International Journal of Future Engineering Innovations

Thermal Performance of CSEBS Residential Buildings in Lagos State

Olatunde Oladoja [1*], **Oladipo Dare-Abel** [2], **Eziyi O Ibem** [3]
[1] PhD Candidate, College of Environmental Sciences and Management, Caleb University, Imota, Lagos, Nigeria
[2] Professor, Department of Architecture, Lagos State University of Science and Technology, Ikorodu, Lagos, Nigeria
[3] Professor, Department of Architecture, University of Nigeria, Enugu Campus, Enugu, Nigeria

* Corresponding Author: **Olatunde Oladoja**

Article Info

ISSN (online): 3049-1215
Volume: 02
Issue: 05
September-October 2025
Received: 21-07-2025
Accepted: 22-08-2025
Published: 16-09-2025
Page No: 56-64

Abstract
Purpose: This study empirically investigates the thermal performance of residential buildings constructed with Compressed Stabilized Earth Blocks (CSEBs) in Lagos State, Nigeria, to determine occupant thermal perception and to evaluate the material's benefits relative to conventional masonry in a hot–humid tropical context.
Methodology: A descriptive design was adopted. Primary data were collected from residents of Amen Estate, Ibeju-Lekki, using a structured questionnaire (n = 221; stratified random sampling) complemented by observational visits and on-site atmospheric measurements. Quantitative data were analyzed with SPSS v26 and Excel using descriptive statistics to summarize thermal sensation and perceived benefits; contextual interpretation was informed by relevant thermal comfort standards (ASHRAE 55, ISO 7730) and literature on earth-based materials.
Findings: The results indicate overwhelmingly positive thermal performance for CSEB buildings: 96% of respondents reported satisfactory indoor thermal conditions, and large majorities endorsed CSEBs as low-embodied-energy (73% agreement), durable (95%), environmentally sustainable (94%), cost-effective (94%), and aesthetically pleasing (91%). These perceptions align with CSEBs' high heat capacity and thermal inertia, which moderate diurnal temperature swings in the tropical monsoon climate of Ibeju-Lekki.
Originality: By providing an evidence-based assessment from a contemporary Nigerian estate, this paper strengthens empirical support for CSEBs as a viable, low-carbon alternative to concrete masonry in hot-humid regions, and it offers actionable recommendations for location-appropriate deployment and further material optimization.

DOI: https://doi.org/10.54660/IJFEI.2025.2.5.56-64

Keywords: Thermal Performance CSEBs, Residential Building, Tropical Climate, Lagos State

Introduction

Both industrialized and developing nations have realized and appreciated the significance of sustainable development in recent years (Bibang Bi Obam Assoumou, Zhu, & Francis Deng, 2023) [9]. The building industry is the largest consumer of materials and energy worldwide (Santamouris & Vasilakopoulou, 2021) [48] and has generated a lot of interest (Elaouzy & El Fadar, 2022) [16], since the built environment has a crucial impact on the climate and the earth's resources. According to Malhi *et al.* (2020), sustainable development and thermal comfort in building constructions in tropical regions are dependent on limiting heat buildup through proper orientation and building materials. In the building industry, sustainable development is becoming more and more significant. Consequently, there is a renewed push for construction methods that minimize industrial processes and use locally accessible materials, such as earth, to lessen their negative effects on the environment (Malbila, Delvoie, Toguyeni, Courard, & Attia, 2022) [30].

Compressed Stabilized Earth Blocks (CSEBs) are small, regular, and controlled masonry pieces that are produced by compressing the earth either statically or dynamically and then immediately demolding it (Paulus, 2015) [41]. CSEBs offer an alternative to sustainable building, as they are more suited to the local climate. Moreover, Malbila *et al*. (2022) [30] add that CSEBs' physical characteristics do, in fact, interact with one another and incorporate additional factors to create a cohesive set of building constructions for people, the environment, and the climate (Malbila, Delvoie, Toguyeni, Courard, & Attia, 2022) [30]. According to Chelghoum and Belhamri (2011) [12], one of the primary prerequisites for comfort, safety, and health is preserving equilibrium between the human body and its surroundings (Chelghoum & Belhamri, 2011) [12].

Kazemi *et al*. (2021) [28] contend that a building's temperature and humidity levels can damage construction components, increase energy use, and make people uncomfortable (Kazemi, Boukhelkhal, Kosinski, & Attia, 2021) [28]. According to Maamar (2016) [29], thermal comfort is the state of mind that conveys contentment with the thermal surroundings and it is evaluated subjectively (Maamar, 2016) [29]. Technical criteria are among the many requirements that must be met in the management of thermal comfort. Thus, the study of materials for walls is important because the wall thermal behavior influences housing thermal comfort and sustainability (He, Yu, Ozaki, Dong, & Zheng, 2017) [22]. Therefore, this study aims to empirically analyze the thermal performance of residential buildings constructed with CSEBs in Lagos State.

Statement of the Problem

Whether the building materials are composite or natural, their nature is an important consideration. Alternative techniques have been created to replace conventional building materials so as to achieve sustainable and thermal efficiency in buildings. However, rather than engaging local materials, which are based on natural soil stabilized with industrial, forestry, and agricultural by-products for building constructions (Imbga, Ouédraogo, Sambou, Kieno, Ouédraogo, & Bathiebo, 2018) [24], Lagos State is today dominated by structures made of concrete and cement blocks. The fact that the latter building materials are hazardous to the environment and have poor thermal characteristics from solar radiation (Abey & Anand, 2019) [1] is more concerning.

