Civil and Sustainable
Urban Engineering

*Research Article*
**Volume 2(2), 2022, 110-127**
https://doi.org/10.53623/csue.v2i2.140

# Rejuvenating the Market for Earth-Based Building Construction Materials in a Developing Economy

**William Nwaki[1*], Emmanuel Eze[2]**

[1]Department of Architecture, University of Delta, Agbor, Delta state, Nigeria
[2]Department of Architecture and Built Environment, Northumbria University Newcastle, United Kingdom

*Correspondence: arkinwaki@gmail.com

**SUBMITTED: 1 November 2022; REVISED: 9 December 2022; ACCEPTED: 11 December 2022**

**ABSTRACT:** Earth-based materials are useful in building and engineering construction projects globally, but they have largely remained unextracted and wasted, and their use has been limited to rural areas and avoided in modern buildings in the cities. The sustainability market in developing countries is still largely unsaturated and undertapped. This situation is blamed on lack of knowledge of the potential, benefits, and characteristics of green and sustainable building materials. This study aimed at determining the benefits of earth-based materials that could lead to the rejuvenation of the market for their adoption in building construction projects in the urban areas of a developing economy. The study adopted a structured questionnaire administered via electronic means to construction experts using the snowball sampling technique in Nigeria. With a response rate of 62.94% and a reliability index of over 0.90, the gathered data were analysed using frequency, percentage, and exploratory factor analysis (EFA). The study revealed that the main clusters of benefits of earth-based materials that can stimulate the market for these materials in urban areas are "cost and pollution-related benefits," "emissions and environmental benefits," "waste and workability benefits," "sound and fire-related benefits," and "thermal insulation and resource efficiency." The study recommended that housing investors, clients, and stakeholders should capitalise on the availability of large quantities of earthen materials to improve the quantity of housing provisions in cities and urban areas.

**KEYWORDS:** Earth-based; green/sustainable building materials; laterite; buildings construction; construction material; Nigeria

## 1. Introduction

Any country's construction industry is responsible for driving infrastructure as well as economic growth and development.In addition to creating job opportunities in both developing and industrialised nations, the sector helps meet housing needs and other infrastructure needs by utilising construction companies, which are the major players in the sector [1]. The need to meet the socio-physical needs and infrastructure of the ever-growing citizenry is what drives house-building provisions by the states [2]. Rural-urban drift causes rapid population growth in the cities; this puts enormous pressure on the few available houses and contributes to the housing problems faced by nations, hence the urban housing crisis [3]. Also, housing deficits are one of the causes of the high cost of building [3]. Conventional building materials and approaches have been relied upon in the course of meeting the housing needs of the citizenry. These materials are injurious to the environment and, by extension, the economy, as well as leading to unsustainable development [4–6]. The traditional, conventional building construction procedures utilise environmentally harmful, eco-unfriendly, and unsustainable products that are inimical to the environment [1]. Traditional building consumes and depletes natural resources, degrades the environment, emits a lot of $CO_2$, and is the world's largest energy user [4, 7, 8]. Studies have advocated for earth-based alternative building materials as a suitable replacement for imported materials in the building of both the substructure and superstructure of building projects [9–11]. The United Nations conference made a case for the development and adaptation of local building materials in building techniques for local conditions [3, 12].

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, and are non-toxic during production and usage [13]. The global environmental issues have increased the demand for environmentally friendly materials to encourage the pursuit of the sustainability agenda in construction. Sustainability in construction allows for approaches and activities that maximise positive benefits and lessen negative impact in achieving equilibrium with regards to natural, social, and financial undertakings [14, 15]. Earth-based materials are environmentally responsible and play a critical role in fighting dangerous gas emissions such as greenhouse gases, imbalances in the ecosystem, and climate change, among other issues. Earth-based materials are regarded as "friends of the environment" as they have zero impact on the environment [16]. Laterite is common in both civil and building construction projects, especially in feeder roads, dams, airport runways, and highways, among others [13]. Their use in housing production for the economically disadvantaged earners in society has dropped in the last decades, owing to advances in technology and client sophistication. Furthermore, the use of laterite has been relegated to the background, and the few that exist in rural areas are less recognised [17, 18]. Furthermore, because of the bias and stigma associated with earthen materials, which associate them with the poor in society, these materials face acceptability issues [3]. These have made owning a house in the cities expensive and uneconomical for the majority of the citizenry in developing countries like Nigeria.

Despite the efforts of the public and private sectors to meet the housing demands 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 [10]. The use of locally sourced building materials such as earth (laterite) would improve the project delivery cost and increase the number of housing provisions for the low-income class. Earthen materials lower construction costs and environmental costs. Nigeria has abundant local building material deposits such as stone, laterite clay, timber, lime, glass sand, and others [19]. Earth-based materials have several advantages over conventional materials, including their availability in large quantities, low excavation costs, fire resistance, and ease of workability [3]. Thus, there is an increasing call for the use of these alternative building materials in the production of residential houses [10]. Despite the glaring contribution of earth-based materials in building and engineering applications, they remain largely unextracted and wasted. Issues surrounding their structural viability for use in modern buildings have limited their usage to local areas [18, 20]. This has hindered the reaping of the economic, social, and environmental benefits of earth-based materials.

Earth-based studies in the Nigerian context are rare, and the few available studies adopted simple descriptive statistics in their methods, among other issues, and none of them emphasised the benefits of earthen materials nor made a case for the rejuvenation and expansion of the adoption of earth materials in building projects in urban areas, especially in the production of low-cost housing [13, 10, 20, 21]. Based on the foregoing, this study made a case for the rejuvenation of the market for the adoption of earth-based building construction materials in urban areas in developing economies. This would be achieved by examining the benefits of earth-based building materials. Green product and service markets have expanded globally as they present a fantastic business opportunity in an increasingly competitive global market [22, 23]. While this is the case in advanced economies, the green building market is still unpopular in developing nations because of the knowledge gap [24, 25]. The United Nations' latest statistics revealed that over 2 billion people still live in different forms of buildings made of earth in the world [26]. This is an indication that the market for earth-based building materials needs to be revived, especially in urban areas for modern construction projects.

The benefits and full potentials of local and readily available building materials have remained untapped, and they experience a slow pace of usage in the Nigerian construction market [27]. This submission was affirmed by previous study, who found that the sustainable construction market is still largely unsaturated and undertapped in Nigeria [28]. This is because of the continuous dependence on imported conventional building materials to meet construction needs [29]. This is in addition to the misperception of the reliability and potential of locally available earth-based materials in building projects as well as the lack of comprehensive knowledge of their benefits. State that the green building products and services market can be created, expanded, and shaped when the benefits they bring are known [30]. In the same vein, previous study proposed that greater awareness of the importance of using green building materials in construction projects could lead to a shift in preference for sustainable materials over imported conventional ones. They posit that knowing the benefits of sustainable building materials and concepts by clients, construction professionals, and other stakeholders influence decisions to adopt them in construction as the major hindrances are overcome [28, 31].

