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# Sensibility for Sustainability: Using Expanded Polystyrene (EPS) Material for Affordable Housing in Nigeria

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## Abstract

*In developing nations, affordable housing for the general public has long been a pipe dream, and the future appears bleak as well due to the rising cost of implementing traditional concrete material technologies and the current emphasis on environmental issues like climate change. In an attempt to buck the trend of inadequate housing supply, certain innovative building materials and technologies are being created to assist creative modular designs, labour reduction, a reduction in the depletion of exhaustible materials, time and money savings, and other aspects. One such substance is expanded polystyrene material. The development of sophisticated plastic materials, especially expanded polystyrene building technologies, is a highly smart and helpful move that will assist in reducing construction costs and making cheap housing more accessible to the general population. As a case study, an Abuja development estate that has mostly used expanded polystyrene building technology is being discussed. Clients and estate residents were given questionnaires, and statistical techniques were used to examine the collected data. Findings from the study show that EPS construction is more well-liked by people who have lived in EPS-built homes for longer stretches of time than by those who have only recently moved into EPS facilities. In conclusion, it is anticipated that more clients and residents will be open to employing EPS building materials for future residential projects, which will facilitate the provision of affordable homes for low-income workers in Nigeria.*

***Keywords:*** ***advance plastics, affordable housing, expanded polystyrene, performance perception, sustainability***

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## Introduction

Conventional building methods are insufficient and resource-wasting in the most industrialised countries of the globe for satisfying the housing needs of the expanding population (Alireza, Chisomo & Ann-Marie, 2023). This has sparked speculative studies aimed at creating new building technology. Numerous logical, constructive studies were carried out, resulting in the introduction of new industrialised production technologies that gave rise to distinctive modular designs and high strength/high load-bearing capacity materials, resulting in savings in terms of materials, labour, and time, which ultimately translates to significant financial savings. Building sustainable homes is becoming simpler all around the world as building materials have improved over time, leading to the genuine breakthroughs in the construction industries of the 21st century through the creation of diverse, simple-to-construct, and economically viable materials (Moghayedi, Awuzie, Omotayo, Le Jeune, Massyn, Ekpo, Braune & Byron, 2021).

A construction material should be thermally insulating, light in weight, and affordable in addition to meeting the safety norms (including seismic resistance) and comfort requirements of the occupants (Lee, Kelly, Jagoda, Rosenfeld, Stubee, Colaco, Gadgil, Akbari, Norford & Burik, 2006). The usage of the Expanded Polystyrene (EPS) initiative, one of the new materials that have entered the traditionally conservative building industry, allows for the fulfilment of all these requirements (Ede & Ogundiran, 2014). For a developing country like Nigeria, where the population is quickly expanding, housing systems that are both inexpensive and sustainable must be made available. EPS appears to be a suitable alternative available to Nigeria for addressing housing issues because it is one of the outcomes of the creative research that led to a dramatic drop in the cost of creating affordable homes in the advanced nations. Additionally, there is a growing concern for the environment worldwide, and every country on the planet is taking action to lessen the effects of human activity on the environment (Ede & Oshiga, 2014).

The careful selection of building materials, and particularly the selection of insulation, is addressing these concerns for the building and construction sectors globally (EPSASA, 2006).

Expanded polystyrene (EPS) is a versatile polymeric substance with a wide range of uses. Due to its lightweight, stiffness, and thermal and acoustic insulating qualities, EPS has a wide variety of uses. Initially, EPS was primarily utilised as an insulating foam for closed cavity walls, roofs, and floor insulation. However, the usage of EPS in the building and construction sector has ultimately greatly expanded, and it is currently employed in the construction of roads, bridges, flotation devices, and drainage systems. The most popular types and sizes of EPS utilised in building construction are those used for slab and wall panels. Steel mesh is used to erect these panels, and it acts as reinforcement.

Typically, the EPS 3D reinforced wall system distributes compression and shear stresses along the wall plane. Applying concrete layers of a suitable thickness to both sides of the wall system complete it and serves the twin purposes of shielding the reinforcements from corrosion and transferring compressive forces (Ede & Ogundiran, 2014). The use of plastic in civil constructions is rapidly expanding due to improved material performance, effective use of technologies in new applications, the need for lightweight, durable materials, and insulation purposes, as well as the strength of plastic materials that have been used in commercial and residential construction over the past 30 years (Parker & Beitel, 2006). The EPS material technology seems to be particularly alluring from an economic perspective for the major players in the construction sector.

