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Use of Advanced Plastic Materials in Nigeria: Performance Assessment of Expanded Polystyrene Building Technology System

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Abstract**:** - The provision of affordable residential houses for the masses in the developing nations has been a mirage over the years and the future does not portend good as the cost of adopting conventional concrete material technologies is escalating while so many environmental issues like climate change are being raised in the recent times.To circumvent this poor housing provision trend, some innovative construction materials and technologies are being introduced to facilitate unique modular designs, reduction of labour, decline in the depletion of exhaustible materials,savings of time and fund. One of such materials is the expanded polystyrene. The introduction of advanced plastic materials and in particular the expanded polystyrene building technologies in the Nigerian constructionindustry will be a very useful and brilliant initiative that will aid the reduction of cost of construction and facilitate access to affordable houses for the masses.This researchaims at studying the applications of this innovative plastic material in the Nigerian building industry with special regard to the performance perception by the clients and the end users. A building estate where expanded polystyrene building technology has been predominantly used in Abuja is considered as a case study. Questionnaires were distributed among clients and residents of the building estate and statistical tools were used to analyse the data collected. Great satisfaction verified among the clients and residents and the high ranking performance confirmed for recyclability, reliability, versatility and moisture resistance of EPS building products all herald a great future for the applications of this advanced building products in the Nigerian building industry.

Keywords: - *Advance Plastics, Expanded Polystyrene,Affordable Housing, Sustainability, Performance Perception.*

I. INTRODUCTION

Housing is a reflection of the cultural, economic and social evolution of a society. It is an expression of a people's ability to meet their needs of shelter (Gardi, 1973). The significance of shelter to man cannot be over emphasized as it is next in importance to air, water and food (Ede, 2011). The most obvious consequence of population growth is influx of multitudes from the rural areas to the cities which in many developing countries such as Nigeria has often led to rapid deterioration of housing setups and living conditions (Lewin, 1981, Olotuah, 2010). This rural-urban drift in search of greener pastures has brought about rapid increase in the residents of urban centers climaxing in higher demand for urban housings and general increase in the cost of living. The high cost of urban land and the consequent high cost of housing scheme in the presence of excessive demands and dearth of housing facilities have made access to comfortable homes out of the economic reach of the majority of the urban dwellers (Ede and Ogundiran, 2014). According to Olotuah and Ajenifujah (2009), most urban centers in Nigeria are characterized by high densities of buildings, overcrowding of most buildings, inadequate spaces for open air between houses, poor health, substandard housing, and acute environmental and sanitary problems. This shortage of decent and affordable accommodations for the urban low income earners is a major difficulty facing Nigeria today. To circumvent this housing problem, some rational constructive processes can be implemented with the introduction of new construction technologies that allow unique modular designs, high strength and load bearing capacity materials, reduction of labour, materials, mass, time and fund (Ogundiran and Adedeji, 2012). The introduction of advanced plastic materials and in particular the expanded

polystyrene building system in the building and construction industry of Nigeria will be a very useful and brilliant initiative that will aid the reduction of cost of construction and facilitate access to affordable houses to the masses.

In the most developed nations of the world, it has been verified that the conventional building technologies are inadequate and resource wasteful towards meeting the housing needs of the teaming population. This has led to futuristic researches towards the development of new building technologies. Many rational constructive researches were undertaken thereby propelling the introduction of new industrialized production technologies which gave birth to unique modular designs, high strength/high load bearing capacity materials resulting to saving in terms of materials, labour and time which ultimately translates to great savings of funds. As the construction materials have evolved over the years till the real breakthroughs in the construction industries of the 21st century through the development of versatile, easy to construct and economically viable materials, it is becoming easier worldwide to build sustainable homes. A building material that meets the safety standards (including seismic resistance) and the dweller‘s comfort requirements must also be thermally insulating, light weight and inexpensive (Lee et al., 2006).

All these requirements are made possible through the use of Expanded Polystyrene (EPS) initiative which represents one of such new materials that have found their way into the previously conservative construction industry(Ede and Ogundiran, 2014). For a developing nation like Nigeria, affordable and sustainable housing systems need to be provided for the rapidly growing population. EPS being one of the results of the innovative researches that gave birth to drastic reduction of cost of building affordable houses in the advanced nations appears to be a good option open to Nigeria for tackling housing problems.