## 2 The benefits of Earth-based building materials in the construction market

The most abundant and accessible building material in the world is "Earth." It is a material that is ubiquitous, readily available on-site, and can be handled directly with different techniques of execution that can be used to produce wonderful architectural pieces in simple to complex forms [32]. Laterite is an earthen material that is resistant to the transmission of sound, resistant to fire, resists insect damage, and regulates interior temperature during hot weather. In terms of extraction, laterite requires little energy, and it is friendly to the environment as a construction material [13]. Green building materials like earthen products are sustainable, offer higher performance, and protect the environment [33]. Furthermore, such materials do not cause an imbalance in nature and are safe and harmless to the environment. Earth-based materials are eco-friendly materials that encourage the production of green buildings because they are low in maintenance and operation costs, offer efficient energy and water consumption, improve indoor environment quality, create safe and healthy buildings, reduce pollution, enhance the environment, and minimise pressure on natural resources [34].

Studies have shown that a lack of knowledge of the benefits, as well as skilled workmanship, are the basic reasons for the seemingly underutilization of earth as building materials in urban areas. These have led to a decline in demand as well as supply for such sustainable materials in the construction industry of developing nations. The benefits of earthen materials such as laterite and clay to include: helping in the provision of cheap and affordable houses and infrastructure, reducing construction costs, creating employment opportunities, meeting the increasing demand for earth-based products, and being a suitable alternative source of energy conservation (low energy cost) [35]. Earth-based materials have the potential to improve sustainable construction practices. The usefulness of local building materials such as laterite, stone, and others in the delivery of cheap and affordable houses for lower-income groups as a sustainable alternative to meeting the housing need of the citizenry [10].

Earth-based materials are green building materials that are used to construct green buildings (GB), which have a range of goals globally, particularly in the areas of climate change and economic growth acceleration. These buildings save money, enhance occupants' performance and productivity, improve occupants' health, reduce waste, and improve water, energy, and resource efficiencies [36]. When used and managed correctly, earth-based materials do not cause the same level of resource depletion, increased waste generation and pollution, or biological changes as imported conventional materials [37]. Earthen materials such as compressed earth bricks are used to create habitats with enhanced quality for human health and better environmental resource preservation. One of their claimed advantages is cost savings [38]. Natural building materials like laterite and clay have been reported to save at least 40% of the building cost in an identical building when compared to conventional building projects [39]. A house made with earthen materials is 75% less costly than a conventional building of masonry wall units [19, 40]. The cost savings in building projects result from the readily available raw materials that are large in quantity in tropical regions; they have natural colours (purplish red to orange-red), are weather resistant, and are aesthetically pleasing. Thus, there are savings in the cost of painting and rendering.

In the tropical regions of developing nations, earth-based building materials such as laterite and clay warm the room during cold weather and cool the room during hot seasons and have low extraction and production costs [13]. The low thermal conductivity and high thermal capacity make the cost of heating and cooling minimal [38]. Evidence from literature [41–47] indicates that earth-based materials are suitable for buildings in Africa and the tropics [19]. This is large because of the good thermal comfort advantages of these materials. Earthen walls could be further fortified with mud brick or plaster.This was confirmed by [48], who found that mud render and mud brick are designed and constructed to provide a protective covering to earthen walls.

Sustainable resources such as laterite, when used to produce compressed earth bricks, are efficient materials, as they use 30% less water in their production compared to conventional building materials. Laterite is recyclable, emits less pollution, and has no toxicity; thus, it is known as a green building material suitable for most foundations, walls, and roofs [38]. They are energy efficient and environmentally friendly, and the amount of cement required in earth-based products is greatly reduced [19]. A reduction in the quantity of cement is proportional to the reduction in carbon IV oxide emissions [49]. Building construction is among the top global emitters of carbon dioxide [50]. Sustainable building materials, such as earthen products, not only produce low-impact buildings, but also improve people's lives.The benefits of these materials cut across the environment, financial, and social spheres. Reduction of construction cost, better productivity, enhanced human health, minimization of waste, protection of the environment, elimination of noise, and improved quality of life are the major benefits of green materials like earth [51].

A case study survey conducted in the Iranian city of Kashan [6] discovered that rammed earth construction reduced $CO_2$ emissions by up to 1,245 kg per tonne and captured 95% of the embodied energy. It was also reported that building material choice should be an important consideration for built environment practitioners. In Spain, researchers identified several bioclimatic characteristics of traditional earthen architecture that influence their adoption for construction projects. These characteristics, which are linked to the benefits obtained from earth-based materials, are: saving on means and materials; solar capture and protection; thermal insulation; conservation of energy; production of interior heat; protection from rain; protection from dampness; and protection from wind and ventilation [52]. Previous study reviewed an establishment of the economic benefits of earthen on the production of low-cost urban housing. A critical literature search conducted for the study found that building with earth offers both low-cost and energy-efficient housing, compared to conventional brick and concrete housing in urban areas [53].

**Table 1: The benefits of Earth-based building materials in the construction market**

| S/N | benefits of earth-based building materials | Source(s) |
|---|---|---|
| 1 | High thermal insulating properties | [3, 13, 19, 23, 38, 41-43, 44-47] |
| 2 | enhance occupants' performance and productivity | [36, 51] |
| 3 | improve water, energy and resources efficiencies | [36, 34] |
| 4 | low in maintenance and operation costs | [34] |
| 5 | Eliminate waste generated during construction | [3, 36, 37, 51] |
| 6 | The workability and flexibility are high | [3, 12] |
| 18 | It is a suitable alternative source of energy conservation | [13, 35, 52] |
| 7 | better fire resistance | [3, 13, 52] |
| 8 | High sound insulation properties | [3, 13, 41, 52, 51] |
| 9 | Earth construction is economically beneficial | [3, 10, 19, 35, 39, 40, 51-53] |
| 10 | involves the use of simple tools and less skilled labour | [3] |
| 12 | improve indoor environment quality and quality of life | [3,3 4, 52, 51] |
| 13 | Earth products absorb pollutants/reduce pollution | [3, 13, 34] |
| 14 | Reduce construction costs | [10, 19, 39, 40, 51, 53] |
| 11 | Suitable for very strong and secured structure | [3] |
| 15 | Create employment opportunity | [35] |
| 16 | Easy to design with high aesthetical value | [3, 17, 19, 32, 40, 52] |
| 17 | Meet the increasing demand for the earth-based products | [35] |
| 19 | Resistant to insect damage | [13] |
| 20 | Environmentally friendly | [13, 19, 40, 51] |
| 21 | Does not contribute to resources depletion (i.e. resources are conserved) | [37, 38, 52] |
| 22 | Enhance the quality of human health and safety | [6, 33, 36, 38, 41, 51, 52] |
| 23 | provide a protective covering to earthen walls | [48,52] |
| 24 | Less harmful, with zero emissions of toxic gasses | [6, 38, 49, 52] |
| 25 | Earth is available in abundance in most regions | [3] |
| 26 | Earth construction promotes local culture, heritage, and material | [3, 12, 41] |

There are efforts by the government in advanced nations to revive the construction of buildings with earth and earthen products. For example, tremendous advancements have been made in countries such as Australia, the USA, New Zealand, New Mexico, and others. A "new earth building" movement now exists in the world, and New Zealand is leading the movement. New Zealand has produced a standard guide for the construction and erection of earthen buildings. The new wave of interest in the use of earth-based materials in the construction industries of some advanced nations is yet to reach Nigerian housing consumers, as experience is still very low, especially in urban areas [16]. Previous study showedd the creation of a new and emerging market as among the top benefits of green building materials [51]. This study tried to trigger this interest and raise the appetite of housing consumers for earth and earthen products to rejuvenate and revive their adoption in the production of houses in the cities. This is the central gap this study fills. Flowing from the review of extant literature and other related concepts, 26 variables were identified and summarised in Table 1.