Most frequently, the fundamental problems of the construction industry—cost, quality, and time—are never settled amicably between customers, designers, contractors, and end users. Every client would like to build a facility of the greatest calibre while keeping expenses and construction time to a minimum (Aina & Wahab, 2011). End customers are drawn to high-quality, reasonably priced housing. The best method to do this is to choose your building materials wisely and appropriately. One product that can help a building project be completed quickly, affordably, and with high quality is expanded polystyrene. EPS has performed well throughout every phase of its life cycle, from production to application through recycling or disposal.

The usage of expanded polystyrene has significant financial and environmental benefits because it helps to improve the environment while costing the least amount of money. These factors are what prompted this study since further research and education are required to determine how well the current applications are performing and to establish a number of potential improvements. This study aims to investigate the uses of this high-tech plastic material in the Nigerian construction sector, paying particular attention to how clients and end users perceive its performance. The case study will focus on a building estate in Abuja where EPS has been employed most frequently.

**Literature Review**

A wide variety of synthetic or semi-synthetic organic solids, most frequently produced from petrochemicals, are used to create plastic polymers. According to Daniel, Stuart & William (2013)., they are typically high-molecular-mass organic polymers with the inclusion of other materials. These polymers are mostly composed of chains of carbon atoms, either alone or in combination with oxygen, sulphur, or nitrogen. It takes copolymerisation between the monomers throughout the plastic production process in order to get the desired properties, depending on the attributes needed (Sabu & Visakh, 2011).

Plastics have become an essential component of 21st-century life. Plastics have a wide and growing range of applications, from paper clips to spaceships, thanks to their low cost, water resistance, adaptability, and ease of manufacture. They even have a significant presence in the traditionally conservative building business. Many conventional materials, including wood, leather, metal, glass, stone, and ceramic, have already been replaced by plastics in the majority of their previous applications. In affluent countries, a third of plastic is used for packaging, a further third for construction, and toys, furniture, and automobiles, which can contain up to 20% plastic. In poor countries, the percentage of using plastic to replace traditional materials is significantly rising, although it is still much behind the ratio in rich countries.

**Polystyrene**

Styrene, a liquid petrochemical monomer, is used to create this synthetic aromatic polymer. One of the most frequently used plastics is polystyrene, which comes in rigid and foamed forms. Polystyrene for general use is clear, rigid, and brittle by nature. It is a resin that costs relatively little. Since polystyrene is a thermoplastic polymer, it is solid at ambient temperature but flows when heated above around 100°C, which is its glass transition temperature. Extrusion, moulding, and vacuum forming all make use of this characteristic that is temperature dependent. Chemically speaking, polystyrene is a long-chain hydrocarbon (C8H8) with phenyl groups bonded to alternate carbon atoms. Short-range Van der Waals attractions between polymer chains control the material's characteristics.

The overall attractive force between the molecules is strong because they are lengthy hydrocarbon chains made up of thousands of atoms. The chains can move past one another when heated and can adopt a higher degree of conformation. Elasticity and flexibility are provided by this intermolecular weakness. Polystyrene can be easily softened and moulded when heated because the system can be easily deformed above its glass transition temperature. Extruded polystyrene foam, sheets, or orientated polystyrene are a few of the often-produced types. You can find debt studies on polystyrene in Sabu & Visakh (2011).

**Expanded Polystyrene (EPS)**

This thermoplastic substance is made from styrene monomer by a polymerisation process that yields translucent polystyrene beads with a spherical shape. As a substance, EPS is created by mixing a large number of polystyrene beads created during a modelling process with a supply of heat as water vapour until the appropriate qualities are fully developed. In order to aid expansion during further processing, a low boiling point hydrocarbon, often pentane gas, is added to the material for the manufacturing of EPS. Three stages are involved in the production of EPS. In the first step, a pre-expander, a sealed vessel heated to roughly 100°C with steam, expands polystyrene beads to between 40 and 50 times their original volume. The beads are continuously swirled throughout this process until the final EPS density is established (Haghi, Arabani & Ahmadi, 2006).