Also, the world is becoming more concerned about the environment, and measures are being taken in every nation of the earth to reduce the impact of activities on environment (Ede and Oshiga, 2014). For the building and construction industries worldwide, these concerns are being addressed by the careful choice of building materials, and in particular, the selection of insulation (EPSASA, 2006). Therefore, the use of environmentally friendly material such as EPS for new and improved building technology system will go a long way to enhance the environmental quality of the Nigerian building industry.

Expanded Polystyrene (EPS) is a multipurpose plastic material made available for a multiplicity of applications. EPS has experienced wide range of applications owing to its lightweight, rigidity & thermal and acoustic insulating properties. Initially, EPS was mainly used for insulation foam for closed cavity walls, roofs and floor insulation. But ultimately, the application has extended vastly in the building and construction industry such that EPS is now used in road construction, bridges, floatation and drainages. EPS used for building construction are of various types and sizes with the most common ones being for wall panels and for slab. These panels are erected with steel meshes. The steel mesh serves as reinforcement. The EPS 3D reinforced wall system usually transfers shear and compression forces along the wall plane. The wall system is completed by applying concrete layers of acceptable thickness on both sides to perform the dual functions of protecting the reinforcements against corrosion and for transference of compressive forces (Ede and Ogundiran, 2014). With the proven strengths of plastic materials used in commercial and residential construction in the past 30 years, the adoption of plastic in civil constructions is dramatically on the increase due to improved material performance, efficient use of technologies in new applications, and the need for lightweight, durable materials and insulation purposes (Parker and Beitel, 2006; Papadopoulous, 2005).

On the economic side, the EPS material technology appears to be very enticing for the key players in the construction industry. Most often, the clients, designers, contractors and end users are always at logger heads over terms of establishing acceptable equilibrium on the major building industry concerns of cost, quality and time. Every client would want to construct a facility of the highest quality while minimizing cost and time (Aina and Wahab, 2011). End users are attracted to good quality houses at affordable cost. The most suitable way to achieve this is through suitable and careful choice of building materials. Expanded Polystyrene is one product that can contribute towards achieving good quality, low cost and record time completion of building product. At all stages of its life cycle, from manufacture, to application, to recycling or disposal, EPS has shown very good performance. The use of expanded polystyrene offers considerable cost and environment advantages since it contributes positively towards a better environment and at the minimal cost.

These are the facts that gave rise to this research as further researches and awareness are needed so that the performance of the existing applications can be ascertained and various ways of improving the applications can be established. This research is aimed at studying the applications of this advanced plastic material in the Nigerian building industry with special regard to the performance perception by the clients and the end users. A building estate where EPS has been predominantly used in Abuja will be the case study.

II. MATERIALS AND METHODS

2.1 Common plastics

Plastic materials are made up of a wide range of synthetic or semi-synthetic organic solids that most commonly derived from petrochemicals. They are typically organic polymers of high molecular mass with the addition of other substances (Wikipedia, 2012). The vast majority of these polymers are based on chains of carbon atoms alone or with oxygen, sulphur, or nitrogen. During the plastic production process and based on the properties required, copolymerization among the monomers is necessary for the desired properties to be achieved (Sabu and Visakh, 2011). The fine tuning of the properties of the polymer by repeating unit's molecular structure has allowed plastics to become an indispensable part of the 21st century. Due to relatively low cost, impermeability to water, versatility of use and ease of manufacture, plastics usage has experienced an enormous and expanding range of applications from paper clips to spaceships and ultimately vast presence in the conservative construction industry. Plastics have already displaced many traditional materials such as wood, leather, metal, glass, stone and ceramic in most of their former uses. In the developed nations, about a third of plastic is used in packaging, another third in buildings, while other uses include automobiles with up to 20% plastic parts, furniture and toys. The ratio of replacing conventional materials with plastics is greatly on the increase in the developing nations but still very far less its ratio in the developed nations.