## 3. Research Methodology

This study took a post-positivism philosophical stance, employing a structured questionnaire to collect participant opinions [54,55]. The Questionnaire is appropriate for studies that require a large audience and cover a wide range of topics, where economy and data collection time are critical [56]. This study covered experienced construction experts in the six states of the south-south geopolitical zone of Nigeria. The experts were divided into four groups for ease of assessment: architects, builders, engineers, and quantity surveyors.Since these experts are scattered across the six states within the study area, the questionnaire becomes appropriate to reach the participants [1]. In addition, these experts form the bulk of the built environment professionals' employees of construction-based organisations, and they play a critical role in the diffusion of innovative ideas and methodologies in the built environment [28, 57]. The number of experts reported is 1252 [58]; this population was obtained in states such as Akwa Ibom, Bayelsa, Cross River, Delta, Edo, and Rivers states. From the table for determining the sample size [59], the equivalent sample size of 197 was obtained from the population of 1252.

The questionnaire used was developed after an extensive review of relevant literature on the main subject of the study. There were two core parts to the questionnaire. The first part gathered data on the demographic information of the participants. The second part collected data on the benefits of earth-based building materials in housing production in urban areas. The questionnaire was designed on a 5-point Likert scale, where 1 is the lowest scale and 5 is the highest scale. The participants were expected to rate the identified variables regarding the benefits of earthen materials on their level of agreement or usefulness in triggering the appetite of housing consumers (clients, investors, construction professionals, etc.) to increase the market for the adoption of these materials in urban areas. Aside from construction experience, participants were required to be knowledgeable about green and sustainable building materials and construction, as well as have at least 5 years of practise experience.This informed the use of the non-probabilistic snow sampling technique.

The snow sampling technique is respondent-driven; it is based on a referral from one respondent to another who meets the sample selection criteria. Furthermore, this sampling technique can increase the sample size [60, 61]. Electronic means were adopted in the distribution of the questionnaire developed using Google Forms. Electronic questionnaires in Google Forms increase the speed of data collection from a wider audience and are an equally economical means of reaching difficult-to-reach audiences. The online questionnaire distribution method (i.e., Google Form) is easy to get to a lot of people that are separated by considerable physical distance [62,63]. The electronic questionnaire is "eco-friendly" as the hardcopy paper questionnaire is avoided [64]. After 16 weeks, 124 valid responses were received and used for the analysis reported. The 62.94% response rate was adequate for analysis as it exceeded the upper limit of the range of 20%–30% suggested for a questionnaire survey [65]. The breakdown of the responses received from the various states is Akwa Ibom = 13 (10.48%), Bayelsa = 11 (8.87%), Cross River = 16 (12.90%), Delta = 34 (27.42%), Edo = 19 (15.32%), and Rivers = 31 (25.00%). The data collected on the respondents' background information was analysed using frequencies and percentages.The mean item score (MIS) and exploratory factor analysis (EFA) were used on the data collected on the benefits of earth-based materials in the construction sector. The EFA was used to reduce and group the assessed variables into a more meaningful and manageable proportion. The EFA used principal component analysis (PCA) with varimax rotation as the data extraction method. Before running the EFA, sample adequacy and factorability tests were carried out and the conditions were met.

The reliability of the research instrument was determined using Cronbach's alpha test, which gave an alpha value of 0.908 for the 26 assessed variables. On this, the instrument was adjudged to be highly reliable, and the data gathered is of good quality and can be relied upon in justifying the need for the study. The entire methodological procedure of the study is summarised in the chart below (Figure 1).

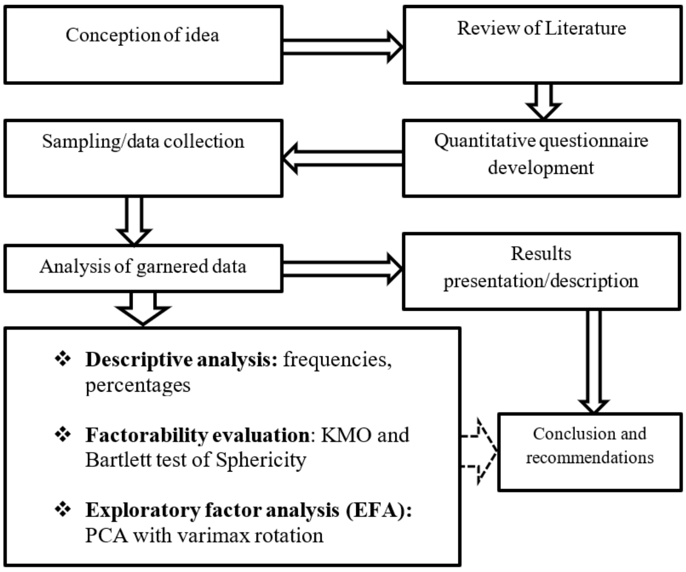


**Figure 1**. Research methodological flow chart.

## 4. Results and Discussion

### *4.1. Basic information of respondents.*

According to the results of the respondents' background information (Table 2), it is clear that the majority of survey participants work for private organisations (56.45%), followed by public organisations (43.5%). The experts that participated in the study represent various disciplines and professions within the built environment. Engineers have the highest proportion (33.06%), followed by architects (29.84%), quantity surveyors (22.58%), and builders (14.52%). This implies a fair representation of the major experts in the construction industry. Furthermore, those with 5-10 years of experience outnumber those with years of experience by 38.71%, followed by those with years of experience by 29.84%, those with 16-20 years of experience by 17.74%, and those with 21 years or more by 13.71%. The participants' average work experience is 12.85 years, which is quite extensive. In terms of education, they have a BSc/B.Tech holders are 40.32%, and then those with a master's degree (MSc. or M.Tech.). The consequence of this is that the respondents are educationally qualified to contribute to the success of this study. Finally, in terms of professional members, 87.10% of the survey participants are corporate members of their various professional bodies, and only 12.9% are probationers with their professional bodies.

**Table 2.** Background information of respondents.

| Variables | Classification | Freq. | Per cent |
|---|---|---|---|
| Organizational ownership | Public organisation | 54.00 | 43.55 |
| | Private organisation | 70.00 | 56.45 |
| | **TOTAL** | **124.00** | **100.00** |
| The profession of construction professionals | Architect | 37.00 | 29.84 |
| | Builders | 18.00 | 14.52 |
| | Engineers (Civil & Services) | 41.00 | 33.06 |
| | Quantity Surveyors | 28.00 | 22.58 |
| | **TOTAL** | **124.00** | **100.00** |
| Years of experience | 5-10years | 48.00 | 38.71 |
| | 11-15 years | 37.00 | 29.84 |
| | 16-20 years | 22.00 | 17.74 |
| | 21-above | 17.00 | 13.71 |
| | **TOTAL** | **124.00** | **100.00** |
| Educational Qualification | Higher National Diploma (HND) | 19.00 | 15.32 |
| | Postgraduate Diploma (PGD) | 17.00 | 13.71 |
| | Bachelor of Science/technology (B.Sc./B.Tech) | 50.00 | 40.32 |
| | Master's Degree (MSc./M.Tech.) | 34.00 | 27.42 |
| | Doctorate (PhD) | 4.00 | 3.23 |
| | **TOTAL** | **124.00** | **100.00** |
| Professional affiliation | Corporate Members | 108.00 | 87.10 |
| | Probationer | 16.00 | 12.90 |
| | **TOTAL** | **124.00** | **100.00** |

*4.2. Benefits of earth-based building materials in the construction.*

The factor analysis was preceded by a factorability and sample adequacy evaluation. The sample size and the number of variables were considered in determining the sample adequacy for EFA. The 124 responses and 26 variables identified are sufficient for EFA. This is premised on the understanding that there is yet to be a consensus on what should be the ideal number of variables and sample size that would be suitable for EFA [66-68]. The communality values obtained are greater than 0.50 thresholds, as evidenced in the test carried out. The average communality value obtained is 0.685, and the minimum and maximum values of 0.553 and 0.814 communality values, respectively, were equally obtained. With the high communality value, the sample size becomes useless in establishing the adequacy of samples for EFA [69]. The factorability of the data was also checked using the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity (BTS) [70-72]. KMO of 0.50 as being satisfactory for EFA. The KMO value obtained for this study is 0.811, as indicated in Table 3.

