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Energy-Efficient Construction in Nigeria: The Adoption of Expanded Polystyrene Wall Panels in Abuja Metropolis

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Abstract
In recent times, Abuja, the Federal capital city of Nigeria has witnessed an extensive use of innovative building materials including Expanded Polystyrene (EPS) in housing delivery. This is in the quest to develop alternative local building materials to the conventional sandcrete blocks, which is of increasing high cost and import dependent. This paper therefore, reports a comparative study on the use of EPS materials over the sandcrete blocks in masonry works in FCT, Abuja. Data for the research were obtained through interview schedules and observations from five (5) selected case studies of housing projects built with EPS panels in Abuja and compared with other housing projects constructed with sandcrete blocks with the aim ascertaining the comparative advantages of EPS panels over the conventional walling materials. Over one hundred and twenty (120) building professionals (Architects, Engineers, Builders and Quantity Surveyors) involved in the construction of these projects were interviewed. Analyses of the findings indicate that EPS buildings demonstrate high thermal insulation capacity, light weight, faster time, higher strength, greater structural stability and cost effectiveness. The paper concludes that EPS panels are better alternatives to the conventional sandcrete blocks and should be used in place of the former in housing delivery in Nigeria.
Keywords: Abuja, building materials, **e**xpanded polystyrene, urban housing

1. INTRODUCTION

Housing is a reflection of the cultural, social and economic values of a society. It is in particular a cultural phenomenon, which finds expression in a people's ability to meet their needs of shelter in the context of their communities. The role of culture in housing is predominant despite the moderating effect of economics, climate, and technology known to them. Housing, a subset of traditional architecture, evolves from the culture of a community in accordance with the lifestyle of its people, the materials of construction available, and technical possibilities open to them (Gardi, 1973; Adedeji, 2010). The most visible and obvious consequences of urbanisation in developing countries, such as Nigeria, is often rapid deterioration of urban housing and living conditions (Lewin, 1981). This is traceable to the fact that urbanisation leads to explosive population growth, which is occasioned by a phenomenal leap in the quantitative housing needs of the populace (Diogu, 2002). The housing needs are not matched by effective demand since the large majority of the populace does not have the wherewithal for adequate housing. According to Adejumo (2008), the rate of provision of new housing stock has lagged severely behind the rate of population growth in Nigeria resulting in staggering housing deficit requiring an annual production of more than 70,000 housing units to cope with the population trend (Onyebueke, 2002; Isimi, 2005; Okedele *et al, 2009*). This deficit is more noticeable in the urban centres.

The rapid increase in the population of urban centres has resulted in an increase in the cost of living because of higher demand on urban commodities. There is a dearth and high cost of urban land, and high cost of housing, which is often in short supply and out of the economic reach of the majority of the urban households (Oladapo & Olotuah, 2007). The urban centres are populated by a large mass of people on low wage and who face irregular employment. This segment of the urban population is indeed poor, and is constrained to limited, insufficient, crowded, cold and dirty shelter and a generally degraded environment. These are the urban poor who are subjected to a life characterized by precarious conditions of nutrition and health, little or poor material possessions (Olotuah, 2010).

As stated by Olotuah & Ajenifujah (2009), most urban centres in Nigeria are characterized by high densities of buildings, the crowding of large numbers of people into those buildings, inadequate spaces for open air between houses, poor health, substandard housing, and acute environmental and sanitary problems. The shortage of affordable and decent accommodations for the urban poor is thus a major housing problem in Nigeria. In large urban centres like Abuja, poor housing conditions often manifest in the high numbers of people living in one room and paying exorbitant rents. This is physical overcrowding, which is a determinant of two major types of problems namely, a health hazard and harmful social behaviour. Overcrowding is a hazard to health where sleeping accommodation is congested and ventilation is poor. Infectious (air and water borne) diseases spread very fast under such conditions (Amado *et al.,* 2007). Recently, in the most developed countries, it has been verified that the traditional and conventional technologies used for construction and maintenance of buildings are inefficient and resource wasteful due to enormous amount of resources consumed. This situation leads to an increasing demand for further development of their technologies (Ghosh, 2002). More rational constructive processes can be implemented with the introduction of new production technologies that allow unique modular designs, high strength and load bearing capacity materials, reduction of labour, materials, mass, time and fund. Such reduction becomes possible through the use of Expanded Polystyrene (EPS) initiative (Adedeji *et al.*, 2011). Such initiative allows the reduction of mass in construction through the use of lightweight and heavy insulated envelope wall and ceiling panels. Thus, the EPS initiative can be classified as a better rationalisation of resources in construction.