Besides, Malbila *et al*. (2022) [30] observe that concrete and its derivatives are currently the most frequently used building materials in the construction industry in most African cities (Malbila, Delvoie, Toguyeni, Courard, & Attia, 2022) [30]. Thus, concrete and cement bricks have replaced local building materials, which are based on earth and natural resources, resulting in the penetration of ultraviolet radiation to the earth surface causing global warming and climate change (Joshua, Bin Kandar, & Aminu, 2017) [27]. Moreover, Bibang, Zhu, and Francis (2023) [9] avow that building with earth is a step in the right direction toward achieving sustainable building in many parts of the world (Bibang Bi Obam Assoumou, Zhu, & Francis Deng, 2023) [9]. This study is, therefore, born out of the necessity to assess the thermal efficiency of CSEBs in Lagos State as a practical step towards creating and achieving sustainable structures and green environments.

Aim and Objectives of the Study

The aim of this study is to examine the thermal performance of CSEB residential buildings in Lagos State. Thus, the specific objectives of the study are to:

1. Determine the thermal perception of occupants of CSEB's residential buildings in Lagos State.
2. Establish the benefits of adopting CSEBs for residential buildings in a tropical climate.

Literature Review

Concept and Characteristics of CSEBs

Compressed Stabilized Earth Blocks (CSEBs) are small, consistent, and measured brickwork pieces that are formed by compressing the earth either statically or dynamically and then instantly demolding it (Paulus, 2015) [41]. The earth brick composition includes some additives and water, as well as earth, which is a mixture of gravels, sands, silts, and clay. Malbila *et al*. (2022) [30] note that additives are added to the earth to improve and develop a final and unique characteristic (Malbila, Delvoie, Toguyeni, Courard, & Attia, 2022) [30]. A manual or motorized press is used to compress the bricks, giving the block's top and bottom a meshing pattern. They are a common substitute for conventional bricks in buildings across the globe because of their interlacing pattern, which enables the bricks to be stacked without the need for mortar. Moreover, they are particularly common in areas with high transportation expenses for conventional building supplies and little access to other high-quality bricks (Bredenoord, 2017).

Nagapan *et al*. (2017) [34] aver that CSEBs need to be compacted using vibro-static, dynamic, or static techniques (Nagapan, Antonyova, Rasiah, Yunus, & Sohu, 2017) [34]. To achieve the greatest outcome while preparing the earth for block production, thorough and accurate soil selection is required. Proper compaction must be assured once the components have been mixed in the mold. Besides, to avoid quick drying, appropriate curing is essential (Reddy & Reddy, 2022) [46]. According to Abey and Anand (2019) [1], the energy used in production and the carbon emissions are two notable differences between CSEBs and conventional bricks (Abey & Anand, 2019) [1]. In comparison to concrete blocks, which produce 143kg of carbon dioxide per tonne, CSEBs produce 22kg of carbon dioxide per tonne. In addition, the production process of CSEBs is straightforward; hence, it requires workers with low to moderate skill levels to produce. Accordingly, the procedure simply requires three steps, which include soil preparation, mix compression, and curing.

***Source*:** Authors' field work

Fig 1: CSEBs in various Molds

CSEBs as a Sustainable Building Material

How to properly increase human well-being while staying within the bounds of the planet's natural resources is one of the key challenges in environmental sciences (Joshua, Bin Kandar, & Aminu, 2017) [27]. Sustainable development in the built environment is one potential way to resolve this conundrum. Contreras, Lezcano, and Fernández (2022) [13] submit that environmentally friendly building materials are those that have minimal to no negative consequences (Contreras, Lezcano, & Fernández, 2022) [13]. It is possible to use these resources to produce structures without denying future generations the necessities of life.

It is essential to understand sustainability in all of its forms, including social, economic, and ecological. This includes improving the temperature and weather patterns, preserving biological diversity, protecting soil and food crops, sequestering carbon dioxide, offering clean air, creating jobs, thereby reducing poverty, and providing recreational amenities (Joshua, Bin Kandar, & Aminu, 2017) [27]. Gupta and Deshmukh (2016) [20] express that a sustainable material must have such qualities as being readily available and reasonably priced, preferably locally; meeting the national standards' requirements in terms of durability and maintainability; being environmentally friendly; posing no health risks; and being versatile in usage (Gupta & Deshmukh, 2016) [20].

Aside from being capable of breaking down after its structural life span with no environmental impact, CSEBs create a pleasant atmosphere and mix well with the surroundings while also having an aesthetic appeal that most other materials lack (Islam, Tausif-E-Elahi, Shahriar, Nahar, & Hossain, 2020) [25]. Thus, using CSEBs in building construction is considered an agent of green architecture. Dixit (2017) [15] argues that a substantial portion of the overall life cycle energy consumption of buildings is accounted for by the embodied energy of their materials, which refers to the total energy expended during the procurement, transportation, and construction of raw materials (Dixit, 2017) [15]. In contrast, CSEBs are produced on sites, thereby using less energy and reducing the need for fossil fuels. Marzouk and Elshaboury (2022) [31] emphasize that CSEB production uses a minimal amount of energy (Marzouk & Elshaboury, 2022) [31].

According to Islam *et al*. (2020) [25], throughout their entire life cycle, CSEBs produce incredibly little waste and do not directly pollute the environment (Islam, Tausif-E-Elahi, Shahriar, Nahar, & Hossain, 2020) [25]. The capacity of CSEBs to absorb atmospheric moisture results in a healthy environment for building occupants. Ibitoye, Abiola, and Babamboni (2023) [23] add that CSEBs have good thermal insulation properties, which help to regulate indoor temperature and reduce energy consumption for heating and cooling (Ibitoye, Abiola, & Babamboni, 2023) [23]. They are made from earth, which is a renewable resource and locally available. These attributes make CSEBs a sustainable building material. Furthermore, several studies (Benidir & Brara, 2021; Islam, Tausif-E-Elahi, Shahriar, Nahar, & Hossain, 2020; Nagapan, Antonyova, Rasiah, Yunus, & Sohu, 2017; Oan, Abdeltawab, & Elhefnawy, 2021; Yogananth, Thanushan, Sangeeth, Coonghe, & Sathiparan, 2019) [8, 25, 34, 38, 51] demonstrate that the strength of CSEBs makes them structurally suitable for any type of construction (Benidir & Brara, 2021; Islam *et al*., 2020; Nagapan *et al*., 2017; Oan, Abdeltawab, & Elhefnawy, 2021; Yogananth *et al*., 2019) [8, 25, 34, 38, 51].