2.2 Polystyrene

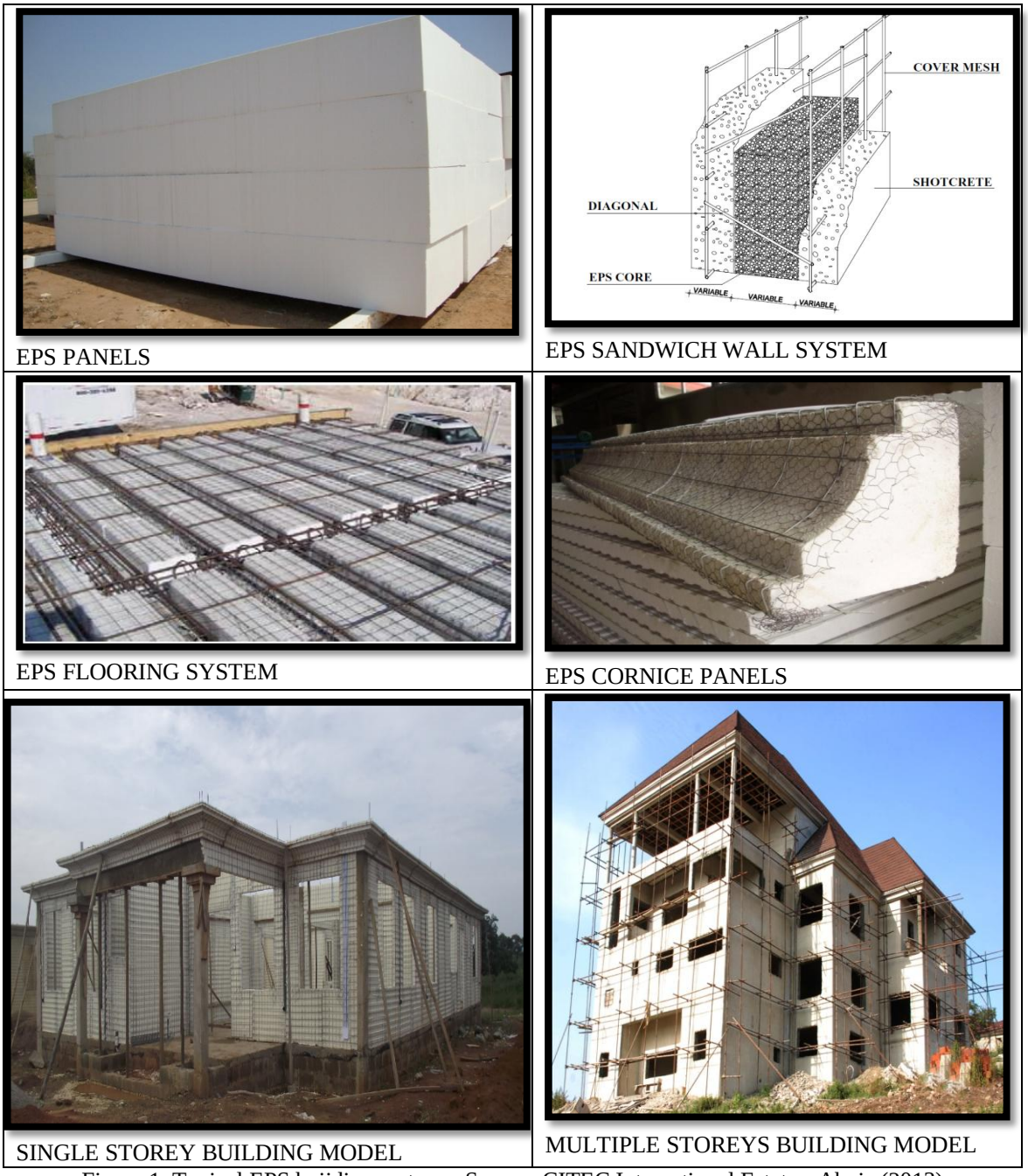
This is a synthetic aromatic polymer made from liquid petrochemical monomer styrene. Polystyrene can be rigid or foamed and is one of the most widely used plastics. General purpose polystyrene is naturally transparent, hard and brittle. It is a very inexpensive resin. As a thermoplastic polymer, polystyrene is in a solid state at room temperature but flows if heated above about 100°C, its glass transition temperature. This temperature dependent behavior is exploited for extrusion, and also for molding and vacuum forming. Chemically, polystyrene is a long chain hydrocarbon $(C_8H_8)_n$ wherein alternating carbon centers are attached to phenyl groups. The material's properties are determined by short-range Van der Waals attractions between polymer chains. Since the molecules are long hydrocarbon chains that consist of thousands of atoms, the total attractive force between the molecules is large. When heated, the chains are able to take on a higher degree of conformation and slide past each other. This intermolecular weakness confers elasticity and flexibility. The ability of the system to be readily deformed above its glass transition temperature allows polystyrene to be readily softened and molded upon heating. Some common forms produced are Sheets, or expanded polystyrene, oriented polystyrene and extruded polystyrene foam. Indebt studies on polystyrene can be found in (Sabu and Visakh, 2011).