BTS with a chi-square value of 1690.870, DF of 325, and significant (p-value) of 0.000 shows the data are factorable. Based on these evaluations, the factor analysis was carried out using PCA with varimax rotation as the extraction method.

**Table 3.** KMO and Bartlett's test.

| | | |
|---|---|---|
| Kaiser-Meyer-Olkin Measure of Sampling Adequacy. | | 0.811 |
| Bartlett's Test of Sphericity | Approx. Chi-Square | 1690.870 |
| | df | 325 |
| | Sig. | 0.000 |

### *4.3. Factor analysis: principal component analysis (PCA) and factor extraction*

The factor analysis resulted in five factors with eigenvalues greater than 1.0 being retained or extracted. The five factors retained accounted for more than 50% of the total variance explained as proposed by [66–67, 71] (Table 4).

**Table 4.** Total Variance Explained (TVE) of barriers to lean construction.

| Component | Initial Eigenvalues | | | Extraction Sums of Squared Loadings | | | Rotation Sums of Squared Loadings | | |
|---|---|---|---|---|---|---|---|---|---|
| | Total | % of Variance | Cum. % | Total | % of Variance | Cum. % | Total | % of Variance | Cum. % |
| 1 | 8.448 | 32.493 | 32.493 | 8.448 | 32.493 | 32.493 | 4.363 | 16.782 | 16.782 |
| 2 | 2.265 | 8.71 | 41.203 | 2.265 | 8.71 | 41.203 | 4.005 | 15.405 | 32.187 |
| 3 | 1.843 | 7.088 | 48.291 | 1.843 | 7.088 | 48.291 | 2.548 | 9.799 | 41.986 |
| 4 | 1.632 | 6.276 | 54.567 | 1.632 | 6.276 | 54.567 | 2.453 | 9.434 | 51.42 |
| 5 | 1.409 | 5.418 | 59.984 | 1.409 | 5.418 | 59.984 | 2.227 | 8.564 | 59.984 |

**Table 5.** Rotated Component Matrix of benefits of Earth-based building materials in the construction market.

| Variables | Component | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| Reduce construction costs | 0.831 | | | | |
| Earth products absorb pollutants/reduce pollution | 0.758 | | | | |
| Earth construction is economically beneficial | 0.652 | | | | |
| improve indoor environment quality and quality of life | 0.623 | | | | |
| low in maintenance and operation costs | 0.616 | | | | |
| Meet the increasing demand for the earth-based products | 0.581 | | | | |
| Easy to design with high aesthetical value | 0.550 | | | | |
| Less harmful, with zero emissions of toxic gasses | | 0.740 | | | |
| Enhance the quality of human health and safety | | 0.734 | | | |
| Environmentally friendly | | 0.697 | | | |
| Earth is available in abundance in most regions | | 0.682 | | | |
| Provide protective covering to earthen walls. | | 0.630 | | | |
| Earth construction promotes local culture, heritage, and material | | 0.541 | | | |
| Create employment opportunities. | | 0.516 | | | |
| Eliminate waste generated during construction | | | 0.725 | | |
| The workability and flexibility are high | | | 0.609 | | |
| It is a suitable alternative source of energy conservation | | | 0.535 | | |
| Resistant to insect damage | | | 0.509 | | |
| High sound insulation properties | | | | 0.748 | |
| better fire resistance | | | | 0.654 | |
| Does not contribute to resource depletion (i.e. resources are conserved) | | | | 0.561 | |
| High thermal insulating properties | | | | | 0.847 |
| Improve water, energy and resources efficiencies | | | | | 0.787 |

In addition, as evidenced in Table 5, only the factors with a factor loading of 0.50 and above are retained according to the previous study [72]. Much of the variance explained lies in the five major components onto which the factors are loaded. The names of the factors were determined by the latent characteristics of the items loaded under the components. However, the item with the largest factor loading (FL) is given priority where it is difficult to name a factor [64].

- *Component 1: cost and pollution-related benefits.*

From Table 5 above, the first component has seven items that are loaded under it, and these accounted for about 32.490% of the total variance explained (TVE) and an Eigenvalue of 8.448 of the retained variables. The items and their factor loading (FL) are as follows: reduce construction costs = 0.831; earth products absorb pollutants and reduce pollution = 0.758; earth construction is economically beneficial = 0.652; improve indoor environment quality and quality of life = 0.623; low maintenance and operation costs = 0.616; meet the increasing demand for earth-based products = 0.581; and easy to design with a high aesthetic value = 0.550. Based on the latent characteristics of these items, the component was named "cost and pollution-related benefits." The finding here is in support of the previous report on green building materials such as earth or laterite [28, 41, 43, 45, 56, 57]. Earthen materials offer a lot of opportunities when it comes to the delivery of cheap and affordable building projects anywhere in the world. These materials are cheap and abundantly available in our locality in their natural forms. Earth-based materials are commonly and readily available, which makes them cheap for the building of houses, thus offering a reduced cost of construction [28, 56]. Earth materials are economical because their maintenance and operation costs are low. Earthen products do not constitute any harm to the environment, as they produce no pollutants but rather absorb them. Thus, one of the major advantages of earth materials is that they do not contribute to environmental pollution [41, 43]. These materials are recyclable, and being re-usable makes it possible for them to be put into continuous use without constituting a problem for society. They provide a conducive interior living environment, and with their pollution-free properties, they improve the quality of life of the occupants [56].

- *Component 2: emissions and environmental benefits.*

The second component has seven items loaded under it. This component accounts for 8.71% of the TVE and has an extracted factor eigenvalue of 2.265.Less harmful, with zero toxic gas emissions = 0.740; improving human health and safety = 0.734; environmentally friendly = 0.697; the earth is abundant in most regions = 0.682; providing a protective covering to earthen walls = 0.630; earth construction promoting local culture, heritage, and material = 0.541; and creating employment opportunities = 0.516.Following a cursory look at the features of these items, it was subsequently named "Emissions and environmental benefits."This finding is in support of the previous findings [6, 44, 54, 56]. The use of green building materials like laterite in foundations, walls, and roofs is because of their inherent characteristics of producing zero toxic gases. There are no harmful emissions from these materials [44]. The building construction sector is known globally as among the top emitters of carbon dioxide [55]. The reduction of the quantity of cement used in buildings through the adoption of earthen materials has helped to reduce carbon dioxide emissions [6, 54]. Thus, these materials offer a form of protection to the environment, as described in [56]. This makes GB safe and healthy for her occupants. One of the benefits of green materials, as identified by [40], is that they are safe and offer appreciable protection to the environment..

