the hardcopy paper questionnaire is completely avoided". Furthermore, it was indicated in the questionnaire that only experts practising within the study area should participate in the survey. This is to avoid participation from unqualified persons. The pilot survey was conducted to ensure the accuracy and reliability of the questionnaire. This was done by piloting small groups of 12 design experts from the industry and academia. These experts consist of design consultants, senior Architects, Urban Environmental engineers, and academic researchers with appreciable knowledge and experience in urban housing provision and sustainable city design and development. The feedback and recommendations from the pilot survey were incorporated into the questionnaire before the final administration of the questionnaire. These measures were taken to improve the study’s reliability and acceptability.

After the survey period of sixteen weeks, data saturation was reached when a total of 101 usable responses were obtained. These 101 responses served as the basis for the arrays of analyses carried out in this study. The breakdown of the responses shows that 11(10.89%) of the design experts participated from Akwa Ibom state, 9(8.91%) are from Bayelsa state, 11(10.89%) from Cross River state, 29(28.71%) from Delta state, 15(14.85%) from Edo state and 26(25.74%) from River's state. The gathered data were analysed using frequencies, percentages, Mean score and normalisation value technique, Mann-Whitney U test, overlap analysis, and exploratory factor analysis (EFA). The Cronbach's alpha test was used to establish the research instrument's reliability. This test also measures the instrument's internal consistency. Cronbach's alpha test generates values that range from 0 to 1, and the nearer the value to 1, the more reliable and acceptable the instrument is [38]. An alpha coefficient of 0.899 was obtained for the 26 assessed variables, and based on this, the research instrument was adjudged to have demonstrated high acceptability and reliability. Frequencies and percentages were used to analyse the respondents' basic information. The mean score was used to rank the variables based on their relative mean weights. The normalisation value (NV) technique was used to reveal the most critical barriers to earth-based materials adoption. Critical items were established using a cut-off point of at least 0.60 [39], and this is determined using the formula below.

$$\text{Normalised value (NV)} = \frac{\text{(Mean value of barrier - Minimum mean value)}}{\text{(Maximum mean value - Minimum mean value)}} \quad [1]$$

The normality test was conducted using the Shapiro-Wilk normality test as suggested by [40], and the result showed that the assessed factors had a significant value less than 0.05 threshold for normality. This showed that the data are non-parametric. Mann-Whitney U test was conducted to determine if there exists a difference in the perception of the Architects and Engineers' rating pattern of the variables. This test compares the median of two respondents' groups [40], which makes it suitable for use in this study. Furthermore, the Mann-Whitney test is appropriate for assessing the significant difference between the views of the two groups since the data are non-parametric. The data collected on the barriers to earth-based materials adoption in urban housing production were analysed using Exploratory factor analysis (EFA). The EFA helped to reduce and group the variables into a more meaningful and manageable proportion. The "principal component analysis" (PCA) with "varimax rotation" was adopted as the data extraction method. The sample adequacy and factorability were confirmed before running the EFA. The adoption of EFA is one of the gaps identified in existing studies. Existing studies on earth-based construction materials adopted frequency, percentage, mean analysis and relative importance index in their analyses. Except for the NV test, the analyses were carried out on a statistical package for social science (SPSS) IBM 20.

4. Results and Discussion

4.1. Basic information of respondents.

From the analysis of the basic respondents' information, 47.52% of the design experts are Architects by profession, and 52.48% of them are Engineers by profession. This is a fair representation of the key construction experts who are involved in design decisions and decisions regarding materials selection and specification in the construction industry. Overall, the average year of experience of the participants is 13 years. However, a further breakdown shows that 37.62% have spent 5-10 years, followed by 32.67% who have spent 11- 15 years, 18.81% have 16-20 years, and 10.89% have spent 21 years and above. This indicates an appreciable level of experience in the industry. In terms of highest educational qualification, those with a bachelor's degree (BSc/B. Tech) are highest with 46.53%, this is followed by those with a master's degree (MSc. /M.Tech.) = 32.67%, then those with Higher National Diploma (HND) =16.83%, then, and finally 3.96% have Doctorate (PhD). This implies that the respondents possess the requisite education to understand the questions and give quality and reliable responses. The experts who participated in this study are mostly chartered professional members of their various professional bodies. This is premised on the number who indicated that they are chartered members (87.10%) of their professional body. Those who are probationer members constitute only about 12.9% of the respondents.