2.3 Expanded Polystyrene

Expanded Polystyrene (EPS) is a thermoplastic material manufactured from styrene monomer, using a polymerization process which produces translucent spherical beads of polystyrene. As a material, EPS is formed by union of so many beads of polystyrene produced during a modelling process with supply of heat as water steam until full formation of the desired properties. For the production of EPS, a low boiling point hydrocarbon, usually pentane gas is added to the material to assist expansion during subsequent processing. EPS is produced in a three stage processes. In the first stage, polystyrene beads are expanded to between 40 and 50 times their original volume by heating to about 100˚C with steam in an enclosed vessel called a pre expander. During this process the beads are stirred continuously until the final density of EPS is determined. From the pre expansion stage, the expanded beads are cooled, dried and then conveyed to storage silos for maturing. During the maturing stage, the expanded beads are stabilized until equilibrium is reached. In the third processing stage, the beads are conveyed into a mold and the softened beads fuse together when correct temperature is reached within the mold. After cooling the mold, the molded product is ejected from the mold at the completion of the cycle.

After many years of trials and errors of advanced plastic materials in general and the EPS material systems in particular, their applications are becoming common place in the construction industry all over the world. Advanced plastic materials are used in many aspects of building work including large structures such as road constructions, bridges, railway lines, embankments, retaining walls, slope stabilization, basement construction, public buildings or even small family residences. One of the areas that advanced plastics have found wide applications is in the improvement of concrete materials. Concrete technology is growing and many advances and innovations have been made to cope with challenges of many construction aspects. Many productions of lightweight concrete had been designed and among them are by the use of lightweight aggregates and artificial aggregates such as EPS beads, fly ash and slag (Ismail *et al*, 2003; Bonacina et al., 2003; EUMES, 2002; Babu and Babu, 2002; Concrete Homes, 2012; Cook, 1973; Cen and Liu, 2004). EPS beads can be added to mixes either partially or fully replacing aggregates subject to the desired strength and properties. Light Weight Concrete is advantageous in many applications and is becoming increasingly used often in the form of cement-foam composites. EPS is commonly adopted as a permanent formwork just as composite construction materials with a sandwiched core are becoming a more common construction material. (Boni and De Almeida, 2008) states that this is usually to improve the unique properties through the combination of both. A common

core used in aerospace applications (which is the focus of Boni and De Almeida's work) is honeycombed with corrugated or cellular materials to produce sandwich construction material of thicker lower density intermediate layer bonded to external facings of a stiffer material. The high stiffness/low weight efficient structures is beneficial both in the aerospace industry and in the construction industry. The lightweight EPS is combined with other stronger materials to make it a viable structural material. Concrete is then used with EPS to create a strong composite structural system.



EPS PANELS | EPS SANDWICH WALL SYSTEM

EPS FLOORING SYSTEM | EPS CORNICE PANELS

SINGLE STOREY BUILDING MODEL | MULTIPLE STOREYS BUILDING MODEL

Figure 1: Typical EPS buiiding systems; Source: CITEC International Estates, Abuja (2013)

EPS panels, tailored for specific projects are used as walls panels for partitioning and for floor slabs. These are normally finished on-site by applying concrete/sand crate with pneumatic devices. On durability issues, strength tests performed on EPS which was first placed in the ground almost 30 years ago show that it is still strong today (BPF, 2009). Typical EPS building systems can be seen in figure 1.