Antique of Earth Building Technology

Earth is the most fundamental building material that humans have encountered. It can perform the most rigorous tasks and has the benefit of being easily combined with the most basic agricultural instruments (Vyncke, Kupers, & Denies, 2018) [50]. Using soil, typically subsurface soil, in conjunction with other building materials is the process of employing earth as a building material. According to Gallipoli *et al*. (2017) [19], civilizations around the world have been using earth as a building material for thousands of years (Gallipoli, Bruno, Perlot, & Mendes, 2017) [19]. Earth has been used as a building material since at least the Ubaid Period in ancient Mesopotamia (5000 - 4000 B.C.). Ancient monumental structures that have remained objects of tourist attractions across the world, such as the ancient temples, the classic shrines, the medieval castles, the large Gothic cathedrals, the Baroque and Renaissance palaces, the pyramids, and part of the Great Wall of China, were built with earth soil.

The earth soil has continued to enjoy benefaction as a building material but with varying notches of improvement in practices as a result of improved know-how. Many different techniques have been developed for using earth as a construction material. Cammas (2018) [11] notes that methods used vary according to the local climate and environment as well as local traditions and customs (Cammas, 2018) [11]. The soil construction technique was widespread in Nigeria until the incursion of cement blocks into the country after independence. Nnamdi, Ejiofor, and Ugoyibo (2022) [36] submit that most pre-independence houses were built of mud walls and sun-dried bricks (Nnamdi, Ejiofor, & Ugoyibo, 2022) [36]. Thus, the central fundamental of the towns consists of houses built with earth techniques. The houses range from bungalows to one- and sometimes two-story buildings and provide adequate shelter for the inhabitants (Aghimien, Makanjuola, & Fadeke, 2016) [3]. The buildings dated between 50 and 100 years in durability, dependent on regular maintenance.

Hence, it can be said that an understanding and appreciation of traditional earth building can inform state-of-the-art and appropriate uses of earth in new buildings. This knowledge is advantageous since it has been noted that at least 42% of the world's population still live in earth houses (Reddy, 2022)

[45]. Thus, the utilization of earth in housing construction is one of the oldest and most common methods employed by a larger percentage of the developing countries' population (Beckett, Jaquin, & Morel, 2020) [7]. The earth materials for buildings are the most readily available and cheap material found everywhere. They are easy to work with, require fewer skills to create and as such encourage and facilitate unskilled individuals and groups of people to participate in their housing construction on a self-help basis.

Interestingly, previous research (Abdallah, Carré, Perlot, La Borderie, & El Ghoche, 2024; Buson, Lopes, Varum, Sposto, & Real, 2013; Ferreira, Luso, Cruz, Mesquita, & Gontijo, 2020) [2, 10, 17] found that earth building offers high resistance to fire and provides a comfortable built living environment due to its high thermal and heat insulation value (Abdallah *et al*., 2024; Buson *et al*., 2013; Ferreira *et al*., 2020) [2, 10, 17]. Presently, development in earth building production techniques ranges from the most rudimentary, manual, and craft-based to the most sophisticated, mechanized, and industrial (Dahmen, 2017; NitelikGelirli & Arpacıoğlu, 2022) [14, 35]. A lot of new generation manual, mechanical, and motor-driven presses have also been invented, leading to the emergence of a genuine market for the production and application of earth blocks (Beckett, Jaquin, & Morel, 2020; Sadeghian, Abdollahi, Akbari, & Javidinejad, 2023) [7, 47].

Benefits of Using CSEBs for Building Construction

Materials play a crucial role in the construction of buildings. Although a structure is made up of many different pieces, the walls make up the majority of its components and are supposed to provide a significant amount of quality and advantages to the building, its occupants, and the surrounding environment. Hence, Bakam *et al*. (2020) [5] and Turco *et al*. (2021) [49] avow that CSEBs offer a good fire-resistant property that enables evacuation of residents and possessions in cases of fire outbreak (Bakam, Mbishida, Danjuma, Zingfat, Hamidu, & Pyendang, 2020; Turco, Junior, Teixeira, & Mateus, 2021) [5, 49]. This meets the sustainability requirement for safety and gives CSEB a competitive advantage over other widely used building materials like steel and wood.

Besides, Hanafi (2021) [21] affirms that CSEBs provide natural, energy-efficient, environmentally beneficial, and agriculturally friendly building materials for sustainable development (Hanafi, 2021) [21]. During the manufacture of this energy-efficient material, no toxic gases are released; it is a cost-effective and environmentally beneficial replacement for conventional building materials like cement blocks and bricks (Mohamed, Moustafa, & Darwish, 2024) [33]. Thus, using CSEBs in building construction is considered an agent of green architecture. Essentially, earth construction is a resource-efficient and cost-effective method of building low-rise dwellings in developing areas.

More so, Nouemssi *et al*. (2023) [37] and Real *et al*. (2024) [44] aver that CSEBs have a high conductivity and thermal capacity (Nouemssi, Ntamack, Mbozo'O, & Djeumako, 2023; Real, Bogas, Cruz, Gomes, & Nabais, 2024) [37, 44]. These two properties make it possible for walling material to absorb a fair amount of solar radiation and postpone its entry into interior spaces during the day. Heat collected throughout the day is transferred to the external environment at night since the exterior temperature is lower than the internal temperature (Pearson, 2015) [42]. This effect improves the occupants' thermal comfort by preventing the interior air temperature from peaking (Jia, Jiang, Zhang, Liao, Hu, Zhang, & Long, 2024) [26]. This effectively lessens the cooling demand in the tropical climate, which is a feature of the region being studied in this study.