2.0 EXPANDED POLYSTYRENE INITIATIVES

The American Society of Testing and Materials (ASTM) defined Expanded Polystyrene (EPS) as a type of foamed plastic formed by the expansion of polystyrene resin beads in a molding process (Arellano and Stark, 2009). The resulting EPS block from the molding process is used in various areas of application ranging from embankments and abutments for roads and bridges in road construction (Styropor, 1993) and for various other applications in building construction.

In building construction, EPS blocks are cut into various predetermined standard sizes (EPSMA, 2009) suitable for use in areas of walls, floors, stairs, cornices and fascias and decorative moldings. For example, EPS panels used for walls with thicknesses ranging from 40mm to 100mm sandwiched between two plan-parallel electro-welded mesh sheets called cover meshes (having a clear spacing of between 13mm and 19mm from the EPS core), and inclined diagonals wires in between that go through the EPS core and that are welded to the cover mesh's line wires results in a lightweight three (3) dimensional truss system with a high inherent stiffness (Matz *et al.*, 2007).

2.1 EPS 3-Dimensional Components

Expanded Polystyrene 3-dimensional components are thin-walled reinforced concrete sandwich elements which can transfer compression and shear forces in the plane of a wall. The concrete layers so applied either manually or mechanically are of at least 40mm thickness on both sides. The concrete performs two functions. Transfer of compressive forces on one hand and the protection of the reinforcements against corrosion on the other hand. For useful protection against corrosion, a minimum concrete thickness of 40mm is required inside a building while a minimum of 50mm is required outside. The flexural resistance perpendicular to the plane of wall is limited; hence buildings erected with these components have all elements interconnected with one another thereby forming a box-like structure (Matz *et al.*, 2007). The panel receives its strength and rigidity from the diagonal spacer wires welded to the welded wire fabric (cover meshes) on each side thereby producing a truss behaviour which is very rigid and provides adequate shear transfer for composite behaviour (EVG, 2001).

Although EPS panels were originally used predominantly for load bearing and non-load bearing walls, they have also proved to be best suitable for different floor slab systems. In the floor slab system, the cover mesh used for the walls can also serve as bottom or top reinforcement of floor slabs. This reinforcement is sufficient for spans of up to approximately 3m; additional rebars can be arranged for spans of up to approximately 5m. Slabs with spans exceeding 5m must be provided with ribs which are reinforced with girders and additional rebars. The system allows spans of up to approximately 7m (EVG, 2001). The 3-dimensional system is unique in providing a fast, economical and easy construction system for both load bearing and non-load bearing applications (Matz *et al.*, 2007)

2.2 Advantages of EPS 3-Dimensional System

2.2.1 Lightweight

It is possible to control the density of EPS during the manufacturing process and it ranges from 15 to 22 kg/m^3 for light fill applications. The low density is only about 1 to 2% of the density of soil and rock making it a superior ultra lightweight fill material that significantly reduces the stress on underlying sub-grades (EPSMA, 2009). Traditional earth materials from soils and rocks are heavy and can cause settlement, instability or lateral pressures. Other lightweight materials such as foamed concrete, wood chips, soil and wood fibre have higher densities, limitations in handling and can be weather sensitive thus requiring staged construction and/or preloading, surcharging and draining (www.geofoam.com). The ultra lightweight of EPS is not surprising when it is understood that as a result of advanced manufacturing technologies, EPS is 98% air captured within a 2% cellular matrix (BPF, 2008).