From the previous paragraphs, the benefits of expanded polystyrene (EPS) in the building industry worldwide can be summed up as lifetime durability, moisture resistance, proven acoustic and excellent thermal

insulation, design versatility, cost-effective, easy installation leading to record time completion, flexible mechanical properties, good strength and structural stability. Specifically on the cost of production and time of construction, EPS material has an edge over conventional building materials. But despite all the merits and advantages of the EPS building system, the application by developers in the Nigerian building industry is very limited. This is due to relatively scarce knowledge of this innovative methods of construction and poor access to the material. Low level of awareness to the building professionals and the general public as well as its non-availability has hampered the diffusion of EPS in Nigeria. Because in Nigeria very few manufacturers of the EPS building material system exist, the EPS blocks or panels used for building processes are scarce and this leads to high cost of production which is transferred from client/contractors to end users. Based on these scenarios and the proven properties and applications of EPS, this research evaluates the performance of EPS construction technologies in the Nigerian construction industry just as the conventional construction materials technologies are rather becoming too expensive for building affordable houses for the low income earners. This will help to enhance the adoption of this innovative, cost effective and environmentally friendly construction technologies.

2.4 Research Methodology

For this research, primary data was collected through structured questionnaires directed to the clients and residents of a functioning estate in Abuja which used expanded polystyrene (EPS)as its major building material. Data were obtained using multiple choice structured questionnaire. The questionnaire wasdeveloped after going through an extensive review of the literature. The questionnaire consists of the degree of satisfaction of respondents affected by expanded polystyrene construction. The population considered consisted of the clients, represented by the construction professionals in CITEC International Estates Limited and the users, who are the residents of Mount Pleasant Estate. The total number of construction professionals in CITEC International Estates Limited as well as Polystyrene Industries Limited is 35. The main respondents were practicing professionals in CITEC International Estate Limited such as Architects, Engineers, Builders and Quantity Surveyors and residents of houses in Mount Pleasant Estate.A total of 110 questionnaires were administered and 94 were received. This results in a response rate of 85.45%.The returned questionnaires were therefore suitable for the analysis. The questionnaires were carefully examined and relevant information required to achieve the various objectives were extracted. The analysis of data and information obtained were done using standard statistical application software. The statistical package provided powerful statistical analysis and offered the representation data in various graphical forms. The procedures adopted for this research were based on (Alegiuno, 2014).

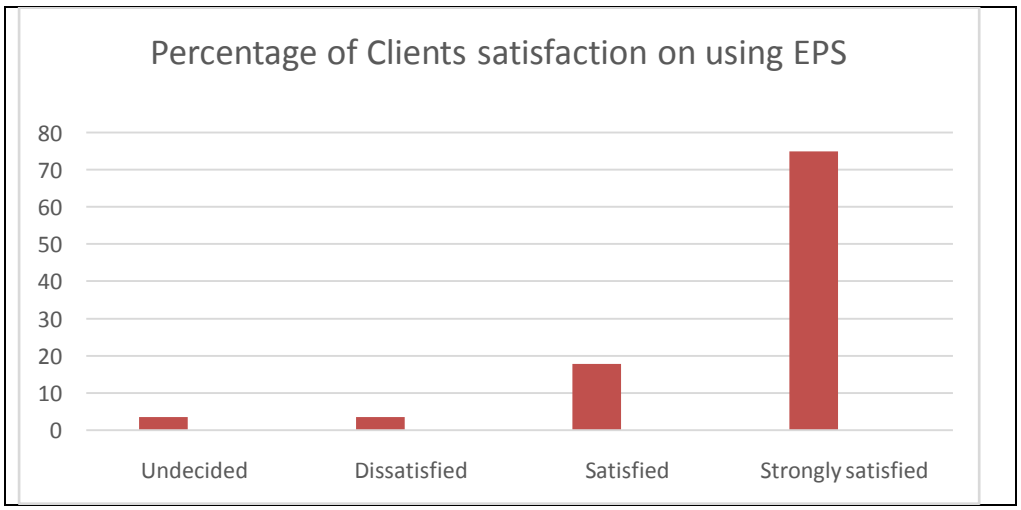


Figure 2: Client's satisfaction of using EPS as a principal building material.