- *Component 3: waste and workability benefits.*

The third component was named *"waste and workability benefits"* after a critical examination of the latent attributes of the items loaded under it. This component has four items that account for 7.088% of the TVE as well as an eigenvalue of 1.843 of the total extracted variables. These items are: they eliminate the waste generated during construction (0.725); their workability and flexibility are high (0.609); they are a suitable alternative source of energy conservation (0.535); and they are resistant to insect damage (0.509). This finding reinforces what has been reported [13, 42–43, 56]. The earth's recyclable and reusability is what makes them suitable for incorporation into buildings. Earthen products, therefore, do not end up as waste in landfills; thus, waste is greatly reduced [42–43]. They support the circularity of natural building materials. Circular products contribute little or nothing to waste in the construction sector. Minimization of waste is one of the benefits reported by [56] for green building materials like earth. Laterite also has an appreciable level of protection by resisting damage by the insect, as reported by previous study [13]. Earthen materials can be used as an alternative source of energy conservation in buildings [28]. This is based on the fact that they self-regulate their interior temperature. GB does not require heating and cooling, as the clay materials are inherently capable of doing those themselves.

- *Component 4: sound and fire-related benefits.*

The fourth component is responsible for 6.276% of the TVE and has three items loaded onto it. The eigenvalue of this component is 1.632, and the three items are: high sound insulation properties (0.748), better fire resistance (0.654), and does not contribute to resource depletion (i.e., resources are conserved) (0.561). This component was subsequently named "sound and fire-related benefits" after an examination of the characteristics of the variables loaded onto it. The grains of earthen materials are densely packed together, which makes them resistant to sound transmission and fire penetration. Clay and laterite are effective at reducing noise penetration and transmission. This is one of the benefits of earthen products identified by previous study [56]. Another study reported that one of the properties of earth-based materials that makes them useful in the production of sustainable buildings Clay and laterite are non-combustible materials, and as such, they do not support fire resistance, which makes them suitable as building materials. Earth materials are considered during decisions on fire strategy planning in buildings because of their excellent non-support of fire transmissions. Furthermore, because of their reusability, clay and other earthen products do encourage resource conservation [13].

- *Component 5: thermal insulation and resource efficiency.*

For the fifth component, the eigenvalue is 1.409 and contains two items that are loaded under it, and they accounted for 5.418% of the TVE and 59.98% of the total cumulative variance (TCV) of the extracted variables. These two items are high thermal insulating properties (0.847) and improved water, energy, and resource efficiencies (0.787). The 5th component was named "thermal insulation and resource efficiency" after a cursory look at the latent attributes of the items that are loaded under it. Earthen materials in buildings are excellent thermal insulators, and they efficiently drive resource consumption. These materials have high thermal capacities and low thermal conductivity, which minimise the cost of heating and cooling [44]. The thermal insulation property of earthen architecture is one of the bioclimatic characteristics of these materials that makes them highly beneficial in building construction projects [23]. The energy, water, and resource efficiencies of earth materials make them suitable for housing construction. This is supported in the report [42]. Figure 2 shows the relative weighting of the extractor factors. The most important benefits of earth-based materials are cost and pollution-related benefits (TFL = 4.611); this is followed by emissions and environmental benefits (TFL = 4.540); waste and workability benefits (TFL = 2.378); sound and fire-related benefits (TFL = 1.963); and lastly, thermal insulation and resource efficiency (TFL = 1.634). Although these factors are relatively unranked, they all contribute to a sustainable built environment. This further shows that the environmental, economic, and social dimensions of sustainability should be the driving forces behind the high patronage of these products in housing production in urban areas.

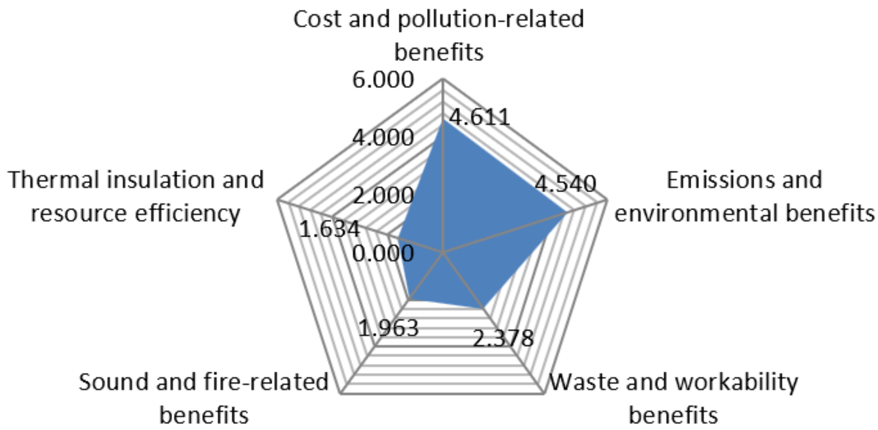


**Figure 2.** Relative weighting of the total factor ading (TFL) of extracted factors.

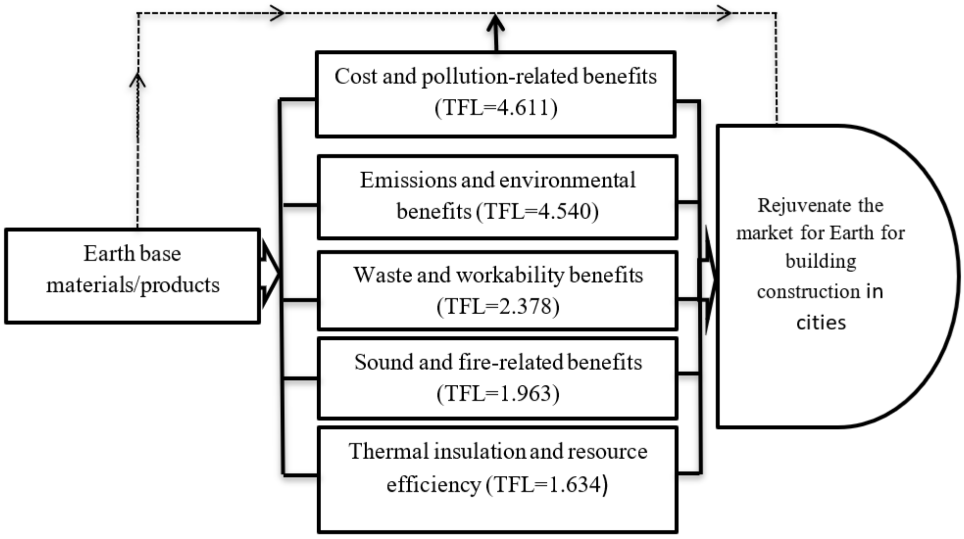


**Figure 3.** Benefits of earth materials adoption in a modern buildings in cities.

Figure 3 is a framework that demonstrates the major clusters of factors obtained from the analysis. While the total factor loading (TFL) for these factors differs, they represent the core benefits of earthen products when used as construction materials. It is the understanding of this study that these benefits, when fully understood and known by the housing consumers in the cities and urban areas, could trigger the demand for these materials, which must be followed by a corresponding supply of these materials. It is the forces of demand and supply that define the market. The willingness of investors to invest in green features is high. The market for earth materials and products could be revitalised in urban areas for construction work, especially in meeting the housing needs of the population in the cities [32].