The lightweight nature of EPS has a lot of advantages. A standard panel weighing only 5.5kg can easily be set in place or stacked using a 1 or 2-man crew. Costly site equipment such as cranes and hoisting implements are not required for setting up the structures (EVG, 2001). These advantages in on-site handling and transportation bring significant economic benefits whilst considerably reducing health and safety risks associated with the lifting of heavier materials. It is therefore an excellent substitute for infill materials and ballast where it also brings load and fill times down in time-critical building projects (BPF, 2008).

2.2.2 High Strength and Load Bearing Capacity

In spite of the lightweight nature of EPS, its structure brings the benefits of exceptional compressive strength.

This has made it suitable for use in areas of construction and civil engineering applications (BPF, 2008). In order to prove the strength of EPS, several research institutes across the globe have carried out several tests whose results have shown that EPS panels can serve as wall panels for multi-storey buildings and as slab panels for residential buildings, office buildings and industrial buildings (EVG, 2001) and as structural base infill in roads (Arellano & Stark, 2009), railway and bridge infrastructure (BPF, 2008).

A test was carried out on EPS 3-dimensional slab by the Insteel Construction Systems of Brunswick, GA., USA where 52 bags of cement weighing above 4000kg were placed on a 150mm x 1200mm x 2700mm slab. The total load including dead weight of the slab amounts to more than 1400 kg/m^2 which is at least twice the load in usual residential buildings (EVG, 2001). In another test performed on a block-molded EPS specimen with a density of 21kg/m^3 to check the typical uniaxial compression stress-strain response of an EPS – block specimen, Arellano and Stark (1999) reported that the EPS did not typically exhibit failure like other solid materials used in construction (metals, concrete, wood) by a physical rupture of the material when uniformly loaded.

2.2.3 Unique Design Opportunities

The ease of cutting or molding of EPS allows the factory production or on-site preparation of complex shapes to match the most demanding architectural and design requirements (BPF, 2008). As a perfect fit for the philosophy of 'Less is More', EPS gives the designers a unique product that works in conjunction with other more traditional materials to solve construction problems with unprecedented strength and stability (EPSMA, 2009). Due to the load bearing capacity in plane of panel a lot of wide open structures which are not possible or feasible with conventional building materials can be built (EVG, 2001). Domes and roofs without internal support can be easily built.

2.2.4 Satisfaction of Green Building Material Requirements

Green building materials according to Spiegel and Meadows (1999) are composed of renewable, rather than non-renewable resources. Green materials are environmentally responsible because impacts are considered over the life cycle of the product. EPS is not just a foam for insulation, but an innovated building material that can be used in a wide variety of construction projects Whether used as a standalone component or part of a highly engineered building system, EPS insulating capabilities contribute to increased energy efficiency (EPSMA, 2009). Energy efficiency is also an important feature in making a building material environmentally sustainable. The ultimate goal in using energy-efficient materials is to reduce the amount of generated energy that must be brought to a building site (Jong – Jin, 1998). When used for sheathing, roofing or below –grade installation, EPS play a key role in a building's ability to comply with ASHRAE 90.1 – 2001, a benchmark requirement for most green building programs (EPSMA, 2009). The EPS Molders Association (EPSMA, 1999) also reported that life cycle analysis have shown that EPS reduces global warming and therefore opined that EPS is an ideal choice for green building designs, offering tangible environmental advantages with long-term energy efficiency. According to the British Plastic Federation (2008), EPS offers exceptional eco-credentials and is therefore ideally suited to the new generation of eco-friendly building projects.

Another goal of Green Building that EPS has met is localized manufacturing and reduction in jobsite waste and labour costs which reduces the impacts of transportation and through its use in innovative applications that improve the overall environmental performance of the building envelope (EPSMA, 2009).