Moreover, CSEBs are made on-site, thereby decreasing transportation costs. To support this claim, previous research (Fundi, Kaluli, & Kinuthia, 2018; Raheem, Bello, & Makinde, 2010; Oyebisi, Olutoge, Ofuyatan, & Abioye, 2017; Oyebisi, Ede, Ofuyatan, Oluwafemi, & Akinwumi, 2018) [18, 43, 40, 39] reveals that around 30% of building expenses and time are saved (Fundi *et al*., 2018; Raheem *et al*., 2010; Oyebisi *et al*., 2017; Oyebisi *et al*., 2018) [18, 43, 40, 39]. Also, roughly 75% of the bricks' construction requires no mortar, in keeping with the earth block concepts of environmental sustainability (Assiamah, Abeka, & Agyeman, 2016) [4]. Thus, compared to conventional blocks, CSEBs allow for speedier building. Oyebisi *et al*. (2018) point out that a bricklayer can create roughly 21m² of walls with 800 CSEBs in a single day, which is three times faster than placing conventional blocks (Oyebisi, Ede, Ofuyatan, Oluwafemi, & Akinwumi, 2018) [39]. As a result, labor time per hour is drastically reduced.

In addition, Aghimien, Makanjuola, and Fadeke (2016) [3] observe that soil, as the main component of CSEB, is available in large quantities in almost all regions, thereby making it affordable (Aghimien, Makanjuola, & Fadeke, 2016) [3]. Also, it is not necessary to render plaster and paint to CSEBs because of their aesthetically pleasing surface. This also lowers the finish cost. Thus, under the guidance of skilled workers, the manufacture and erection of CSEBs are straightforward to accomplish. Therefore, using sustainable building materials like CSEBs can enormously benefit the owner greatly in a number of ways, including energy conservation, lower maintenance and replacement costs, increased occupant productivity and health, reduced costs related to changing space configurations, increased design flexibility, enhanced public perception, and overall cost savings.

Materials and Methods

This study employs a descriptive research design to assess the thermal performance of residential buildings constructed with CSEBs in Lagos State. Primary data were gathered through a structured questionnaire administered to residents of Amen Estate in Ibeju-Lekki, Lagos. The research instrument focused on the thermal perception of occupants of CSEB's residential buildings and the benefits of adopting CSEBs for residential buildings. Observational visits to the residential estate complemented the survey, allowing the researchers to assess the building typology and measurements of the atmospheric conditions of the location.

Secondary data were collected through a comprehensive literature review of academic articles, conference proceedings, case studies, and book publications, providing context and theoretical frameworks for interpreting the study's findings. The research employed a stratified random sampling method with sample size determined based on number of household units. The essence of stratified random sampling lies in its ability to improve the representativeness and accuracy of a sample by dividing the population into distinct subgroups and then randomly sampling from each subgroup. The data collected were analyzed using descriptive statistical techniques for quantitative data with the aid of SPSS (version 26) and Excel spreadsheets. This approach was aimed at providing a comprehensive understanding of the topic under investigation and hence enabled the formulation of evidence-based conclusions and recommendations. Essentially, ethical considerations were prioritized, ensuring informed consent, confidentiality, and the right to withdraw from the study at any time.

Amen Estate in Ibeju-Lekki, Lagos State

Amen estate is a posh residential community within the Ibeju-Lekki neighborhood of Lagos State. Redbricks Homes International Limited constructed this gated estate with the goal of giving its inhabitants a luxurious lifestyle. The estate spans more than 100 acres and includes a variety of residential structures, including terraces, apartments, and villas, in addition to recreational areas, parks, playgrounds, a clubhouse, a tennis court, swimming pool, and a shopping center built with CSEBs. Amen estate is one of the estates at the vanguard of using substitute construction material, with a focus on developing a sustainable community. According to this study's field survey, Amen estate boasts of 148 buildings comprising 300 dwelling units of 118 five-bedroom and 182 four-bedroom, all of which are constructed with CSEBs.

***Source*:** Authors' field work

Fig 2: Picture of Amen Estate, Ibeju-Lekki, Lagos State

Climate of the Study Area

Ibeju-Lekki in Lagos State witnesses a tropical monsoon climate characterized by distinct wet and dry seasons. While the dry season, which runs from November to March, delivers drier air and harmattan winds, the rainy season comes with heavy downpours and runs from April to October. All year long, the average high temperature is between 28 and 32°C (82 and 90°F), while the average low temperature is between 22 and 24°C (72 and 75°F). Despite some breezes from the coastal setting, the humidity is strong all year round. In tropical climates, Bay and Ong (2006) [6] state that active and passive cooling is more important than heating up buildings. Therefore, designing buildings to fit in with tropical environment characteristics by engaging the appropriate building materials is an excellent way to derive high thermal performance.

Results and Discussion

The questionnaire administered for the purpose of this study was divided into three sections. The first section examined the respondent's profile, while the second and third sections surveyed the thermal perception of occupants and the benefits of adopting CSEBs, respectively. In the course of the survey, a total of Two Hundred and Fifty (250) questionnaires were administered, out of which Two Hundred and Twenty-One (221) were completely filled and successfully returned. The high rate of questionnaires returned demonstrates the level of acceptance of the study. Hence, analyses and results are presented in tables and charts.

Profile of Study Respondents

Table 1 shows the gender, age, marital status, highest academic qualifications, occupancy period, and household size of respondents.