4.2. Ranking of barriers to Earth-based materials in urban housing.

The outcome of the mean score $(\bar{x})$ and normalisation value (NV) techniques carried out on the barriers to earth-based materials adoption in urban housing production are displayed in (Table 1). Notwithstanding the relative ranking of the barriers by the respondents, the most important barriers based on the overall mean score are low social image and poverty ($\bar{x}$=4.43), easily wearing and erosion ($\bar{x}$=4.42), low structural strength ($\bar{x}$=4.35), Pressure from Industrial materials ($\bar{x}$=4.34), and lack of scientific/technical data ($\bar{x}$=4.30). The least important barriers are being vulnerable to termite attached ($\bar{x}$=3.80), requiring high numbers of labour ($\bar{x}$=3.75), non-availability of skilled workmanship ($\bar{x}$=3.75), low technical performance ($\bar{x}$=3.65), and low demand for the materials and products ($\bar{x}$=3.53). However, regardless of the relative ranking of these variables, they are all significant in hindering the use of earthen materials in urban housing production. This is premised on the maximum, minimum and average mean values of 4.43 (88.68%), 3.53 (70.57%) and 4.07(81.38%), respectively. Furthermore, the normalisation value (NV) technique was used to reveal the most critical barriers to earth-based materials adoption. Overall, based on the NV technique, fourteen barriers with normalised values ≥ 0.60 are B01, B02, B03, B04, B05, B06, B07, B09, B11, B12, B13, B15, B16, B18, and B20. Twelve (46.15%) of the barriers were rated to be critical by the Architects, and the Engineers rated 14(53.85%) of them as critical barriers (Table 2). To determine if any significant difference exists between the respondent groups, the Mann-Whitney (M-W) test was carried out. The test showed a convergence view in the rating pattern of 25(96.15%) of the variables, as the p-value was higher than 0.05. The views of the respondents, however, differ in 1(3.85%) of the assessed variables, as the p-value was less than 0.05. Therefore, a significant difference exists in the view of the participant regarding "professionals make less money (B19) (Z=-1.974; Sig.=0.048).

4.3. Factorability evaluation and factor extraction.

The adequacy and factorability of the data for factor analysis were established by considering the sample size and the number of variables, commonalities values, Kaiser-Meyer-Olkin (KMO), and Bartlett's test of sphericity (BTS). The sample size of 101 and the number of variables of 26 are sufficient for EFA since there is yet to be a consensus regarding what should be the ideal number of variables and sample size for EFA [41]. Furthermore, with a high average communalities value of 0.696 obtained for the variables, the sample size becomes less important. The KMO of 0.789 obtained is satisfactory as it is greater than 0.50 [42]. In addition, with the BTS of chi-square (X^2) = 1734.407, df = 325 and Sig. = 0.000, the data are adjudged factorable. It is based on these checks that the decision to proceed with factor analysis was made, and it was subsequently done using PCA with varimax rotation as the extraction method. Five factors with eigenvalues of higher than one was extracted/retained following the PCA. These factors accounted for over 50% of the total variance explained (TVE), as suggested by [41] (Table 2).

Table 1. Barriers to adoption of earth materials in housing construction.

