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Exploring the Potentials of Expanded Polystyrene (EPS) for Zero-waste Construction in Akure Nigeria

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Abstract: Construction and demolition wastes (CDW) pose serious challenges to the environment and as such creates so much concern in the Architecture, Engineering and Construction (AEC) industry. The challenges and impacts of construction in AEC activities are obviously avoidable. Practitioners in the industry have been slow to recognize that modern methods of construction (MMC) such as the use of Industrialized Building System (IBS) have the potentials to minimize wastes on job sites compared to the traditional methods of construction which are pointedly wasteful. This study reports a survey conducted in two residential estates where Expanded Polystyrene (EPS) – an Industrialized Building System (IBS) and conventional building materials and techniques were used. Stratified random sampling was adopted because of the different types of housing units within the two selected housing estates. It was found that the Industrial prefabrication of Expanded Polystyrene (EPS) wall panels, floor ribs, blocks and fascias enables components to be produced to exact specification thus significantly reducing waste on job sites. Also, the light weight nature of EPS facilitates easier handling and reduces labour and saves time for the installation. The study therefore seeks for the adoption of prefabricated building components such as standardized EPS as a modern methods of construction (MMC) in Nigeria.

Keywords: Construction and demolition wastes, expanded polystyrene (eps), job sites, sustainable construction, traditional methods of construction, zero-waste construction.

1.0 Introduction

The rate at which construction activities are adversely affecting man and his environment is alarming and this calls for serious attention. In response to this challenge, pragmatic measures are being taken globally to

curtail the negative impacts of the construction industry on the environment (Ede and Oshiga, 2014). Studies have shown that the various challenges to man and his environment are sequel to the ways of construction of the modern world. Guy, Shell and Homsey (2002) asserted that construction activities in most developing countries are clearly characterized by wastes and toxicity, which is harmful to man and the environment. Reflecting on the Nigerian context, Adebayo and Iweka (2009) noted design and construction of infrastructure, particularly buildings have not been sustainable. These methods of construction, using traditional and conventional materials often results in the generation of enormous quantities of wastes which are detrimental and hazardous. The material waste produced from new construction, renovation and demolition is 25% to 30% of the total waste produced each year in the United States and UK (EPA, 1996; Pulaski, Hewitt, Horman and Guy, 2004). Similarly, waste generation through building construction and renovation is on the increase in many developing countries (Adedeji, Taiwo, Fadairo and Olotuah, 2013).

In Nigeria, like other developing nations, the need to minimize construction wastes on job sites has become imperative. With the increasing demand for infrastructure, a large quantity of construction wastes is being generated in the course of infrastructural development. To tackle this, the adoption of standardization of design and modular design, use of renewable, prefabricated building materials and dry methods of construction, among others have been recommended (Adedeji et al., 2013). Expanded polystyrene (or EPS) which offers these attributes has been widely adopted in developed countries to reduce waste and solve environmental challenges while giving adequate consideration to cost, time and energy (Olawuyi and Babafemi, 2009). Marhani, Jaapar, Azmi and Bari (2012) opined that EPS as an Industrialized Building System (IBS) may help ease the pressure of labour requirements, boosts quality and productivity, and serves as a means to overcome environmental problems associated with conventional materials and techniques.

This paper presents a study on the suitability of expanded polystyrene to reduce construction wastes on Nigerian construction job sites to the barest minimum level.

2.0 An Overview of Construction Wastes

The traditional methods of construction produce enormous wastes and consequently impact negatively on the environment. The way in which the design and construction of buildings are carried out in developing countries today is irrational, disorganised and inefficient (Adebayo and Iweka, 2009). This wasteful nature of today's construction could be based on the fallacious notion that natural resources are free and inexhaustible (Papakyriakou and Hopkinson, 2012). It is noteworthy that the current menace of construction and demolition wastes (CDW) and its impacts such as resource depletion, energy waste, pollution, species and habitat loss,

human health, and social issues (Crowther, 1999) are obviously avoidable (Adebayo and Iweka, 2009). Previous studies have shown that buildings utilize large proportion of energy and available natural resources and that worldwide 30 – 40% of all primary energy is used for the construction of buildings (Ramesh, Prakash and Shukla, 2010). Designers are crucial to mitigating the impacts of the construction activities. Architects and Engineers among other professionals are pointedly important to reducing waste. They are directly responsible for making design choices, specifying materials among other decisions at the design and construction stages (Guy, Shell and Homsey, 2002; Pulaski et al., 2004; Papakyriakou and Hopkinson, 2012). Studies have shown that the choice of appropriate building materials which are prefabricated offers opportunities for preassembly, modular construction, ease of handling without compromising workers' safety, are germane to minimizing wastes on construction job sites (Crowther, 1999; Pulaski et al., 2004; Adebayo and Iweka, 2009; Papakyriakou and Hopkinson, 2012).