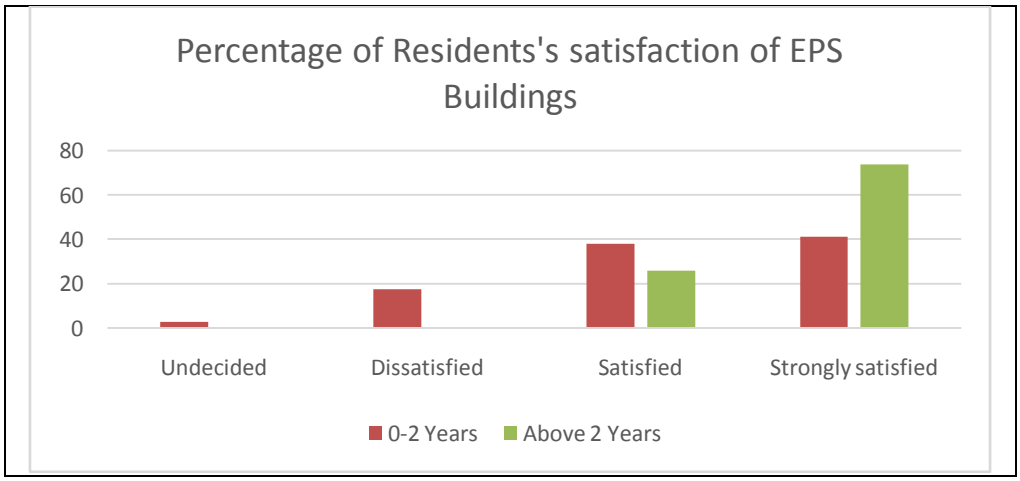


Figure 3: Residents satisfaction of EPS buildings.