## 5. Conclusion and Recommendations

This study emphasised the need to embrace the use of earth materials in meeting the housing needs of urban areas. Bringing the benefits and potentials of earth-based materials into building construction can ignite the appetite of housing consumers, clients, investors, and others. This is understood to trigger the forces of demand and supply for these materials in the cities of not only Nigeria, where this study was carried out, but by extension, the developing countries of Africa and beyond. To achieve the objective of this study, a structured electronic questionnaire was adopted to gather data from experienced construction experts in both the private and public sectors of organisations within the south-south region of Nigeria, using a snowball sampling technique. Meaningful findings were made following the analysis of the data gathered using EFA. The study found that the cluster of benefits of earthen materials that could ignite renewed interest in the use of earth-base materials for building construction in urban areas are: cost and pollution-related benefits; emissions and environmental benefits; waste and workability benefits; sound and fire-related benefits; and thermal insulation and resource efficiency. The exposition of the various benefits of earth in the built environment could trigger interest, which could lead to demand, and this must be accompanied by the supply of these materials. The use of these materials could further assist in meeting the SDG target of providing cheap and affordable housing for all in a sustainable way. The benefits of using earth in construction cut across the three main pillars of sustainability: economic, social, and environmental benefits. Climate change, which is a major challenge around the globe, is partly caused by the construction sector. Dangerous emissions (toxic gases and $CO_2$), enormous construction and demolition waste, excess pressure on natural resources, and high energy and other resource consumption by the industry are some of the problems construction works bring to larger communities. Earth-based materials have the inherent capability of overcoming these problems. As revealed in this study, cost reduction and pollution avoidance, non-emission of dangerous gases, waste elimination, soundproofing and fire resistance, thermal regulation, and efficiencies in resource utilisation are the most important benefits of earthen materials in the building sector. Based on the findings of this study, it is recommended that for the government to meet the housing needs of her nations, it should leverage earthen materials and products, as they are readily available in their natural form within every locality. Also, as the economic fortune of the nation continues to dwindle, the only available sustainable material to deliver cheap and affordable housing for the masses, particularly in urban areas, is earth. This is because these materials have proved to be economical and have social and environmental relevance. Furthermore, it is another way to contribute to meeting the SDG target. Housing investors, clients, and stakeholders are encouraged to capitalise on the availability of large quantities of earthen materials to improve the number of housing provisions in the cities. This study adds to the available literature on sustainable/green building material adoption in the construction industries of developed and developing nations. The stakeholders in the construction industry, such as the government, consultants, clients, and contractors, would find this study useful in making decisions on the choice of sustainable materials for their building projects, especially in urban areas. The sustainable construction market in some countries is still largely unsaturated and untapped. The implication is that this study provides the opportunity for investors in the building industry to invest in earth-based materials, and this could bring a good return on investment. While this study covered more areas than existing studies, especially those carried out in Nigeria, it has some limitations that can impact the generalisation of the findings. First of all, the study is limited to the six states of the south-south region of Nigeria. A similar study could be conducted in other parts of the country or in other African developing countries in the future. The study adopted a questionnaire as the research instrument and collected data from construction experts. A further study should adopt interviews, case studies, and other stakeholders in the sector. Although earth-based building materials and products offer great benefits to the built environment, their use in urban housing has been limited by certain barriers. In a separate study, the authors assessed the barriers to the use of earth-based building materials in urban housing development.

**Acknowledgments**

The authors appreciate the efforts of the anonymous reviewers for their constructive comments in making this paper better. Also, the creative contributions of the editorial team are acknowledged.

**Competing Interest**

All authors declear that there is no confict of interestd with any organisations or groups**.**

**References**

[1] Eze, E.C.; Ugulu, R.A.; Onyeagam, O.P.; Adegboyega, A.A. (2021). Determinants of sustainable building materials (SBM) selection on construction projects. *International Journal of Construction Supply Chain Management*, *11*, 166-194. https://doi.org/10.14424/ijcscm110221-166-194.

[2] John, T.A.; Alumbugu, P.O.; Micheal, A.I. (2019). Contract awards disparity among multinational and indigenous construction companies. *Journal of Engineering, Project, and Production Management, 9,* 126-131. https://doi.org/10.2478/jeppm-2019-0014.

[3] Daniel, A.A.; Benjamin, G.K.; Tali, J.O. (2018). Adopting Stabilized Earth Construction to Address Urban Low-cost Housing Crisis in Jos, Nigeria. *Journal of Ergonomics Studies and Research, 1*, 1-10.

[4] Mahboob, M.; Ali, M.; Tu, R.; Hassan, R. (2021). Assessment of Embodied Energy and Environmental Impact of Sustainable Building Materials and Technologies for Residential Sector. *Engineering Proceedings, 12*, 62. https://doi.org/10.3390/engproc2021012062.

[5] AlSanad, S. (2015). Awareness, drivers, actions, and barriers of sustainable construction in Kuwait. *Procedia Engineering*, *118*, 969-983. https://doi.org/10.1016/j.proeng.2015.08.538.

[6] Nouri, H.; Safehian, M.; Mir-Mohammad, H.S.M. (2021). Life cycle assessment of earthen materials for low-cost housing a comparison between rammed earth and fired clay bricks. *International Journal of Building Pathology and Adaptation*. https://doi.org/10.1108/IJBPA-02-2021-0021.

[7] Arduin, D.; Caldas, L.R.; Paiva, R.d.L.M.; Rocha, F. (2022). Life Cycle Assessment (LCA) in Earth Construction: A Systematic Literature Review Considering Five Construction Techniques. *Sustainability, 14*, 13228. https://doi.org/10.3390/su142013228.

[8] Ansari, A.S. (2017). Life cycle assessment of residential villa. *IOSR Journal of Mechanical and Civil Engineering*, *14*, 50-59.

[9] Mpakati-Gama, E.C.; Wamuziri, S.C.; Sloan, B. (2012). The Use Of Alternative Building Materials In Developing Countries: Addressing Challenges Faced By Stakeholders. World Construction Conference 2012 – Global Challenges in Construction Industry. Colombo, Sri Lanka; pp. 266-275.

[10] Kayode, O.; Olusegun, A.E. (2013). Local Building Materials: a Tool Towards Effective Low-Income Housing in Nigeria. *Middle-East Journal of Scientific Research*, *18*, 492-497. https://doi.org/10.5829/idosi.mejsr.2013.18.4.11707.

[11] Fernandes, J.; Peixoto, M.; Mateus, R.; Gervasio, H. (2019). Life cycle analysis of environmental impacts of earthen materials in the Portuguese context: rammed earth and compressed earth blocks. *Journal of Cleaner Production*, *241*, 118286. https://doi.org/10.1016/j.jclepro.2019.118286.

[12] Ega, A.E.; Job, C. (2011). Traditional earth plasters and renders in Nigeria: A preliminary study. *Journal of Environmental Sciences University of Jos*, *15*, 1-6.

[13] Muntari, M.Y.; Abbas, U.K. (2016). Sustainable Environment: Laterite As Sustainable Building Materials In Construction Industry. *International Journal of Advances in Mechanical and Civil Engineering, 3*, 70-73.

[14] Zabihi, H.; Habib, F.; Mirsaeedie, L. (2012). Sustainability in building and construction: revising definitions and concepts. *International Journal of Emerging Science, 2*, 570-578.