2.1. Construction Wastes in Developed Countries and Nigeria

The construction industry is one of the largest solid waste generators with 30 – 40% of natural resources exploited by the AEC industry (Adedeji et al., 2013). Sustainable development necessitates increase in the reuse and recycling of existing facilities. This implies that there will be increase in the reuse and recycling of existing materials, resources and facilities (Guy et al., 2002). Studies reveal that of the total 25 – 30% of material waste produced from construction, renovation and demolition generate waste of about 92% which is higher than the 8% generated by new construction (Pulaski, et al., 2004). In the United States, construction and demolition waste is about 143 million metric tons (MMT) annually (Chini and Bruening, 2003). In the United Kingdom, the construction waste is about 18 million tons (Akinade et al., 2016), while in Nigeria, an estimated 2.2 million tons of waste is generated per annum. If the challenges of construction waste of developed countries would serve as a lesson for Nigeria, it is imperative that the AEC industry in Nigeria embraces modern methods of construction (MMC) as a waste minimization strategy.

2.2. Modern Methods of Construction as Waste Minimization Strategies

Lawson (2019) opines that waste minimization revolves around three R's as reduce, reuse and recycle. Reduce calls for using resources that are just enough to cater for the needs of a construction work which is an effective way of conserving resources. It also lowers the costs. Reuse involves effective reclaim of existing materials and buildings thus lowering waste volumes and saving money. Recycle comprises using left over resources or those resources that have reached the end of their life. This minimizes the need for new materials as well as lowers the volume that ends up in landfills. Other strategies identified are optimization of resources, quality control improvement and process monitoring,

exchange of waste, shipping to the point of use, zero waste and waste minimization for household (Lawson, 2019)

Akinade et al., (2016) remarked that conscious efforts are being taken by the AEC industry to understand the concept of sustainable construction and the long-term effects of construction activities on the environment. As a result, the focus of the practitioners is being shifted from the traditional methods of building disposal to modern methods of construction which include among others the use of Expanded Polystyrene (EPS) which is an Industrialized Building System (IBS). That the traditional methods of building construction generate up to 50% of the waste stream worldwide has made the paradigm shift from traditional to modern methods imperative (Akinade et al., 2016).

Waste and Resources Action Programme (2019) explains that modern methods of construction include improvements in the products or processes employed. This ranges from innovative components to be used on site to whole, off-Site Manufacturing - utilising prefabrication, factory assembly, preassembly, off-site assembly/manufacture, panelised or modular volumetric construction where possible, for example in staircases, lift assemblies, architectural steelwork and toilet blocks for hotels, prisons and student accommodation. Waste Minimization is realized due to the controlled environment and the type process where there is repeatability in construction building systems manufactured off-site.

3.0. Research Methodology

A survey of two case studies of residential building construction sites at Akure was undertaken to elicit primary data for the study. Data was gathered through physical observation of the construction sites and interview with the stakeholders involved in the design and construction about their awareness and level of involvement in the use of EPS and convectional method of construction. Also, interview was conducted with the specialist in the design, manufacture and marketing of polystyrene building systems. The first case study (Case A) is on-going and completed residential buildings' sites at Alpha 3D Estate located along Irese road, Akure. The estate engages the use of EPS – an Industrialized Building System (IBS) for the construction of walls, intermediate floors and fascias of its 506-housing unit scheme. Owing to the heterogeneous nature of the estate, stratified sampling was used to divide the estate into four mutually exclusive and collectively exhaustive building typology strata. A building typology was randomly selected from each stratum for this study. The typology selected from each of the four categories of buildings includes