3.0 RESEARCH METHODOLOGY

Primary data were collected and used for the research. The main research instruments for data collection were interview schedule and observations from selected case studies. The interview schedule designed to investigate 25 variables on housing materials, structured in question form and written in English language, was targeted to elicit responses from clients and professionals in the building industry on the use of these materials. The selected professionals (Architects, Engineers, Quantity Surveyors and Builders) that were involved in the designs and supervisions of these projects presented their opinions on the subject. The addresses of these professionals were obtained from the Physical Planning Unit of their respective institutions. Interview for the professionals were conducted in their respective offices and construction sites on one on one basis using the interview schedule. Observations were also made from five hundred and twenty housing units constructed with EPS materials investigated and compared with similar buildings constructed with sandcrete blocks through case studies. Most of these buildings located in Mount Pleasant Estate of Mbora District constructed by Citec International Estates Limited where EPS was used for the construction of walls, floors, and fascias. Houses built outside the estate which were owned by individual clients and located in districts of Gwarimpa, Gudu, Asokoro and Kubwa in Abuja were also investigated. In these privately owned houses, EPS were used in floors and fascias. Analysis of the interview schedule was carried out using frequency Table 1.

Apart from the interview and observations made from case studies, laboratory tests to determine the strength, load-bearing capacity and thermal efficiency of EPS would have been necessary. But these have been carried out by earlier researchers as reported in the literature review (EVG, 2001; Arellano & Stark, 2009; BPF, 2008).

ABUJA, FCT

Abuja, city in central Nigeria, capital of the country, located in the Federal Capital Territory. Abuja officially replaced Lagos as the capital in December 1991, after 15 years of planning and construction. The city is located in a scenic valley of rolling grasslands in a relatively undeveloped, ethnically neutral area.

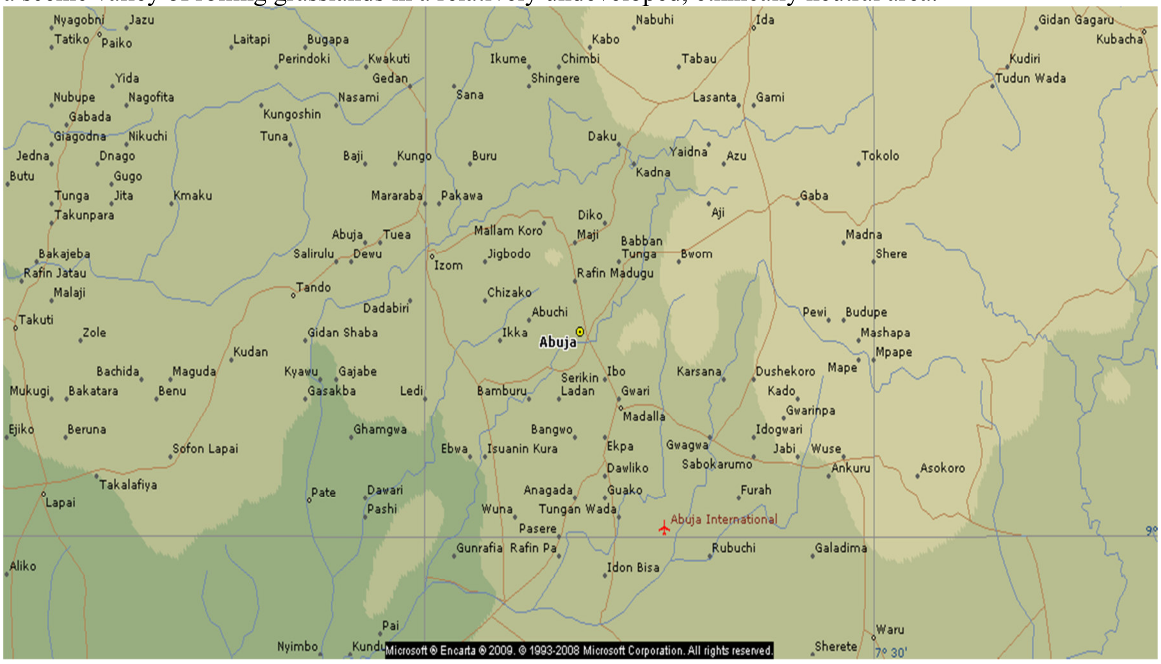

Fig. 1 Map of Abuja

Source:Microsoft Encarta (2009)