Table 1: Profile of Respondents

		Frequency	Percent (%)
Gender	Male	195	88.2
	Female	26	11.8
Age Category	16-25 years	3	1.4
	26-35 years	26	11.8
	36-45 years	36	16.3
	46-55 years	82	37.1
	56 years +	74	33.5
Marital Status	Single	12	5.4
	Married	206	93.2
	Separated	3	1.4
Academic Qualification	GCE/WASSCE	2	0.9
	NCE/OND	21	9.5
	HND/B.Sc./B.Ed.	127	57.5
	Post Graduate	71	32.1
Occupancy Period	1-5 years	38	17.2
	6-10 years	110	49.8
	11-15 years	73	33.0
Household Size	1-2	8	3.6
	3-4	35	15.8
	5-6	135	61.1
	7-8	43	19.5
Total		221	100

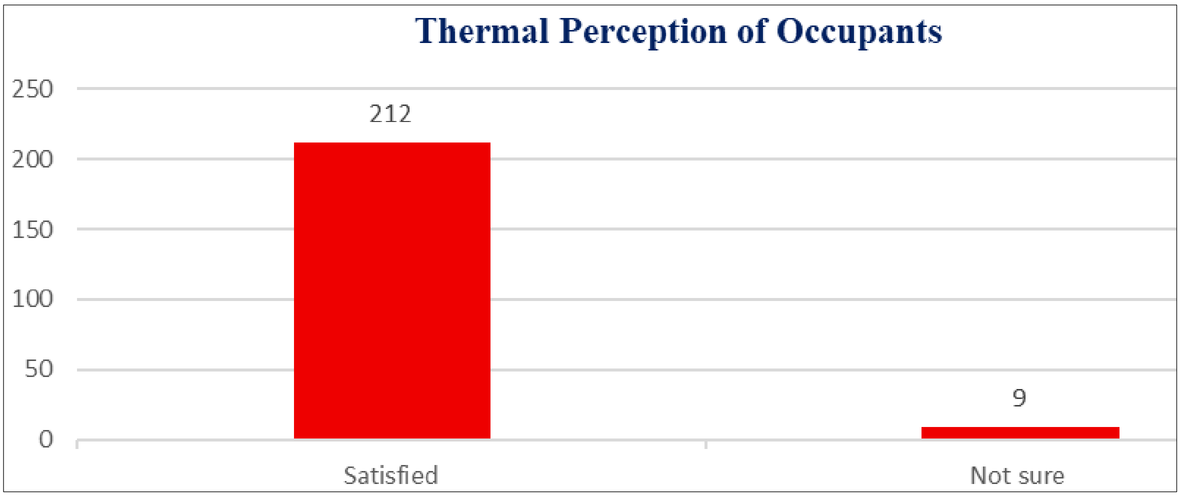
Source: Researcher's computation from SPSS (version 26.0)

The analysis of the profile of the sampled residents presented in Table 1 shows that more male than female respondents were surveyed, as 88.2% of the study's participants were male compared to the female counterparts, who accounted for 11.8%. In the age category of respondents, the age group 46-55 years dominates with 37.1%, closely followed by the age category 56 years and above with 33.5%. While respondents aged 36-45 years accounted for 16.3%, those in the age category 26-35 years accounted for 11.8%, and the age group 16-25 years recorded the least with 1.4%. In terms of highest academic qualifications, the majority of the study respondents were HND/B.Sc./B.Ed. holders at 57.5%. This is followed by holders of postgraduate degrees at 32.1%. Respondents holding OND/NCE accounted for 9.5% of the sampled residents, while the remaining 0.9% had GCE/WASSCE at the time of the survey.

The analysis further demonstrates that respondents with household size 5-6 have the highest representation with 61.1%. This is followed by respondents with household size 7-8, which accounted for 19.5%. Moreover, those with household size 3-4 accounted for 15.8%, while the least in terms of representation, with 3.6%, were residents whose household size was between 1 and 2. As for the marital status of the study respondents, 206 were married, accounting for the overwhelming highest in representation (93.2%). The singles (12) accounted for 5.4%, while residents with separated marital status (3) accounted for 1.4%. Responses as regards occupancy periods revealed that the majority of respondents, 49.8%, have occupied the CSEB building for 6-10 years; 33% of respondents had 11-15 years; and 17.2% of respondents had 1-5 years of occupancy experience. These analyses are essential, as they demonstrate that respondents of the study possess the required qualities and information to offer reliable responses to the research questions.

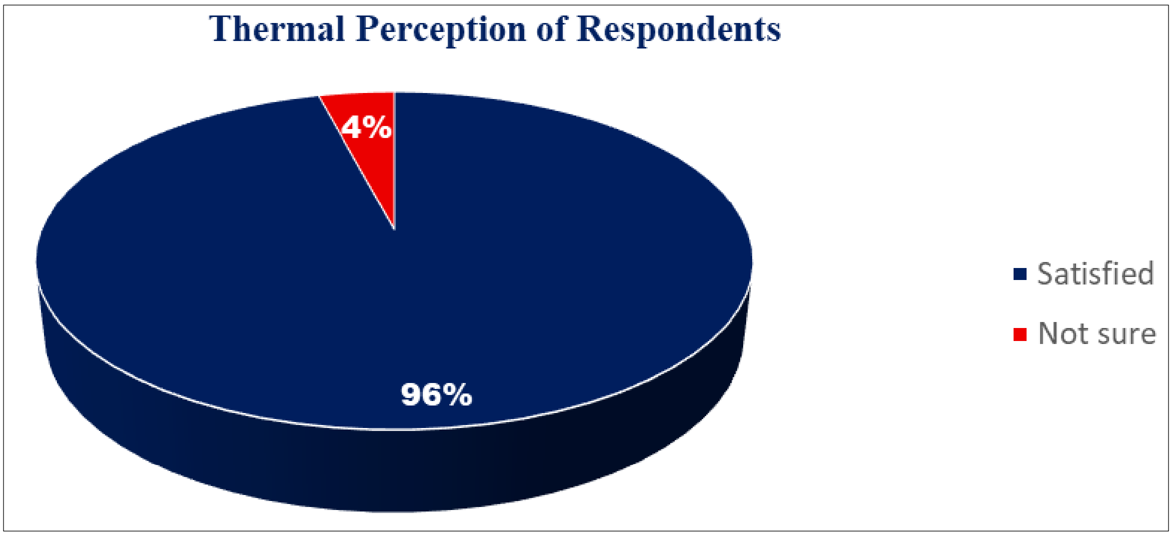
Thermal Perception of Occupants of CSEBs Residential Buildings