[15] Haque, M.O.; Aman, J.; Mohammad, F. (2022). Construction sustainability of container-modular-housing in coastal regions towards resilient community. *Built Environment Project and Asset Management, 12*, 467-485. https://doi.org/10.1108/BEPAM-01-2021-0011.

[16] Onyegiri, I.; Ugochukwu, I.B, (2016). Traditional building materials as a sustainable resource and material for low cost housing in Nigeria: Advantages, challenges and the way forward. *International Journal of Research in Chemical, Metallurgical and Civil Engineering, 3*, 247-252. https://doi.org/10.15242/IJRCMCE.U0716311.

[17] Oshike, E.E. (2015). Building with earth in Nigeria: a review of the past and present efforts to enhance future housing developments. *International Journal of Science, Environment and Technology*, *4*, 646 – 660.

[18] Mensah, S.; Ameyaw, C.; Abaitey, B.A.; Yeboah, H.O. (2021). Optimizing stabilization of laterite as walling unit. *Journal of Engineering, Design and Technology*, *20*, 1482-1498. https://doi.org/10.1108/JEDT-12-2020-0501.

[19] Adegun, O.B.; Adedeji, Y.M.D. (2017). Review of economic and environmental benefits ofearthen materials for housing in Africa. *Frontiers of Architectural Research*, *6*, 519–528. https://doi.org/10.1016/j.foar.2017.08.003.

[20] Amadi, A.I.; Chijioke, A.K. (2018). Uncertainties Surrounding the Economic Potential of Locally Available Laterite Deposits in Promoting Environmentally Sustainable Housing in Nigeria. *American Journal of Civil and Environmental Engineering, 3*, 43-51.

[21] Afolami, A.J.; Oyebamiji, I.O. (2017).Thermal Perception of Residents in Housing Developments Built With Laterite Interlocking Blocks in Ado-Ekiti, Nigeria. *FUTY Journal of the Environment, 11*, 120-135.

[22] World green building trends 2016: developing markets accelerate global green growth, smart market report. (accessed on 1 October 2022) Available online: https://worldgbc.org/article/world-green-building-trends-2016/#:~:text=The%20study%2C%20World%20Green%20Building,currently%2C%20to%2037%20per%20cent.

[23] Oyewole, M.O.; Ojutalayo, A.A.; Araloyin, F.M. (2019). Developers' willingness to invest in green features in Abuja, Nigeria. *Smart and Sustainable Built Environment*, *8*, 206-219. https://doi.org/10.1108/SASBE-06-2018-0031.

[24] Komolafe, M.O.; Oyewole, M.O.; Kolawole, J.T. (2016). Extent of incorporation of green features in office properties in Lagos, Nigeria. *Smart and Sustainable Built Environment, 5*, 232-260. https://doi.org/10.1108/SASBE-08-2015-0019.

[25] Fuerst, F.; McAllister, P.; Wetering, J.; Wyatt, P. (2011). Measuring the financial performance of green buildings in the UK commercial property market address the data issues. *Journal of Financial Management of Property and Construction*, *16,* 163-185. https://doi.org/10.1108/13664381111153132.

[26] Zhang, K.; Lu, B.; Wang,Y.; Lei, Z.; Yang, Z (2019). Experimental Strength of Earth-Based Construction Materials in Different Regions of China. *Advances in Materials Science and Engineering, 2019*, 8130743. https://doi.org/10.1155/2019/8130743.

[27] Alade, K.T.; Oyebade, A.N.; Nzewi, N.U. (2018). Assessment of the Use of Locally Available Materials for Building Construction in Ado-Ekiti Nigeria. *Journal of Construction Business and Management, 2*, 36-41. https://doi.org/10.15641/jcbm.2.2.449.

[28] Eze,C.E.; Ugulu, R.A.; Egwunatum,S.I.; Awodele, I.A. (2021b). Green Building Materials Products and Service Market in the Construction Industry. *Journal of Engineering, Project, and Production Management*, *11*, 89-101. http://doi.org/10.2478/jeppm-2021-0010.

[29] Ugochukwu, I.B.; Chioma, M.I.B. (2015). Local Building Materials: Affordable Strategy for Housing the Urban Poor in Nigeria. *Procedia Engineering*, *118,* 42-49. https://doi.org/10.1016/j.proeng.2015.08.402.

[30] Mayhoub, M.M.G.; El Sayad, Z.M.T.; Ali, A.A.M.; Ibrahim, M.G. (2021). Assessment of Green Building Materials' Attributes to Achieve Sustainable Building Façades Using AHP. *Buildings*, *11*, 474. https://doi.org/10.3390/buildings11100474.

[31] Aghimien, D.O.; Aigbavboa, C.O.; Thwala, W.D. (2019). Microscoping the challenges of sustainable construction in developing countries. *Journal of Engineering, Design and Technology*, *17*, 1110-1128. https://doi.org/10.1108/JEDT-01-2019-0002.

[32] Mileto, C.; Vegas, L.M.F. (2022). Earthen architectural heritage in the international context: values, threats, conservation principles and strategies. *Journal of Cultural Heritage Management and Sustainable Development*, *12*, 192-205. https://doi.org/10.1108/JCHMSD-06-2021-0115.

[33] Balali, A.; Valipour, A.; Zavadskas, E.K.; Turskis, Z. (2020). Multi-Criteria Ranking of Green Materials According to the Goals of Sustainable Development. *Sustainability*, *12*, 9482. https://doi.org/10.3390/su12229482.

[34] Eco-friendly Construction: 8 Advantages of Green Building. (accessed on 1 October 2022) Available online: https://nationwideconstruction.com/eco-friendly-construction-8-advantages-of-green-building/.

[35] Muntari, M.Y.; Narimah, K.; Babangida, H. (2013). Investigation the utilisation of laterite and clay as sustainable buildings Materials. The International Conference on Sustainable Built Environment for Now and the Future, 311-316.

[36] Fu, Y.; Wang, H.; Sun, W.; Zhang, X. (2021). New Dimension to Green Buildings: Turning Green into Occupant Well-Being. *Buildings, 11*, 534. https://doi.org/10.3390/buildings11110534.

[37] Bachar, M.; Azzouz, L.; Rabehi, M.; Mezghiche, B. (2014). Characterization of a stabilized earth concrete and the effect of incorporation of aggregates of cork on its thermo mechanical properties: *Construction and Building Materials, 74*, 259-267. https://doi.org/10.1016/j.conbuildmat.2014.09.106.

[38] Oyelami, C.A.; Van Rooy, J.L. (2016). A review of the use of lateritic soils in the construction/development of sustainable housing in Africa: A geological perspective. *Journal of African Earth Sciences*, *119*, 226–237. https://doi.org/10.1016/j.jafrearsci.2016.03.018.

[39] Olotuah, A.O. (2002). Recourse to earth for low-cost housing in Nigeria. *Building and Environment, 37*, 123–129. https://doi.org/10.1016/S0360-1323(00)00081-0.

[40] Interlocking Stabilised Soil Blocks-Eco-Friendly construction in Kenya. (accessed on 1 October 2022) Available online: https://www.a4architect.com/2012/02/interlocking-stabilised-soil-blocks-eco-friendly-construction-in-kenya/.