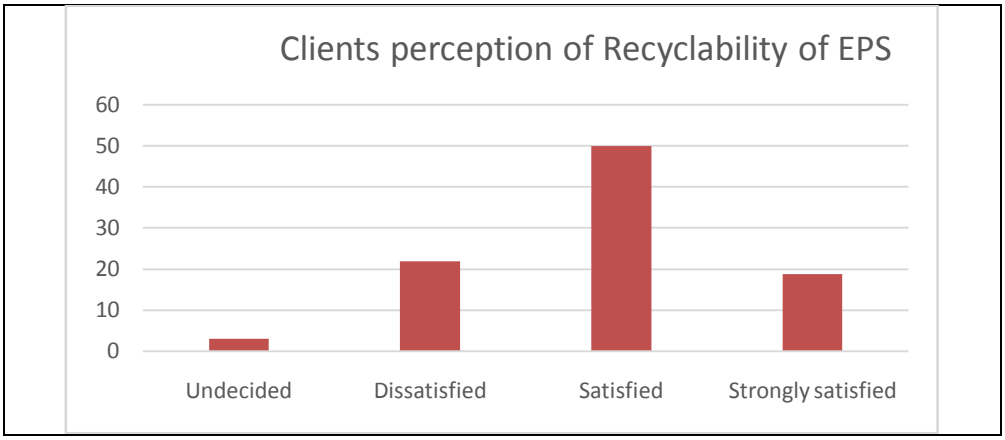


Figure 4: Client's perception of EPS recyclability

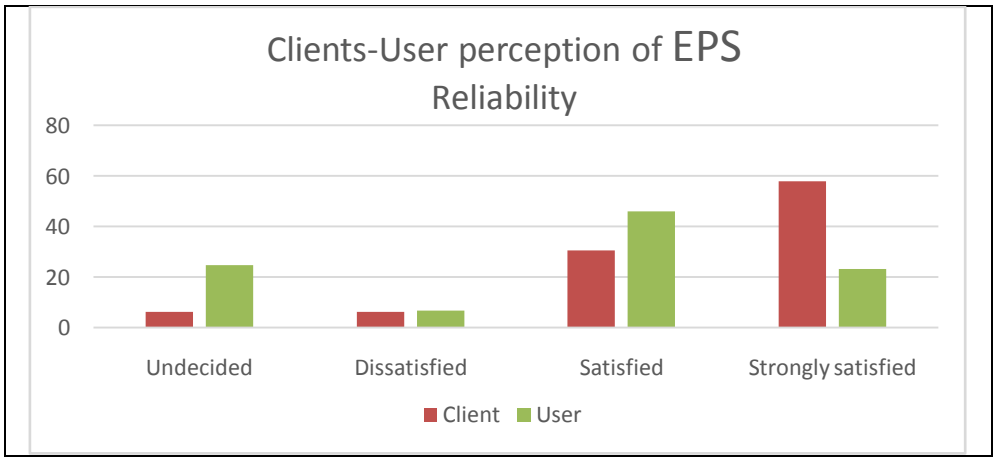


Figure 5: Clients-user's perception of EPS reliability

III. RESULTS AND DISCUSSIONS

The data collected from the questionnaires were analyzed with statistical tool. The information extracted from the collected data included client's satisfaction of using EPS as a principal building material, residents satisfaction of EPS buildings, client's perception of EPS recyclability, clients-user's perception of EPS reliability, client's perception of versatility of EPS products and user's perception of moisture resistance of EPS building products. Figure 2 captures the client's satisfaction of using EPS as a principal building material. The over 90% of satisfaction shown by the client justifies the adoption of EPS as a principal building material.

Figure 3 shows the residents' perception of EPS building products. In this case, residents that have lived in the EPS buildings for more than 2 years were more satisfied (99%) than those that lived in the building

for a shorter period (79%). That is a comforting news as the more one gets involved with EPS products, the more satisfied with the product. Figure 4 depicts the Client's perception of recyclability of EPS products. The 68.8% of satisfaction of recyclability of EPS building products is good. Figure 5 shows clients-resident's perception of EPS reliability. The 87.9%of satisfaction for the client and the 68.9%for the residents of the reliability of EPS building system is good both for the client and the end user. Figure 6 contains the client's perception of versatility of EPS products. The 96.6% of satisfaction for the client appears to be very good for the EPS building products. Figure 7 then shows the user's perception of moisture resistance of EPS building products. The 80.4% of satisfaction of user's perception of moisture resistance of EPS building products is good for the EPS building technology. Figure 8 sums up the result of the research as it depicts the positive aspects against the negative aspects.

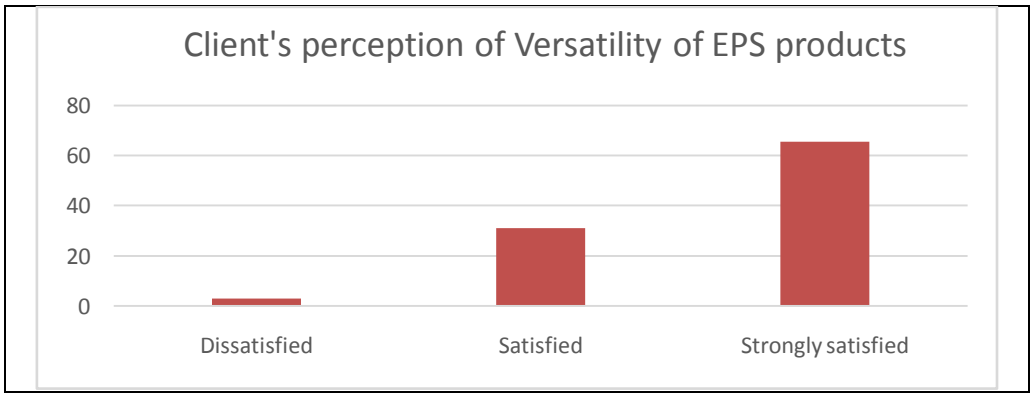


Figure 6: Client's perception of versatility of EPS products.