The section presents the perception of occupants of residential CSEB buildings in Lagos State, using charts for the analysis. The two well-known international standards for assessing thermal comfort in indoor spaces are ASHRAE Standard 55 and ISO 7730. Taking into account variables like air temperature, radiant temperature, air speed, and humidity, they establish suitable thermal conditions for human habitation. The goal of these criteria is to guarantee that a sizable portion of the population (usually 80% or more) finds the surroundings to be thermally acceptable. Both criteria are applicable when assessing thermal comfort in contemporary interior spaces, such as homes and businesses. However, ISO 7730 is a globally acknowledged standard, but ASHRAE Standard 55 is more widely accepted in the USA.



***Source*:** Authors' computation from Microsoft Excel

Fig 3: A Bar Chart showing the Thermal Sensation of Respondents



***Source*:** Authors' computation from Microsoft Excel

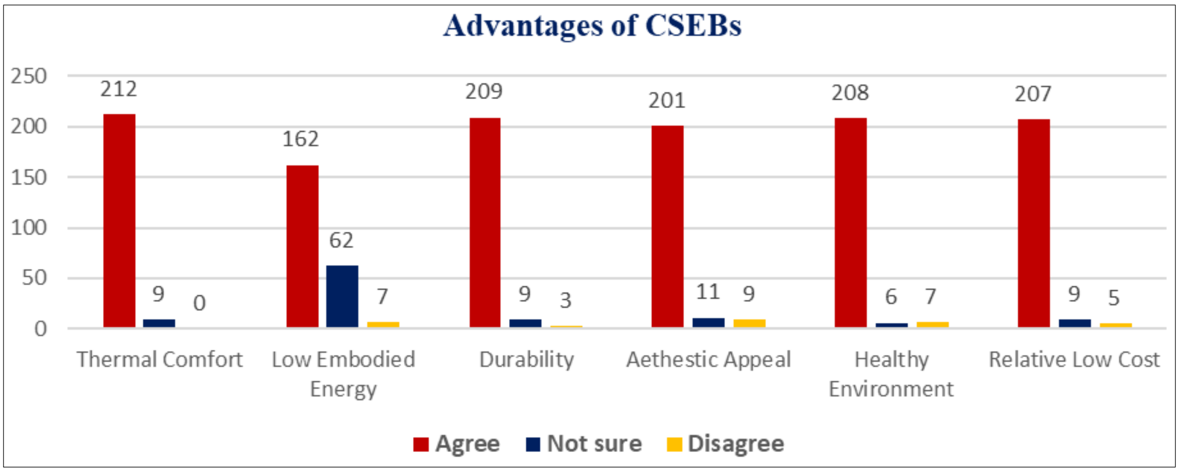
Fig 4: A Pie Chart showing the Thermal Sensation of Respondents

A total of 221 occupants were surveyed with regard to how they feel about the indoor temperature during mornings, afternoons, nights, dry seasons, rainy seasons, harmattan seasons, and overall indoor sensation. More so, their perception about direct sunlight, air speed, and movement within the building. Thus, the analysis in Figure 3 shows that only 9 occupants, that is, 4% (see Figure 4), were neither satisfied nor dissatisfied with the thermal performance of the CSEB buildings. However, 212 occupants expressed their satisfaction with the thermal condition of their residential buildings. This number accounts for 96% of the total study respondents as depicted in Figure 4.

Therefore, based on both ASHRAE Standard 55 and ISO 7730 criteria for assessing thermal comfort in modern-day indoor spaces in homes, CSEB's residential buildings in Lagos State possess high thermal performance. This result substantiates the findings of Jia *et al*. (2024) [26], Nouemssi *et al*. (2023) [37], and Real *et al*. (2024) [44] that CSEBs have a high conductivity and thermal capacity (Jia, Jiang, Zhang, Liao, Hu, Zhang, & Long, 2024; Nouemssi, Ntamack, Mbozo'O, & Djeumako, 2023; Real, Bogas, Cruz, Gomes, & Nabais, 2024) [26, 37, 44]. In addition, Ibitoye, Abiola, and Babamboni (2023) [23] add that CSEBs have good thermal insulation properties, which help to regulate indoor temperature and reduce energy consumption for heating and cooling (Ibitoye, Abiola, & Babamboni, 2023) [23].

Benefits of Adopting CSEBs for Residential Building

A three-point Likert scale (agree, not sure, and disagree) was employed to collect data from 221 residents of CSEB buildings in Lagos. The result of the survey is summarized in Figure 5.



Source: Authors' computation from Microsoft Excel

Fig 5: A Bar Chart showing responses in relation to Benefits of CSEBs

Result of the analysis revealed that 212 (95.9%) respondents approved that CSEBs possess thermal comfort when used for building construction, while 9 (4.1%) respondents remained undecided. Although 7 (3.2%) respondents disagreed, 62 (28.1%) respondents were not sure, and 162 (73.3%) respondents stated that CSEBs have low embodied energy. Result also establishes that CSEBs have durability capacity, as 209 (94.6%) occupants agreed, 9 (4.1%) occupants were undecided, and only 3 occupants disagreed. More so, responses show that CSEBs give buildings an attractive appearance. This explains why 201 (90.6%) respondents indicated their support, as against 9 (4.1%) respondents who disapproved of the assertion.