[41] Adam, E.A.; Agib, A.R.A. (2001). Compressed stabilized earth block manufacture in Sudan. UNESCO: Paris, France.
[42] Makaka, G.; Meyer, E. (2006). Temperature stability of traditional and low-cost modern housingin the Eastern Cape, South Africa. *Journal of Building Physics, 30*, 71–86. https://doi.org/10.1177/1744259106065674.
[43] Oti, J.E.; Kinuthia, J.M.; Bai, J. (2009). Engineering properties of unfired clay masonry bricks. *Engineering Geology*, *107*,130–139. https://doi.org/10.1016/j.enggeo.2009.05.002.
[44] Bui, Q.; Hans, S.; Morel, J.; Do, A. (2011). First exploratory study on dynamic characteristics of rammed earth buildings. *Engineering Structures*, *33*, 3690–3695. https://doi.org/10.1016/j.engstruct.2011.08.004.
[45] Lawal, A.; Ojo, J. (2011). Assessment of thermal performance of residential buildings in Ibadan Land, Nigeria. *Journal of Emerging Trends in Engineering and Applied Sciences, 2*, 581–586.
[46] Palme, M.; Guerra, J.; Sergio Alfaro, S., (2012). Earth of the Andes Comparing techniques and materials used in houses in San Pedro de Atacama. PLEA Proceedings of the 28th Conference, Lima, Peru, 7-9 November 2012.
[47] Persson, S. (2014). Indigenous Materials in Modern Building - For Low Energy Houses in West Africa. Master Thesis, Uppsala University, Sweden.
[48] Fodde, E.; Watanabe, K.; Fujii, Y. (2014). Measuring evaporation distribution of mud brick and rammed earth. *Structural Survey*, *32*, 32-48. https://doi.org/10.1108/SS-06-2013-0025.
[49] Lemougna, P.N.; Melo, U.F.C.; Kamseu, E.; Tchamba, A.B. (2011). Laterite Based Stabilized Products for Sustainable Building Applications in Tropical Countries: Review and Prospects for the Case of Cameroon. *Sustainability*, *3*, 293-305; https://doi.org/10.3390/su3010293.
[50] Radhi, H. (2009). Evaluating the potential impact of global warming on the UAE residential buildings—A contribution to reduce the $CO_2$ emissions. *Building and Environment*, *44,* 2451-2462. https://doi.org/10.1016/j.buildenv.2009.04.006.
[51] Ten Benefits of Sustainable Construction. (accessed on 1 October 2022) Available online: https://www.constructionexec.com/article/ten-benefits-of-sustainable-construction.
[52] Balaguer, L.; Mileto, C.; Vegas, L.M.F.; García-Soriano, L. (2019). Bioclimatic strategies of traditional earthen architecture. *Journal of Cultural Heritage Management and Sustainable Development*, *9*, 227-246. https://doi.org/10.1108/JCHMSD-07-2018-0054.
[53] Zami, M.S.; Lee, A. (2010). Economic benefits of contemporary earth construction in low-cost urban housing – State-of-the-art review. *Journal of Building Appraisal*, *5*, 259–271. https://doi.org/10.1057/jba.2009.3.
[54] Ghansah, F.A.; Owusu-Manu, D.; Ayarkwa, J.; Darko, A.; Edwards, D.J. (2020). Underlying indicators for measuring smartness of buildings in the construction industry. *Smart and Sustainable Built Environment*, *11*, 126-142. https://doi.org/10.1108/SASBE-05-2020-0061.
[55] Olanrewaju, O.I.; Kineber, F.A.; Chileshe, N.; Edwards, D.J. (2021). Modelling the impact of building information modelling (BIM) implementation drivers and awareness on project lifecycle. *Sustainability*, *13*, 8887. https://doi.org/10.3390/su13168887.
[56] Tan, W. (2011). Practical Research Methods, 4$^{th}$ ed.; Pearson Custom: Singapore.
[57] Eze, C.E.; Awodele, I.A.; Adegboyega, A.A.; Onyeagam, O.P.; Guto, J.A. (2020). Assessment of the triggers of inefficient materials management practices by construction SMEs in Nigeria. *International Journal of Real Estate Studies*, *14*, 38-56.
[58] Otali, M.; Oladokun, M.G.; Anih, P. (2020). Influence of Construction Firm Size on the Level of Adoption of Sustainability Practices in Niger Delta, Nigeria. *Baltic Journal of Real Estate Economics and Construction Management, 8*, 102–118. https://doi.org/10.2478/bjreecm-2020-0008.

[59] Krejcie, R.V.; Morgan, D.W. (1970). Determining Sample Size for Research Activities. *Educational and Psychological Measurement*, *30*, 607–610. https://doi.org/10.1177/001316447003000308.

[60] Zhang, Y.; Zhang, H.; Yang, Z.; Sun, J.; Tan, C.D. (2019). Snowball Effect of User Participation in Online Environmental Communities: Elaboration Likelihood under Social Influence. *International Journal of Environmental Research and Public Health*, *16*, 3198. https://doi.org/10.3390/ijerph16173198.

[61] Heckathorn, D.D. (2011). Comments: Snowballing versus respondent-driven sampling. *Sociological Methodology, 41*, 355-366. https://doi.org/10.1111/j.1467-9531.2011.01244.x.

[62] Chan, A.P.C.; Darko, A.; Ameyaw, E.E. (2017). Strategies for promoting green building technologies adoption in the construction industry – an international study. *Sustainability, 9*, 969-986, https://doi.org/0.3390/su9060969.

[63] Fang, Q.; Chen, L.; Zeng, D.; Zhang, L. (2019). Drivers of Professional Service Model Innovation in the Chinese Construction Industry. *Sustainability*, *11*, 941. https://doi.org/10.3390/su11040941.

[64] Nwaki, W.; Eze, E.; Awodele, I. (2021). Major Barriers Assessment Of Lean Construction Application In Construction Projects Delivery. *CSID Journal of Infrastructure Development, 4*, 63-82.

[65] Moser, C.; Kalton, G. (1971). Survey methods in social investigation, 1st Ed.; Routledge: London, UK. https://doi.org/10.4324/9781315241999.

[66] Pallant, J. (2002). SPSS survival manual: A step-by-step guide to data analysis using SPSS version 7th Ed.; Routledge: London, UK. https://doi.org/10.4324/9781003117452.

[67] Hair, J.F.; Black, W.C.; Babin, B.J.; Anderson, R.E. (2010). Multivariate data analysis, 7th Ed.; Pearson: New York, USA.

[68] Tabachnick, B.G.; Fidel, L.S. (2007). Using multivariate statistics, 5th ed.; Pearson: New York, USA.

[69] Vozzi, A.; Ronca, V.; Aricò, P.; Borghini, G.; Sciaraffa, N.; Cherubino, P.; Trettel, A.; Babiloni, F.; Di Flumeri, G. (2021). The Sample Size Matters: To What Extent the Participant Reduction Affects the Outcomes of a Neuroscientific Research. A Case-Study in Neuromarketing Field. *Sensors*, *21*, 6088. https://doi.org/10.3390/s21186088.

[70] Field, A. (2005). Discovering Statistics, Using SPSS for Windows, 1st ed.; Sage Publications: London, UK.

[71] Stern, L. (2010). A visual approach to SPSS for windows: A guide to SPSS 17.0, 2nd ed.; Pearson: New York, USA.

[72] Spector, P. (1992). Summated Rating Scale Construction: An Introduction, 1st ed.; Sage Publications: London, UK.