The expanded beads from the pre-expansion stage are then transported to storage silos for maturation before being cooled, dried, and packaged (Michael, 2013). The enlarged beads are stabilised during the maturing phase until equilibrium is established. The beads are transported into a mould during the third manufacturing stage, where they soften and fuse together when the mould reaches the proper temperature. At the end of the cycle, the formed product is released from the mould once it has cooled. After extensive testing and failure, EPS material systems in particular and modern plastic materials in general are now being used often in the global building sector (Raps, Hossieny, Park & Altstadt, 2014).

Many different types of construction activity, including huge structures like roads, bridges, railway lines, embankments, retaining walls, slope stabilisation, basement construction, public buildings, or even tiny family homes, utilise advanced plastic materials. Modern plastics have several uses, and one of them is in the development of concrete materials. The use of concrete technology is expanding, and numerous improvements and innovations have been produced to meet the challenges of various construction-related tasks. The use of lightweight aggregates and synthetic aggregates like EPS beads, fly ash, and slag has been used in many productions of lightweight concrete (Ismail, 2003; Bonacina, 2003; EUMES, 2002; Babu & Babu, 2002; Concrete Homes, 2012; Cook, 1973; Cen & Liu, 2004).

EPS beads can be used entirely or partially in place of aggregates in mixes, depending on the desired strength and characteristics. Lightweight concrete-cement composites are becoming more and more common since they have several benefits for a variety of uses. EPS is often employed as a permanent formwork at the same time that composite building materials with a sandwiched core are rising in popularity. The purpose of doing this, according to Boni & De Almeida (2008), is normally to strengthen the unique traits of both through the mixture of both. In order to create sandwich construction materials with thicker, lower-density intermediate layers attached to the exterior facings of a stiffer material, Binici, Aksogan & Shah (2005) research focuses on the use of a common core in aerospace applications that is honeycombed with corrugated or cellular materials. The high stiffness/low weight efficient designs are advantageous for both the aerospace industry and the construction industry and are combined to form a robust composite structural system for walls, partitions, and floor slabs, the use of EPS panels designed for specific uses.


***Fig. 1:*** ***A typical example of EPS building systems. Source: CITEC International Estate Abuja***

In order to add concrete or sand crates, these are frequently finished on-site using pneumatic tools. Strength tests on EPS, which was initially buried about 30 years ago, show that it is still resilient today (BPF, 2009). This is relevant to issues with durability. The standard EPS building systems are shown in Figure 1. In the global construction sector, expanded polystyrene (EPS) benefits include lifetime durability, moisture resistance, proven acoustics, outstanding thermal insulation, design versatility., cost-effectiveness, simple installation that may be finished in a record amount of time, flexible mechanical characteristics, good strength, and structural stability. With regard to production costs and construction time in particular, EPS material has an edge over conventional building materials. Nevertheless, despite all of the advantages and capabilities of the EPS building system, very little of it is being utilised by builders in Nigeria. This is a result of the material's limited accessibility and the general lack of familiarity with these unique construction methods.

Due to its scarcity, the lack of awareness among building professionals, and the general lack of public awareness, EPS has not spread widely in Nigeria. The cost of making EPS blocks or panels for use in construction operations is expensive in Nigeria due to a scarcity of EPS building material producers, and this expense is passed on to end users by customers or contractors. This study evaluates the efficacy of EPS construction technologies in the Nigerian construction sector at a time when traditional construction material technologies are increasingly becoming out of reach for the construction of affordable homes for low-income earners based on these scenarios and the proven properties and uses of EPS.

**Expanded Polystyrene and its Use in Housing Construction**

The usage of EPS as an alternative material in housing construction has been taken into consideration based on the necessity to develop strategies in order to optimise construction issues. Although Kageni (2014) and Ngugi, Kaluli & Gairy (2017) assert that the use of EPS in construction is relatively new, the usage of EPS in industrial packaging dates back considerably further. According to Ede, Alegiuno & Aawoyera (2014) and Ngugi, Kaluli & Gairy (2017)., EPS is a thermoplastic material that is created by joining a large number of polystyrene beads produced during a modelling process with a supply of heat as water vapour until the full development of the desired qualities.