In addition, 208 (94.1%) occupants approved of CSEBs' environmental sustainability, while 7 (3.2%) disapproved, and 6 (2.7%) were neutral. Furthermore, 207 (93.7%) respondents indicated that CSEBs are cost-effective building materials, although 5 (2.3%) respondents and 9 (4.1%) respondents indicated disagree and not sure, respectively. These findings are in tandem with the results of Fundi *et al.* (2018); Hanafi (2021); Mohamed *et al*. (2024); Oyebisi *et al.* (2017); and Oyebisi *et al*. (2018) [18, 21, 33, 40, 39].

Conclusions and Recommendations

This study sought to determine the thermal perception of occupants of CSEB's residential buildings in Lagos State. Also, to establish the benefits of adopting CSEBs for residential buildings in a tropical climate. On this backdrop, the study findings demonstrate that CSEBs' residential buildings in Lagos State possess high thermal capacity. Indeed, the thermal performance of building constructions in tropical regions relies on mitigating heat accumulation through the use of sustainable building materials. More so, the benefits of employing CSEBs for building construction include relatively low cost, environmental sustainability, low embodied energy, high thermal capacity, and aesthetic appeal. Hence, the study recommends promotion of the usage of CSEBs among stakeholders as an alternative to conventional building materials in construction, owing to their significant advantages.

Recommendations for Further Studies

Subsequent research should include continuous thermal performance assessment of structures built with CSEBs throughout several climatic regions, such as hot-humid, hot-arid, and temperate. This would facilitate a more thorough comprehension of seasonal performance fluctuations. More so, it is essential to investigate how different ratios of stabilizers (cement, lime) and soil types influence thermal conductivity, heat capacity, and overall comfort.

References

1. Abey ST, Anand KB. Embodied energy comparison of prefabricated and conventional building construction. J Inst Eng India Ser A. 2019;100(4):777-90.
2. Abdallah R, Carré H, Perlot C, La Borderie C, El Ghoche

H. Study of the risk of instability in earthen bricks subjected to fire. Mater Struct. 2024;57(1):16-31.
3. Aghimien D, Makanjuola S, Fadeke A. Drivers and barriers of compressed stabilized interlocking earth blocks for building construction in Nigeria. In: Proceedings of the Joint International Conference (JIC) on 21st Century Human Habitat: Issues, Sustainability and Development; 2016 Mar 21-24; Akure, Nigeria. p. 21-4.
4. Assiamah S, Abeka H, Agyeman S. Comparative study of interlocking and sandcrete blocks for building walling systems. Int J Res Eng Technol. 2016;5(1):1-10.
5. Bakam VA, Mbishida MA, Danjuma T, Zingfat MJ, Hamidu LAJ, Pyendang ZS. Effect of firing temperature on abrasive and compressive strengths of an interlocking compressed stabilized earth block (CSEB). Int J Recent Eng Sci. 2020;7:44-6.
6. Bay J, Ong BL. Tropical sustainable architecture, social and environmental dimensions. Oxford: Architectural Press; 2006.
7. Beckett CTS, Jaquin PA, Morel JC. Weathering the storm: a framework to assess the resistance of earthen structures to water damage. Constr Build Mater. 2020;242:118098.
8. Benidir A, Brara A. Experimental assessment of mechanical behaviour of a compressed stabilized earth blocks (CSEB) and walls. J Mater Eng Struct. 2021;8(1):95-110.
9. Bibang Bi Obam Assoumou SS, Zhu L, Francis Deng C. A conceptual framework for achieving sustainable building through compressed earth block: a case of Ouagadougou, Burkina Faso. Circ Econ Sustain. 2023;3(2):1029-43.
10. Buson M, Lopes N, Varum H, Sposto RM, Real PV. Fire resistance of walls made of soil-cement and Kraftterra compressed earth blocks. Fire Mater. 2013;37(7):547-62.
11. Cammas C. Micromorphology of earth building materials: toward the reconstruction of former technological processes (Protohistoric and Historic Periods). Quat Int. 2018;483:160-79.
12. Chelghoum Z, Belhamri A. Analyse des propriétés thermiques des materiaux de constructions utilises dans la ville de Tamanrasset. Sci Technol D Sci Terre. 2011:47-56.
13. Contreras GS, Lezcano RAG, Fernández EJL. Analysis and typology of the most commonly used thermal insulation materials in the construction industry. Contemp Eng Sci. 2022;15(1):63-73.
14. Dahmen J. Perceptions of earth in the age of global architecture. In: Vernacular and Earthen Architecture: Conservation and Sustainability. CRC Press; 2017. p. 569-74.
15. Dixit MK. Embodied energy and cost of building materials: correlation analysis. Build Res Inf. 2017;45(5):508-23.
16. Elaouzy Y, El Fadar A. Energy, economic and environmental benefits of integrating passive design strategies into buildings: a review. Renew Sustain Energy Rev. 2022;167:112828.
17. Ferreira DM, Luso E, Cruz ML, Mesquita LM, Gontijo G. Fire behaviour of ecological soil-cement blocks with waste incorporation: experimental and numerical analysis. J Fire Sci. 2020;38(2):173-93.
18. Fundi SI, Kaluli JW, Kinuthia J. Performance of interlocking laterite soil block walls under static loading. Constr Build Mater. 2018;171:75-82.
19. Gallipoli D, Bruno AW, Perlot C, Mendes J. A geotechnical perspective of raw earth building. Acta Geotech. 2017;12:463-78.
20. Gupta AR, Deshmukh SK. Energy efficient construction materials. Key Eng Mater. 2016;678:35-49.
21. Hanafi WHH. Compressed stabilized earth block: environmentally sustainable alternative for villages housing. J Eng Appl Sci. 2021;68(1):1-13.
22. He Y, Yu H, Ozaki A, Dong N, Zheng S. An investigation on the thermal and energy performance of living wall system in Shanghai area. Energy Build. 2017;140:324-35.
23. Ibitoye OA, Abiola OA, Babamboni AS. Demographic characteristics of housing estates developed with ISSB technology in selected southwestern Nigerian (SWN) cities. Fudma J Sci. 2023;7(2):275-83.
24. Imbga KB, Ouédraogo E, Sambou V, Kieno FP, Ouédraogo A, Bathiebo DJ. New materials for thermal insulation in rural construction. Curr J Appl Sci Technol. 2018;29(4):1-10.
25. Islam MS, Tausif-E-Elahi, Shahriar AR, Nahar K, Hossain TR. Strength and durability characteristics of cement-sand stabilized earth blocks. J Mater Civ Eng. 2020;32(5):04020087.
26. Jia Y, Jiang X, Zhang W, Liao Y, Hu W, Zhang Y, Long E. Experimental study on improvement of indoor thermal environment of buildings in high altitude areas at night in winter by different sheltering methods. Energy Build. 2024;311:114142.
27. Joshua A, Bin Kandar MZ, Aminu DY. A review of compressed stabilized earth brick as a sustainable building material in Nigeria. Int J Sci Res Sci Eng Technol. 2017;3:827-34.
28. Kazemi M, Boukhelkhal I, Kosinski P, Attia S. Heat and moisture transfer measurement protocols for building envelopes. Liege: Sustainable Building Design Lab; 2021.
29. Maamar H. Choice of orientation and construction materials to improve the thermal performance of buildings. Tlemcen: University Abou-Bekr Belkaïd; 2016.
30. Malbila E, Delvoie S, Toguyeni D, Courard L, Attia S. Improving the building energy efficiency and thermal comfort through the design of walls in compressed earth blocks of agricultural and biopolymer residues masonry: a recent study. Curr J Appl Sci Technol. 2022;40(45):69-92.
31. Marzouk M, Elshaboury N. Science mapping analysis of embodied energy in the construction industry. Energy Rep. 2022;8:1362-76.
32. Moussa SH, Nshimiyimana P, Hema C, Zoungrana O, Messan A, Courard L. Comparative study of thermal comfort induced from masonry made of stabilized compressed earth block vs conventional cementitious material. J Miner Mater Charact Eng. 2019;7:385-403.
33. Mohamed NAG, Moustafa A, Darwish EA. Structural, acoustical, and thermal evaluation of an experimental house built with reinforced/hollow interlocking compressed stabilized earth brick-masonry. J Build Eng. 2024;86:108790.
34. Nagapan S, Antonyova A, Rasiah K, Yunus R, Sohu S.