Code	Barriers to the adoption of earth materials in construction	AR (N=124)			Arch (N=48)			Engr. (N=53)			M-W test	
		x̄	NV	Rank	x̄	NV	Rank	x̄	NV	Rank	Z	Sig.
B01	low social image and poverty	4.43	1.00*	1st	4.52	0.98*	2nd	4.36	0.90*	3rd	-.758	0.448
B02	Pressure from Industrial materials	4.34	0.90*	4th	4.29	0.80*	6th	4.38	0.92*	2nd	-0.51	0.61
B03	lack of scientific/technical data	4.30	0.85*	5th	4.23	0.75*	9th	4.36	0.90*	3rd	-.868	0.385
B04	Inadequate/lack of building codes and policies	4.13	0.67*	11th	3.98	0.54	15th	4.26	0.78*	9th	-.617	0.106
B05	frequent maintenance requirement	4.10	0.64*	14th	3.90	0.47	18th	4.28	0.80*	8th	-1.327	0.185
B06	low structural strength	4.35	0.91*	3rd	4.23	0.75*	9th	4.45	1.00*	1st	-1.696	0.09
B07	easily wearing and erosion	4.42	0.98*	2nd	4.54	1.00*	1st	4.31	0.84*	5th	-0.688	0.491
B08	Requires a high number of labourers	3.75	0.25	23rd	3.77	0.37	22nd	3.74	0.18	24th	-0.013	0.989
B09	short lifespan	4.28	0.83*	6th	4.35	0.85*	4th	4.22	0.74*	11th	-0.708	0.479
B10	vulnerable to termites attached	3.80	0.3	22nd	3.71	0.32	24th	3.88	0.34	20th	-0.908	0.364
B11	lack standardisation	4.16	0.70*	10th	3.98	0.54	15th	4.31	0.84*	5th	-1.478	0.139
B12	Demographic changes	4.18	0.72*	9th	4.10	0.64*	12th	4.24	0.76*	10th	-0.76	0.448
B13	negative perception of earthen materials	3.99	0.51	19th	4.21	0.73*	11th	3.81	0.26	21st	-1.695	0.09
B14	Lack of technology	3.90	0.41	21st	3.88	0.46	19th	3.91	0.38	18th	-0.321	0.748
B15	Lack of courses in universities	4.20	0.74*	7th	4.25	0.76*	8th	4.16	0.66*	13th	-0.437	0.662
B16	Lack of good quality exemplar buildings	4.12	0.66*	12th	4.00	0.56	14th	4.22	0.74*	11th	-1.059	0.289
B17	Low technical performance.	3.65	0.14	25th	3.73	0.34	23rd	3.59	0	26th	-0.445	0.656
B18	lack of care for comfort and Aesthetic appeal	4.20	0.74*	7th	4.40	0.88*	3rd	4.03	0.52	16th	-0.988	0.323
B19	Professionals make less money	4.07	0.59	15th	4.27	0.78*	7th	3.90	0.36	19th	-1.974	0.048**
B20	Lack of policy minimising energy-intensive materials	4.12	0.66*	12th	3.92	0.49	17th	4.29	0.82*	7th	-1.622	0.105
B21	Lack of knowledge among stakeholders	4.03	0.55	17th	4.33	0.83*	5th	3.78	0.22	22nd	-1.905	0.057
B22	perceived high upfront cost	4.06	0.58	16th	4.04	0.59	13th	4.07	0.56	15th	-0.129	0.898
B23	low demand for the materials and products	3.53	0	26th	3.31	0	26th	3.71	0.14	25th	-1.687	0.092
B24	Non-compatibility with other materials	3.92	0.44	20th	3.88	0.46	19th	3.97	0.44	17th	-0.603	0.546
B25	Resistance to innovations	4.01	0.53	18th	3.85	0.44	21st	4.14	0.64*	14th	-1.123	0.261
B26	Non-availability of skilled workmanship	3.75	0.24	24th	3.71	0.32	24th	3.78	0.22	22nd	-0.427	0.669

**Sig. < 0.05; *= factor is critical (NV ≥ 0.60); □ = mean; AR= (All Respondents); Arch.= Architects; Engr = Engineers

4.4. Factor naming and discussion of results.

Table 2 shows the rotated component matrix (TCM) of the assessed variables and contains only extracted variables with a factor loading of ≥0.50. This implies that much of the variance explained falls within the five major factors unto which they are loaded. The latent characteristics of the items that are loaded on a component influence the naming of the component. However, where it is difficult to name a factor, the item with the highest factor loading (FL) is prioritised [43].

Table 2. Inhibitors to the adoption of earth-based materials in urban housing construction.

Variables	**Component** 1	2	3	4	5
Cluster 1: Image and aesthetic barriers					
low social image and poverty	0.787				
lack of care for the comfort and Aesthetic appeal	0.784				
The negative perception of earthen materials	0.707				
Require a high number of labourers	0.628				
vulnerable to termites attached	0.554				
Low technical performance.	0.527				
lack standardisation	0.510				
Cluster 2: Knowledge and resistance barriers					
Lack of knowledge among stakeholders		0.800			
Resistance to innovations		0.650			
Non-availability of skilled workmanship		0.641			
Lack of good quality exemplar buildings		0.630			
Non-compatibility with other materials		0.594			
The perceived high upfront cost		0.558			
easily wearing and erosion		0.530			
Cluster 3: Technology and data barriers					
Lack of technology			0.7940		
lack of scientific/technical data			0.7420		
Pressure from Industrial materials			0.7210		
short lifespan			0.6280		
Professionals make less money.			0.5860		
Lack of courses in universities			0.5180		
Cluster 4: Strength and maintenance barriers					
low structural strength				0.745	
frequent maintenance requirement				0.667	
Lack of policy minimising energy-intensive materials				0.567	
Inadequate/lack of building codes and policies.				0.545	
Cluster 5: Demand and demographic barriers					
low demand for the materials and products					0.819
Demographic changes					0.592
Eigenvalues	12.600	1.853	1.500	1.246	1.099
% of Variance	48.462	7.128	5.770	4.793	4.227
Cum. %	48.462	55.590	61.360	66.153	70.380