Thus, planners hoped to create a national city where none of Nigeria's social and religious groups would be dominant. A large hill known as Aso Rock provides the backdrop for the city's government district, which is laid out along three axes representing the executive, legislative, and judicial branches. Government agencies began moving into the new capital in the early 1980s, as residential neighborhoods were being developed in outlying areas. Abuja has a population of more than 450,000 people. (Microsoft Encarta, 2009).

4.0 FINDINGS AND DICUSSIONS

The case study selected for this study is Mbora Mount Pleasant Estate. The estate is currently in four phases (I-IV) of over three thousand (3000) housing units. Phases I and II constructed 2003- 2006 were mixture of prefabricated concrete panels and conventional sandcrete blocks. Houses in these phases are combination of bungalows, storey and terrace buildings. While phase III which built between 2007-2008 was constructed with conventional sandcrete blocks, phase IV constructed with EPS materials started in 2009 till date.

500 housing units were selected from phases III and IV i.e. 250 from phase III and 250 from phase IV. Housing selected for study comprises of Bungalow, 2- Storey Buildings and Terrace Buildings as shown in Table 1 below:

Table 1: Housing Types Investigated

s/no	Housing Types (Conventional)	Housing Types (EPS)	Frequency	%
1	Bungalow	Bungalow	280	56
2	2 Storey Building	2 Storey Building	200	40
3	Terrace Building	Terrace Building	20	4

Source: Researcher's data (2015).

Materials for the construction of the substructure of the examined buildings in both Phases III and IV were conventional sandcrete foundation walls. The only difference was the inserted starter bars on the oversite concrete of the EPS buildings. These starter bars which were inserted either before the casting of the oversite concrete or after the oversite concrete was cast are usually high tensile reinforcing steel of diameter 10mm protruding 1000mm above the oversite concrete and at 600mm centre to centre spacing. When the dowel bars were inserted after the oversite concrete has been cast, they are considered as part of the superstructure. In all the examined buildings, the starter bars were inserted after the oversite concrete has been cast, hence considered as part of the superstructure. The starter bars so inserted are to give the EPS wall panels a firm anchorage to the concrete slab. This means that the materials for the construction of the substructure for both EPS and the conventional sandcrete block houses were the same except for the insertion of starter bars in the former.

The walls of the housing units in Phase III were mainly sandcrete blocks of 150mm and 225mm with cast lintels on all the windows, doors, archways and other openings. The walls of all these conventional housing units were tied together by a course of ring beam which also supports the roof members, whereas the walls of housing units in Phase IV were made of EPS panels of 100mm width arranged together in their modular sizes of 1200mm by 3000mm with the use of splice meshes to join the panel reinforcing meshes together. Lintels were absent on all the openings and archways, and also ring beams not used.

The roofing, ceiling and general finishing of both Conventional sandcrete block and EPS housing units were done the same way using the same materials.

Both EPS and Conventional Housing units were in terms of materials similar in foundation, window, ceiling, roof, electrical and mechanical fittings, tiling, painting and other finishes but differ in walls, lintels, fascia and ring beams.

Summary of Comparative Analysis of the estimate of these buildings are reflected in Table 2 below.

Table 2: Comparative Summary between the Bills of Quantities of the Project Constructed with Conventional Sandcrete Blocks and that constructed with the Expanded Polystyrene (EPS)

S/No	Elements'Summary	Conventional	Recommended EPS	Differences	% of Difference
1	Substructure	2,577,200.00	2,577,200.00	-	
2	Walls and Fascia	4,082,635.00	3,102,838.77	979,796.23	32
3	Concrete Work	247,640.00	247,640.00	-	
4	Roofs	3,041,965.00	3,041,965.00	-	
5	Window	1,263,240.00	1,263,240.00	-	
6	Doors	467,400.00	467,400.00	-	
7	Finishings	3,894,186.00	3,894,186.00	-	
8	Fittings	585,000.00	585,000.00		
9	Services	1,633,920.00	1,633,920.00	-	
10	External Works	166,440.00	166,440.00	-	
11	Contingencies	448,990.65	424,495.74	24,494.91	6.00
	Total	18,408,616.65	17,404,325.51	1,004,291.14	

Source: Researcher's data (2016).