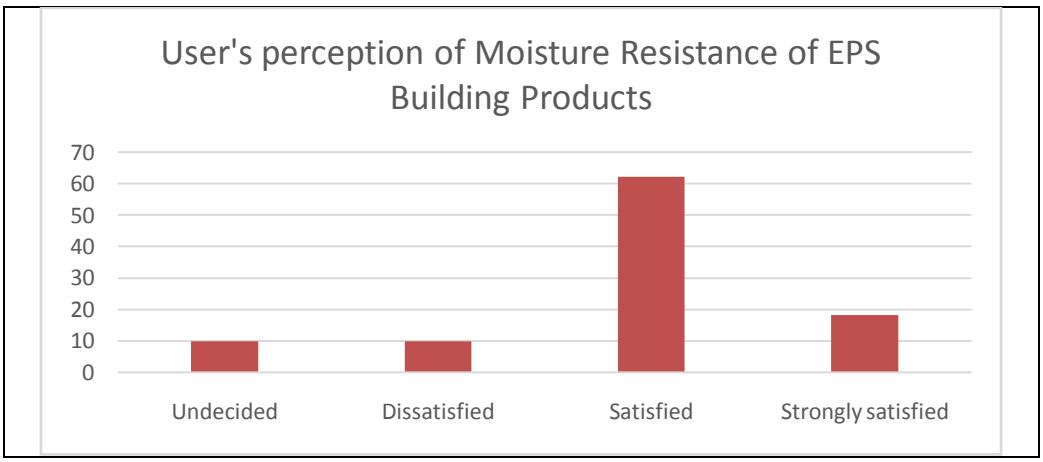


Figure 7: User's perception of moisture resistance of EPS building products.

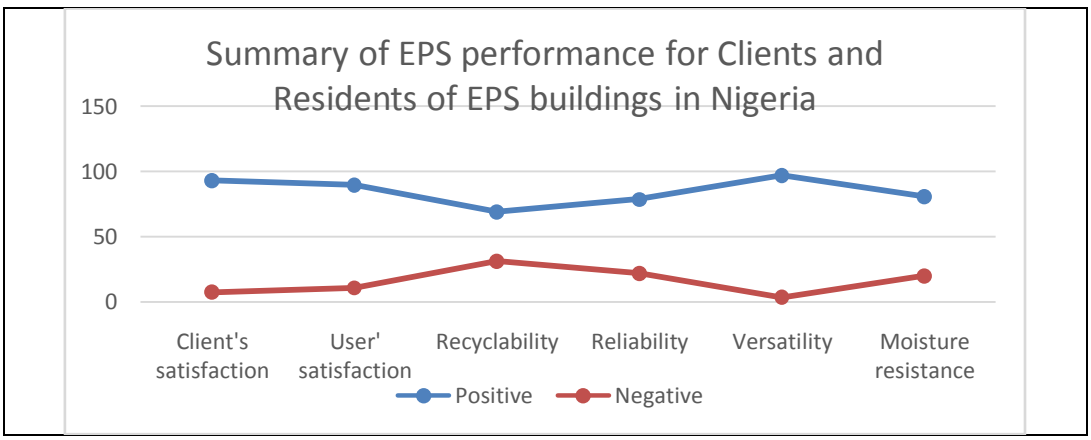


Figure 8: Summarizes the result of this research

IV. CONCLUSION

This study assessed the level of clients' and users' satisfaction with prefabricated expanded polystyrene (EPS) construction in Mount Pleasant Estate, Abuja. The study evaluated several factors that help to determinethe efficiency and the trend of acceptance of expanded polystyrene (EPS) building system in Nigeria as an alternative to the conventional building materialssuch as sand crate blocks. Great satisfaction for both client and residents and high ranking performances for recyclability, reliability, versatility and moisture resistance of EPS building products obtained from this research all herald a great future for the applications of this innovative building products in the Nigerian building industry. The research also showed that the residents who lived in houses constructed with EPS for longer periods are more satisfied with EPS construction than those who have spent shorter time in the EPS facilities.This research therefore concludes that more clients and residents will be interested in accepting EPS building products for future residential houses and this will facilitate the provision of affordable houses for low income earners in Nigeria.

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