The 1st component in Table 3 has an eigenvalue of 12.600 and accounted for about 48.462% of the TVE of the extracted variables. This component has 7 items loaded under it, and these items with their FL are low social image and poverty (FL=0.788), lack of care of comfort and Aesthetic appeal (FL=0.784), negative perception of earthen materials (F=0.707), Require a high number of labours (FL=0.628), vulnerable to termite attached (FL=0.554), Low technical performance (FL=0.527) and lack standardisation (FL=0.510). An examination of these items shows that they are related to image and aesthetic appeal, and this component was named image and aesthetic barriers. This result supports the report of [17, 29]. The way the community view or perceive earth material houses is one of the major drawbacks in the renewed acceptance of earth-based house. There is the general perception that a low social image of the Earth is evidence of poverty, and for this reason, the material adoption level has remained very poor in housing production [11]. This has led to the neglect of these naturally occurring and natural gifts in our environment, especially in urban areas. Earth houses are perceived to be meant for people experiencing poverty or those living in those houses who are having financial difficulty. This is the image that is presented, and it is a critical barrier to the use of these materials not only in urban areas but also in rural areas [17].

The 2nd component equally has 7 items that are loaded under it, and the component accounts for 7.128% of the TVE and eigenvalue of 1.853 of the retained factors. The items loaded under the component are Lack of knowledge among stakeholders (FL=0.800), Resistance to innovations (FL=0.650), non-availability of skilled workmanship (FL=0.641), Lack of good quality exemplar buildings (FL=0.630), non-compatibility with other materials (FL=0.594), perceived high upfront cost (FL=0.558), and easy wearing and erosion (F=0.530). The latent examination of the characteristics of these items influenced the naming of the component as 'Knowledge and resistance barriers. There is a general understanding that the awareness and knowledge of the benefits of the Earth as a sustainable material are low among stakeholders. This has also been linked to the then high level of resistance to the use of the Earth. [44] reported that the sustainable building market is largely untapped and unsaturated, and knowledge is one of the factors responsible for this situation. [29] identified a lack of knowledge among stakeholders and the lack of good quality exemplar buildings as part of the barriers to the widespread use of the Earth in housing construction. Therefore, knowledge and awareness are key variables in the consideration and decision to use Earth in building construction. [28] observed that resistance to changes and innovation is a contributor to the low adoption of the Earth in construction. Client understanding of the benefits and functionality of a concept or idea was linked to the high level of resistance or otherwise. With better awareness and knowledge, the level of resistance to innovation will be reduced tremendously. The lack of existence of a sample building upon which reference could be made and the non-availability of experienced and skilled labour also contribute to the low adoption level of the Earth in housing production in urban areas [21, 29]. Compatibility issues and higher upfront costs can contribute to the resistance to the use of Earth in construction, as evidenced in the studies of [32, 28].

The 3rd component was named ‘Technology and data barriers’ following a cursory look at the latent features of the items loaded under it. This component has 6 items that are loaded onto it and account for 5.770% of the TVE, and the eigenvalue is 1.500 of the TVE of retained variables. These items are Lack of technology (F=0.794), lack of scientific/technical data (FL=0.742), Pressure from Industrial materials (FL=0.721), short lifespan 9FL=0.628), Professionals making less money (FL=0.586) and lack of courses in universities (FL=0.518). Technology and data-related factors have contributed to the low adoption rate of the Earth in housing production. The construction industry is slow to update innovative ideas and technology, and this has impacted the performance of the sector. The lack of technology to improve the properties of the Earth and make them more suitable for building is lacking [29]. The absence of scientific/technical data on earth materials and buildings is a barrier to earth-based buildings in cities. Experts require some sort of historical data for analysis and planning of new projects, but when this is not available, it makes it impracticable for them to make informed decisions on material choices. The lack of available technical data is one of the problems that have negatively impacted the performance of the construction industry. The construction industry, especially in developing nations like Nigeria, is known to be weak in record keeping, and this has impacted planning and forecasting activities in the sector. Scientific data include sensitivity to water, fire and heat resistant data, historical data on earthen buildings, and performance quantification data. These data can be collected through scientific experiences, and when they are properly analysed, they could help stakeholders make decisions on earthen material adoption in buildings. Pressure from the highly industrialised nations' innovative materials is a factor that affects the use of the Earth. There are a lot of modern materials for use in buildings that can be imported from developed nations. This puts a lot of pressure on clients and investors as they are convinced that these materials are appealing, even when they are expensive and could impact the environment. Preference for imported materials is a big change to rejuvenating the market for earth-based materials in the delivery of housing in rural and urban areas [17, 21]. Earthen buildings are believed to be less durable with a short lifespan than conventional buildings. This affects the effort to rejuvenate the use of the Earth in housing production in nations [28].