Comparison of strength between laterite soil and clay compressed stabilized earth bricks (CSEBs). In: MATEC Web Conf. 2017;103:01029.
35. NitelikGelirli D, Arpacıoğlu Ü. Earth buildings from traditional to present. Architect Sci Build Mater. 2022;1:147-72.
36. Nnamdi EA, Ejiofor NEO, Ugoyibo ODV. Assessment of stabilized earth blocks (STEB) strength to sandcrete blocks used in housing construction. Am J Civ Eng. 2022;10(2):70-8.
37. Nouemssi GA, Ntamack GE, Mbozo'O MN, Djeumako B. Thermal properties of earth bricks stabilised with cement and sawdust residue using the asymmetrical hot-plane method. Open J Appl Sci. 2023;13(11):1910-34.
38. Oan A, Abdeltawab A, Elhefnawy A. Compressive strength and water absorption of CSEB mixtures. MEJ-Mansoura Eng J. 2021;45(4):14-20.
39. Oyebisi SO, Ede A, Ofuyatan O, Oluwafemi J, Akinwumi I. Comparative study of corncob ash-based lateritic interlocking and sandcrete hollow blocks. GEOMATE J. 2018;15(51):209-16.
40. Oyebisi SO, Olutoge FA, Ofuyatan OM, Abioye AA. Effect of corncob ash blended cement on the properties of lateritic interlocking blocks. Prog Ind Ecol Int J. 2017;11(4):373-87.
41. Paulus J. Construction en terre crue: dispositions qualitatives, constructives et architecturales - application à un cas pratique: Ouagadougou. 2015.
42. Pearson GT. Conservation of clay and chalk buildings. London: Routledge; 2015.
43. Raheem AA, Bello OA, Makinde OA. A comparative study of cement and lime stabilized lateritic interlocking blocks. Pac J Sci Technol. 2010;11(2):27-34.
44. Real S, Bogas JA, Cruz R, Gomes MG, Nabais M. Thermal performance of compressed earth blocks stabilised with thermoactivated recycled cement. Energy Build. 2024;314:114288.
45. Reddy BV. Earthen materials and earthen structures. In: Compressed Earth Block & Rammed Earth Structures. Singapore: Springer Nature Singapore; 2022. p. 3-55.
46. Reddy BV, Reddy BV. Compressed earth block & rammed earth structures. Singapore: Springer Singapore Pte. Limited; 2022.
47. Sadeghian A, Abdollahi R, Akbari A, Javidinejad M. An analysis on promoting the public acceptability of earth architecture in Yazd city. J Iran Architect Urban. 2023;14(2):215-32.
48. Santamouris M, Vasilakopoulou K. Present and future energy consumption of buildings: challenges and opportunities towards decarbonisation. e-Prime Adv Electr Eng Electron Energy. 2021;1:100002.
49. Turco C, Junior ACP, Teixeira ER, Mateus R. Optimisation of compressed earth blocks (CEBs) using natural origin materials: a systematic literature review. Constr Build Mater. 2021;309:125140.
50. Vyncke J, Kupers L, Denies N. Earth as building material – an overview of RILEM activities and recent innovations in geotechnics. In: MATEC Web Conf. 2018;149:02001.
51. Yogananth Y, Thanushan K, Sangeeth P, Coonghe JG, Sathiparan N. Comparison of strength and durability properties between earth-cement blocks and cement-sand blocks. Innov Infrastruct Solut. 2019;4:1-9.