Pre-expansion, intermediate maturation, and final moulding are the three steps in the production of EPS. According to Kageni (2014), Ede et al. (2014) & Ngugi et al. (2017), the raw material (the beads) is heated with steam in specialised equipment called pre-expanders at temperatures of about 100°C during the pre-expansion step. The beads inflate up to about 50 times their original size during this process, and after reaching the proper volume, they are cooled, dried, and then transported to storage silos for maturing. The expanded beads are stabilised during the maturation stage to increase their mechanical elasticity and expandability. The cycle continues until equilibrium is established. The beads are transported into moulds for the third manufacturing stage, where they are further heated with steam as they are squeezed to create a block (also known as "block moulding").

Although the three processes mentioned above are employed in the creation of EPS, Ibrahim (2013) & Ngugi et al. (2017) went on to state that EPS utilised in the design and construction of buildings must additionally contain steel mesh reinforcement. In terms of home construction, EPS has been reported to be utilised for roofs, floor slabs, wall panels, and other building elements, as shown in Table 1.

**Table 1: Building elements made with EPS**

| | Elements | References |
|---|---|---|
| **1** | Wall | Daouas, Hassen & Aissia, (2009); Paolella & Grifoni (2013); Ede et al. (2014). |
| **2** | Floor (lightweight) | Paolella & Grifoni (2013); Ede et al. (2014); Ngugi et al. (2017). |
| **3** | Roof (insulation) | Paolella & Grifoni (2013); Ngugi et al. (2017). |
| **4** | Staircase | Ibrahim et al. (2013). |
| **5** | Ceiling | Paolella & Grifoni (2013); (Ngugi et al. 2017). |

*Source: Researcher's Archive, 2023.*

While Daouas, Hassen & Aissia (2009) described the usage of EPS in Tunisia, the works of Kageni (2014) and also Ngugi et al. (2017) illustrate the use of

EPS in housing building in Kenya. Doroudiani & Omidian (2010) provide evidence of the use of EPS in Canada. Both Ibrahim et al. (2013) & Ede et al. (2014) published publications in Nigeria that addressed the usage of EPS as a building material. Despite the fact that the scope of this research varied, they all came to the same conclusion: employing EPS in housing building is definitely sustainable.

**Factors Characterizing Expanded Polystyrene as a Sustainable Material**

A number of studies have been done to determine the potential of EPS as a sustainable material in the construction of houses. Research findings have provided information on its potential for usage in the development of sustainable homes. Table 2 shows a few of these potentials as reported by various writers, whose studies on EPS utilised in construction have different foci.

**Table 2: Factors attributed to using EPS in construction**

| | Factors | References |
|---|---|---|
| 1 | Reusability potential | Briga-Sá et al. (2013); Ede et al. (2014). |
| 2 | Time savings | Giuliania, F., Autelitanoa, F., Garillia, E., Monteparaa, A. (2020). |
| 3 | Job opportunity | Kageni (2014). |
| 4 | Aesthetics | Ibrahim et al. (2013). |
| 5 | Hot weather resistance | EUMEPS (2013); Lakatos & Kalmar (2013); Alam et al. (2013); Briga-Sá et al. (2013). |
| 6 | Fire resistance | EUMEPS (2013); Alam et al. (2013); Briga-Sá et al. (2013). |
| 7 | Cold weather resistance | Daouas et al. (2009); Kageni (2014); Raj et al. (2014); Ngugi et al. (2017); Ibrahim et al. (2013); Raj et al. (2014); Shi et al. (2016); Binici et al. (2005) Ede et al. (2014); EUMEPS (2013); Alam et al. (2013); Kageni (2014). |
| 8 | Strength and stability | Ngugi et al. (2017) |
| 9 | Resistance to impact of sound | Raj et al. (2014); Ngugi et al. (2017); Briga-Sá et al. (2013) |

*Source: Researcher's Archive, 2023.*

**CITEC Estate and the use of Expanded Polystyrene**

A prime example of the employment of EPS in residential building is found in the Abuja neighbourhood of Citec Mbora Mount Pleasant Estates Mbora. A 3,000-unit mass housing development with EPS-built homes is being considered. The construction process started in 2003 and is still going strong. A workshop for the fabrication of EPS construction components is located on the estate. Figure 2 shows the polystyrene material and several products made from it.