The 4th component is responsible for 4.793% of the TVE and eigenvalue of 1.246 and has 4 items loaded onto it. These items are low structural strength (FL=0.745), frequent maintenance requirement (F=0.667), lack of policy minimising energy-intensive materials (FL=0.567), and Inadequate/lack of building codes and policies (FL=0.545). This component was subsequently named *'Strength and maintenance barriers'* after an examination of the characteristics of the variables loaded onto it. The low structural strength and high maintenance requirement of earth buildings have been blamed for the low acceptance of Earth in housing construction. The earthen building is generally perceived to have a low structural strength, which is believed to impact their durability and survival over time [21]. The reliability and viability issues of the structural strength of earthen materials in buildings have remained one of the factors limiting their use in modern buildings. This has hindered the reaping of the economic, social and environmental benefits of earth-based materials. The frequent and high level of maintenance of earth-base buildings has contributed to their limited interest by the public [18]. This high maintenance requirement is linked to the unstable nature when hit by weather elements. Earth is easily eroded by rain and is vulnerable to attack by termites. This exposes them to requiring more attention than required. This is a big challenge, and it is responsible for the lack of interest in earth building. The lack of policy on the part of the government to control the use of high energy-intensive materials in construction and the absence of building codes and policies to guide the use of the Earth have impacted the interest and demand for earth houses [29].

The 5th component has an eigenvalue of 1.099 and is loaded with 2 items, which account for 4.227% of the TVE and 70.380% of the total cumulative variance (TCV) of the retained variables. These two items are low demand for the materials and products (FL=0.819) and demographic changes (F=0.592). This component was named 'Demand and demographic barriers' after a cursory look at the latent characteristics of the items that are loaded under it. The demand for earth materials and products is low [32]. One of the factors that contribute to this is earth benefits awareness and knowledge. People tend to go for items whose benefits are known to them. Therefore, to improve the demand for earth materials and products in the construction industry, there is a need for awareness creation through conferences, seminars, workshops and training on the environmental, economic and social benefits of these materials. This is because when people are aware of the importance of a material, they are most likely to increase interest and demand in those materials [44]. Changes in the economy and the status of clients and investors have been identified as a barrier to earth-building acceptance [27]. Demand and demographic barriers can be mitigated when stakeholders are educated on the importance of the Earth in building construction, especially for low-cost housing in urban areas.

5. Conclusion and Recommendations

The study found that the cluster of factors that limit the adoption of earth-based materials in urban housing construction in developing countries are image and aesthetic barriers, knowledge and resistance barriers, technology and data barriers, strength and maintenance barriers, and demand and demographic barriers. It is recommended that more campaigns and workshops to educate the public and improve their awareness of the benefits of earth materials, and their contribution to sustainability are required. Government should provide policies, regulations, and initiatives to support the adoption of earth in urban housing production. This study adds to the understanding of the barriers to earth-based materials usage in buildings, and the implication is that stakeholders are better prepared to overcome the challenges since the problems are known. This study also adds to the few available studies, particularly in Nigeria and, by extension, other developing countries. This study is however, limited by geographical boundaries, a similar study could be carried out in other zones of the country or other developing nations. The study should consider the sample size, the number of variables and the research approach (e.g., mixed methods). The proposed study could also consider the factors responsible for the low technology and innovation adoption in the use of earthen materials to increase access to housing and the use of locally available materials for constriction. This will make data available for comparison purposes.

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Competing Interest

All authors declare that there is no conflict of interest with any organisations or groups.

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