2-bedroom semi-detached bungalow,
3-bedroom detached bungalow,
4-bedroom detached duplex and
4-bedroom detached bungalow. The second case study (Case B) was selected from on-going and completed residential buildings' sites at Alagbaka Extension area of Akure where conventional building materials and

techniques are engaged for construction. Conventional materials and techniques in this context refer to materials and methods of construction that are widely accepted and adopted for building construction in any particular geographical setting. While sandcrete masonry blocks of 225 x 225 x 450mm are predominantly used for walls, reinforced concrete is conventionally used for intermediate floors and fascias in the study area. The same method of sampling used for Case B was used to select 3-bedroom detached bungalow, 4-bedroom detached bungalow, 4-bedroom detached duplex and 5-bedroom detached duplex building typologies in the study area.

3.1 Design and Construction with Expanded Polystyrene (Walls, Intermediate Floors and Fascias)

Expanded polystyrene (EPS) is a prefabricated modular material for walls, floors, stairs, fascias and ornamentation in construction. EPS for walling is produced as panels in standardized modular sizes of 'n x 1200 x 3000' (thickness x width x height) with varying thickness of between 50mm and 250mm depending on the overall thickness of walls to be achieved. The design of an EPS building is undertaken using the modular sizes and dimensions of the EPS components. The resultant design is therefore made up of modularly prefabricated EPS wall panels, EPS floor blocks and EPS fascias which are thereafter assembled on the site. The component EPS panels including those for openings and archways are properly coded on the plan to ease specification; and transferred to the factory for production.

The wall panels, floor ribs and fascias so produced were to exact specification which prevents further cutting on the job sites and hence reduced waste. In cases where cutting was unavoidable warranted by unforeseen circumstances the off-cuts of the EPS products were easily recycled via the use of recycler. It is noteworthy that in EPS wall construction, lintel and beams are not needed by virtue of design as the panels themselves are deep beams joined together to form a box-like structure. As a result of this, formwork associated with the construction of lintels, beams and archways were absent. Also, in the construction of EPS fascias, formwork was not used as the fascias were tied to each other and to the walls with meshes to ensure continuous reinforcement. The result of these is that waste commonly associated with formwork in the construction of walls and fascias were generally eliminated in the EPS construction. The formwork used for the suspended floors and columns were easily struck and reused.

The conventional masonry method is the predominant technique of walling construction in Nigeria particularly in Akure. The method involves the use of sandcrete block walls with sand-cement mortar as joints and bedding adhesives. The intermediate floor, stairs and fascias are conventionally constructed mainly with reinforced concrete. Usually, all the structural and non-structural components in the masonry method require enormous formwork many of which are neither

reusable nor recyclable after use. The aftermath is usually heap of wastes found littered around the entire site in addition to wastes from walls.

4.0. Findings and Discussions

An assessment of the construction methods and materials adopted in the two case studies revealed that the techniques used in the construction of substructure are similar. Except for the insertion of dowel bars of 10mm diameter employed on the solid ground floor which was to receive EPS panels and provide an aligned anchorage for the panels. The thickness of the oversite concrete for the EPS building was also reduced to between 75mm and 100mm owing to the light weight attribute of the panels it was to receive. The thickness of the oversite concrete in the conventional building typologies is 150mm. This implies that concrete was saved in the EPS oversite concrete, hence a reduction in the cost of the foundation. On the superstructure however, the industrial fabrication of EPS wall panels, floor blocks and fascias enables the components to be produced to the exact specification of the design and thus significantly prevented wastes on the job sites, whereas in the conventional building typologies job sites, there were enormous wastes emanating from cutting of blocks and other materials that were not of required specifications.

The light weight nature of the EPS components facilitated easier handling and reduced number of employed labour and saved significant time for the installation (See Plates 1-10). On the conventional construction job sites, sandcrete blocks were found to be heavy and the substandard ones were easily damaged during handling. The traditional method required a large number of workers on the sites. Contrary to this case of masonry construction technique, EPS eliminated the use of formwork materials in lintels, beams, hoods, arches, beams and fascias. The enormous wastes associated with formwork in these and other structural elements were dramatically reduced in the EPS buildings.