***Fig. 2:*** ***EPS elements used at Citec Mbora Mount Pleasant Estate Abuja.***
***Source: Researcher's Archive, 2023.***

Although the fabrication of EPS elements of variable size, shape, or colour can be done off-site, their assembling and subsequent finishing is done on-site.

**Methodology**

The quantitative research approach was used to conduct this study. The clients and inhabitants of a working estate in Abuja that employed expanded polystyrene (EPS) as its primary building material were given a multiple-choice structured questionnaire to complete to collect data. Following a thorough examination of the literature, the questionnaire was developed. The questionnaire asks respondents about their level of satisfaction with expanded polystyrene construction.

The users, who are the inhabitants of the Citec Mbora Mount Pleasant Estate Abuja, and the clients, who are represented by the construction experts at CITEC International Estates Limited, made up the population under consideration. There are 35 construction professionals working for Polystyrene Industries Limited and CITEC International Estates Limited. The primary responders were homeowners in Abuja's Citec Mbora Mount Pleasant Estate as well as working professionals at CITEC International Estate Limited, including architects, engineers, constructors, and quantity surveyors.

Ninety-four of the 110 questionnaires that were distributed were collected. This yields an 85.45% response rate. The sample size stayed at 94 since the researcher thought the population size was feasible. As a result, the returned surveys were appropriate for analysis. After a thorough analysis of the surveys, pertinent data needed to accomplish the different goals was collected. The Statistical Package for the Social Sciences (SPSS) was used to analyse the information and data that was collected. The statistics package featured data representation in various graphical formats in addition to statistical analysis. The methods used in this study were derived from earlier research findings (Alegiuno, 2014).

**Results and Discussion**

SPSS was used to analyse the information gathered from the surveys. Client satisfaction with EPS as a primary building material, resident satisfaction with EPS buildings, client perceptions of EPS recyclability, client-user perceptions of EPS reliability, client perceptions of EPS product versatility, and user perceptions of EPS building product moisture resistance were among the data that was taken from the data presentation.

The client's satisfaction with EPS as a primary building material is depicted in Figure 3. The use of EPS as a primary building material is justified by the client's over 90% satisfaction rate. Residents' opinions of EPS building products are depicted in Figure 4. In this instance, people who had occupied the EPS buildings for more than two years expressed more satisfaction (99%) than those who had occupied the building for less time (79%). This is good news because people are increasingly satisfied with EPS items the longer, they use them.

The client's opinion regarding the recyclability of EPS products is shown in Figure 5. 68.8% of respondents are satisfied with how recyclable EPS building materials are. The perception of EPS reliability by residents and clients is depicted in Figure 6. Both the customer and the end user are satisfied with the EPS building system's reliability, as evidenced by the 87.9% client satisfaction rate and the 68.9% resident satisfaction rate.

The client's opinion of the adaptability of EPS products is shown in Figure 7. For the EPS building materials, the client satisfaction rate of 96.6% seems to be excellent. The user's assessment of EPS construction goods' moisture resistance is subsequently displayed in Figure 8. It is positive for EPS construction technology that 80.4% of users are satisfied with the products' ability to withstand dampness. The research's findings are summarised in Figure 9, which contrasts the good and negative elements.