The above analysis shows a significant difference in the cost of walls and fascia of EPS panels over the conventional sandcrete blocks which is the focus of this study. This difference can be attributed to the absence of lintels and beams in EPS housing units but which are indispensable in the construction of houses with sandcrete blocks. In addition to this, the difference can also be attributed to the low cost of labour involved in the construction of EPS walls. Lesser number of labour is required for the erection of walls and the time required for the construction is greatly reduced. This comparative advantage noted above is in consonance with what Matz *et al* (2007) has observed that 3-dimensional system is unique in providing a fast, economical and easy construction system for both load bearing and non-load bearing applications.

Interactions with the consultants (architects, civil engineers, builders) and contractors who were directly involved in the use of EPS for construction also revealed that EPS wall panels were easier to carry because of their lightweight and that the erection did not require any special skills. They reported that because of the lightweight and ease of construction, EPS walls erection was faster than the conventional sandcrete blocks, which corroborates what British Plastic Federation (2008) has asserted.

In order to ascertain the energy efficiency of EPS material, the interview conducted with the occupants of finished EPS housing units noted that use of fans and air conditioners in houses are unnecessary and yet comfortable inside the houses even when the external temperature is high. This observation confirms that EPS uses less operational energy and hence energy efficient, which is an advantage over the conventional sandcrete blocks earlier observed by Jong-Jin (1998) and EPSMA (2009). It was further observed that in spite of the advantages of EPS, the usage has been limited to few developers that use it extensively in the development of some estates in Abuja city. These developers either produce or have direct linkage with the manufacturers who produce it. Few individuals patronize the use of the material in the construction of houses partly because of inadequate information on the material or relatively costly compared with.

5.0 POLICY IMPLICATION AND RECOMMENDATIONS

The Nigerian urban housing is faced with multi-faceted housing challenges ranging from access to finance, inadequacy in terms quantities and qualities, materials and technology among others. The intelligent adoption of EPS material will ameliorate some of these challenges towards achieving efficient housing delivery in Nigeria. The usage of EPS will facilitate modular design and construction in the building industry. This is because of the geometric nature of EPS that helps to ensure structural stability and uniform load transfer between the layers. Professionals and stakeholders in the building industry can easily visualise with clearer perception their proposed housing projects, thus, making materials and cost planning easier.

Although the study revealed unparalleled advantages of EPS in terms of short time of operation, lesser labour and reduced cost of construction, its usage in construction of houses is very low. This is partly due to low level of awareness on the part of professionals and the public and its non-availability in the market. In view of this, Government agencies and stakeholders in the building industry should accept these concepts as proposed in this research to give a wide publicity to them and make the proposed building materials available in the market for users. EPS should be used in public housing projects to demonstrate government's sincerity and to create awareness within the Nigerian populace. Specialisation on building materials at entrepreneurship scale should be facilitated to generate employment opportunities for teeming unemployed youths. Small scale entrepreneurship production workshop should be set up on-site for production and easy replication of building components thus facilitating employment generation. In the alternative, standard building components can be purchased off-site to be assembled with few workers and within a short period of time.

6.0 CONCLUSIONS

This paper has reviewed the comparative advantages of expanded polystyrene (EPS) panels in housing delivery in Nigeria. It asserted that EPS has overiding advantages over the sandcrete block masonry in urban housing delivery in Nigeria. It further stressed that mass production and wide publicity should be given to the material to ensure cost-efficiency and better patronage in construction of housing units. In addition, more research efforts can be intensified on the material towards achieving sustainable housing delivery in Nigeria.

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