Plate 1: The foundation for EPS same as convectional method

Plate 4: Same method of plastering for EPS and

Convectional Sandcrete building

Plate 2: Starter Bars of Diameter 10mm are inserted At 500mm c/c before oversite concrete is cast

Plate 5: An EPS envelope ready to receive first stage of shortcreting (Spraying)

Plate 3: Same method of construction for the Doors and windows hoods

Plate 6: EPS Fascia (Cornices) are carefully strongly tied to the walls using wires and splice meshes

Plate 7: Roofing done same way as in the conventional method

Plate 8: An EPS house ready for painting

Plate 9: A Completed EPS House

Majority of the Architects and Engineers who are involved in the design and construction of buildings and specification of materials in Akure are fully aware of the use of EPS as modern method of construction but do not understand the technique of construction. This underscores the relevance of modularization of design that is expected in EPS. However, all the stakeholders displayed high level of understanding of conventional methods including the technique required at various stages of construction.

The specialist in the design, development, manufacture and marketing of polystyrene building systems in Nigeria are very limited. A large number of buildings constructed of prefabricated materials and EPS was prominent in cities like Abuja, Portharcourt and Akure. Polystyrene Industry Limited, Cubic Homes, CIBP Limited are located in Abuja while Zifax Global Services, E- Pack Polymers Private Limited are located in Lagos. The only available company that deals with EPS in Ondo State is Alpha 3D Limited and it is located in Ikare – Akoko.

5.0. Implication for the Nigerian Building Industry

Total reduction or reduction of wastes on the Nigerian construction job sites has been identified as one of the ways to address the adverse impact of construction activities on the environment. Waste prevention, recycling and materials reuse on job sites are some of the ways to save embodied energy to achieve sustainable development. Sustainable development is development with low environmental impact. However, irrespective of the on-going global crusade on wastes minimization and energy efficiency in construction, and numerous disadvantages of conventional materials to the environment, a large percentage of the Nigerian building stock was erected with the use of conventional or traditional materials and techniques.

This poor receptivity of the Nigerian construction industry to make a paradigm shift from the use of conventional method towards the application of alternative materials and techniques is one of the hindrances which may prevent it from achieving environmental sustainability goals.

The use of EPS which is an IBS is environmentally friendly and help minimize wastes associated with mismanagement of materials, miscalculation, poor supervision, poor design and detailing errors. It has been proven that its adoption gives the industry environmental sustainability gains as well as social and economic gains.

6.0 Conclusion & Recommendations

This paper has explored the potentials of expanded polystyrene (or EPS) for reducing construction waste on job sites to the minimum. With the use of case studies approach, two different construction sites which adopted traditional methods of construction and EPS as Industrialized Building System of modern methods of construction respectively were compared. It was discovered that contrary to the enormous wastes generated using traditional method of construction on job sites, the use of EPS – an Industrialized Building System, prevents wastes on the sites. Suffice it to say that a paradigm shifts from unsustainable traditional method of construction to a sustainable modern method of construction which encourages the use of modularization and industrialized building system to prevent wastes and reduce negative impacts of construction activities on the environment is a panacea to achieving not only environmental sustainability goals but social and economic benefits in Nigeria.

In view of the foregoing implications of wastes to the Nigerian industry, it is recommended that

1. the professionals especially the designers who are directly involved with the design of buildings and specifications should embrace modularization of components in design to prevent or minimize wastes on job sites.
2. The use of prefabricated building components such as standardized EPS wall panels, floor blocks and fascias should be encouraged.
3. Currently in Nigeria, there are few and insufficient manufacturers of prefabricated components for walling, intermediate flooring and fascias. The establishment of factories for the production of these standardized components should be encouraged by the government by making policies that will create enabling and conducive environment for such factories to operate.
4. In addition, in the face of looming climate change, public awareness on environmental issues should constantly be raised at the Federal, state and local government levels through governmental and non-governmental organizations' initiatives. Through various sensitization programs, all stakeholders directly or indirectly involved in the design, construction and operation of buildings must be educated on the importance of waste reduction and the adoption of

more energy efficient materials and techniques on job sites.

5. It is also recommended that the National Building Code incorporates the use of standardized prefabricated building materials, use of alternative building materials, energy efficiency, prevention of wastes through conservation of materials at both production and construction stages. Lastly, it is recommended that the principles of deconstruction and materials reuse should be widely encouraged and adopted by the various stakeholders in the industry.

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