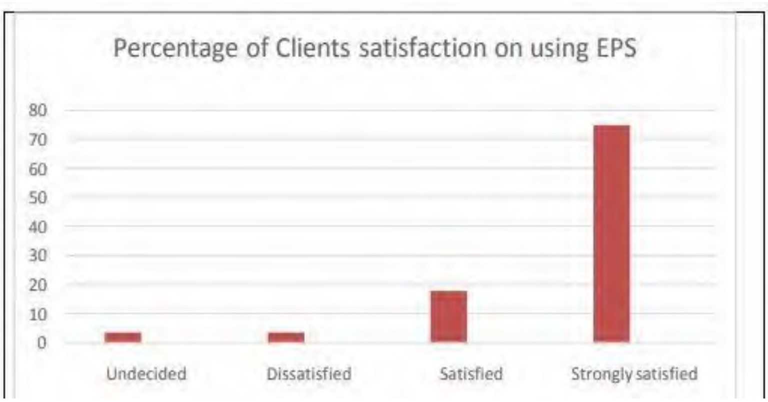


*Fig. 3: Client's satisfaction of using EPS as a principal building material.*

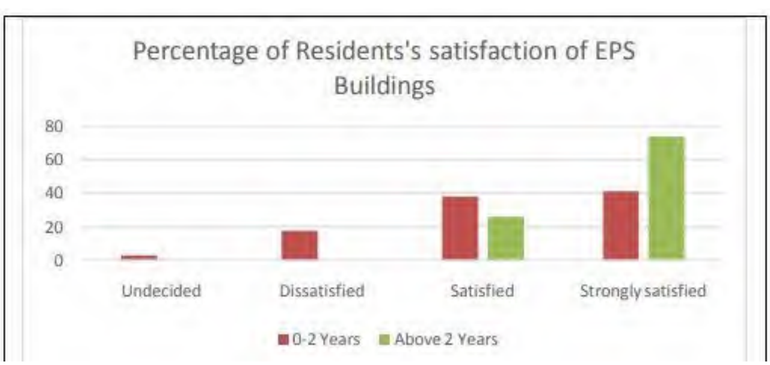


*Fig. 4: Residents satisfaction of EPS buildings*

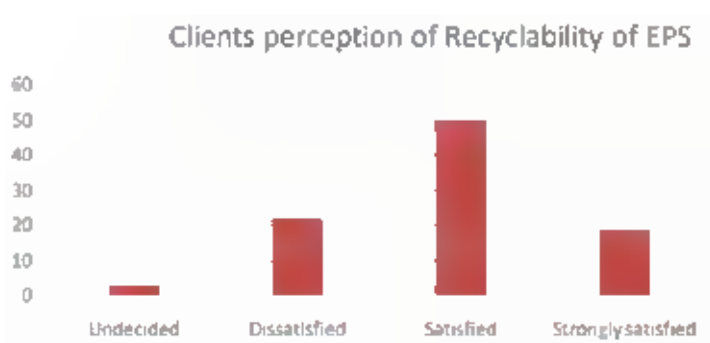


*Fig. 5: Client's perception of EPS recyclability*

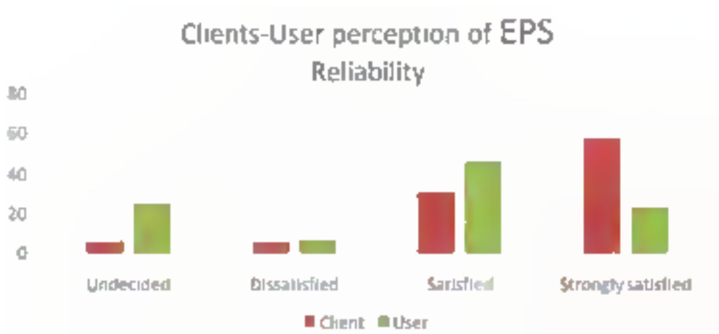


*Fig. 6: Clients-user's perception of EPS reliability*

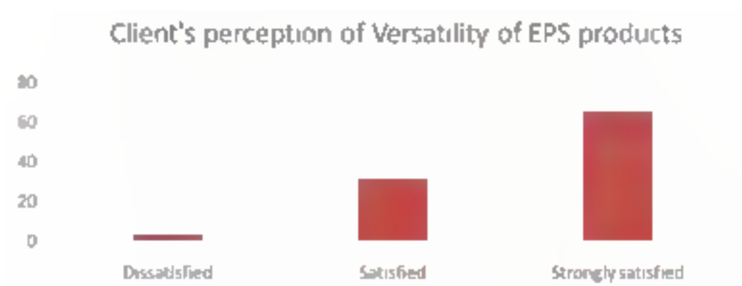


*Fig. 7: Client's perception of versatility of EPS products.*

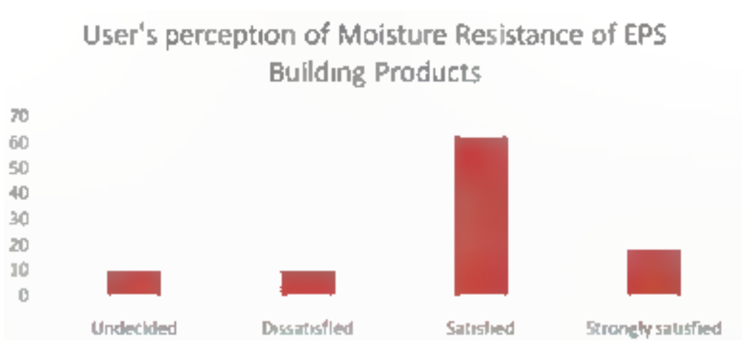


*Fig. 8: User's perception of moisture resistance of EPS building products*

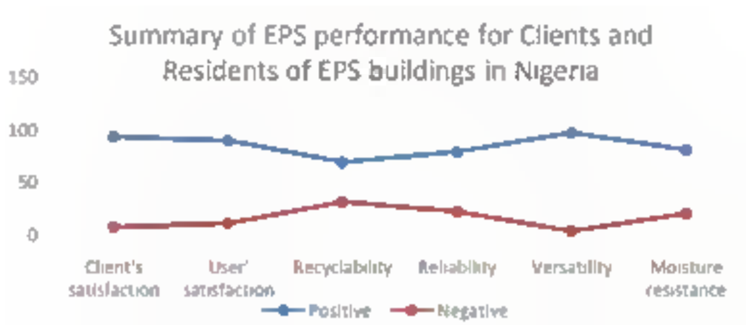


***Fig. 9:*** ***Summary of the results of this research***

This study evaluated the degree to which Citec Mbora Mount Pleasant Estate, Abuja residents were satisfied with prefabricated expanded polystyrene (EPS) construction. In order to assess the effectiveness and acceptance of expanded polystyrene (EPS) building systems in Nigeria as a replacement for traditional building materials like sand and bricks, the study looked at a number of variables.

High-ranking performances for EPS building products' recyclability, reliability, versatility, and moisture resistance as determined by this research, as well as high satisfaction for both clients and residents, all portend a bright future for the use of these innovative building products in the Nigerian construction industry.

Results from this study reveal that EPS is perceived to be of better use for hot weather resistance than for cold weather resistance. This finding is consistent with that of Ibrahim et al. (2013) and also Ede et al. (2014) regarding the commendable heat resistance of EPS in Abuja. This property is an indication of the probable sustainability in the use of EPS, primarily considering the hot climatic condition, particularly during the daytime. Also, the annual variation of temperature in Abuja is such that the hot weather lasts longer than the cold weather. This, by extension, could result in achieving efficient insulation and cooling depending on the variations in the climatic conditions.

Additionally, this study shows that since "economic factors" (such as reusability, time savings, and job opportunities) rank higher (1st and 2nd) than "functional performance factors" (strength and stability resistance to the impact of sound, which rank 3rd to 7th), using EPS may have economic advantages, which is a sign that it qualifies as a sustainable building material. This result supports that of Ngugi et al. (2017) and Ede et al. (2014), who found that mechanical aspects were not as important as the performance perception of EPS reusability.

The study also revealed that EPS construction is more well-liked by people who have lived in EPS-built homes for longer stretches of time than by those who have only recently moved into EPS facilities.

## Conclusion

According to this study, EPS has the potential to be used as a sustainable building material for the construction of homes in Abuja, even though its performance in terms of fire and sound insulation still has to be improved.

At the end of this study, it is expected that an awareness of the use of polystyrene be created, retrospectively causing a lesser overall cost of projects and a lesser time for completion of various milestones in projects. This will be beneficial to quantity surveyors as their aim is to maximise satisfaction and minimise cost. From a bigger picture, it benefits the construction industry at large with its easier, time-saving, and better structural properties.

Also, the government should provide support for the use of EPS material in affordable housing, including tax incentives and subsidies; this will encourage the construction industry to adopt EPS material as a standard building material for affordable housing.

The future research should focus on a comprehensive assessment of the environmental impact of using EPS material, engage with stakeholders to provide valuable insights into the practicality and feasibility of using EPS material for affordable housing, and provide a comprehensive comparison of EPS material with traditional building materials.

In conclusion, it is envisaged that more customers and locals will be willing to adopt EPS building materials for upcoming residential structures, which will make it easier to provide inexpensive housing for low-income workers in Nigeria.

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