PERFORMANCE EVALUATION OF POLYSTYRENE WALLING UNITS

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ABSTRACT

The trend in building materials research is the search for alternatives and in Nigeria like other developing countries the use of plastics in modern construction is being widely adopted as in advance countries. The adoption of polystyrene walling units/panels is fast gaining grounds in Nigeria with variety of approaches been seen around. This study thereby examines polystyrene walling units in comparison with the conventional sandcrete blocks with a view to ascertain its efficiency. A total of 18 numbers of polystyrene walling units were obtained from two different organisations in Abuja adopting different approaches of use (Polystyrene Specimen A (PSA) and Polystyrene Specimen B (PSB)), while nine (9) numbers of sandcrete block units were gotten from a factory in Minna. The samples were cut / prepared to required sizes and then subjected to Laboratory tests to assess their performance level as regards compressive strength, thermal conductivity and fire resistance. The results reflect that PSB has the highest compressive strength value of 3.33N/mm^2, followed by the sandcrete block with a value of 0.62N/mm^2 while the least compressive strength value is that of PSA giving 0.22N/mm^2. The thermal conductivity test revealed both PSA and PSB having low values of 0.0047w/mk (for PSB) and 0.0056w/mk (for PSA) as against sandcrete block's value of 0.079w/mk. The fire test further revealed PSA failing at a time of 24.5mins, and 808.5^{o}C temperature while PSB failed at 15.5mins, a temperature of 743.4^{o}C, the Sandcrete block (SHB) at 17.0mins, temperature of 757.2^{o}C as against timber which failed at a time of 4.5mins and a temperature of 561.0^{o}C. The polystyrene walling units were found to have high resistance to fire; they are poor heat conductors and thereby fit well as alternative walling material. The use should be restricted to partition / curtain walls based on their low compressive strength.

KEYWORDS: Polystyrene Units, Sandcrete blocks, Compressive Strength, Thermal Conductivity, Fire Resistance.

INTRODUCTION

Shelter is universally acknowledged as one of the most essential human need while the seventh of the eight outlined goals of the Millennium Development Goals is to ensure **environmental sustainability** (UNDP, 2005)**.** In the words of Melnick et al (2005), "environmental sustainability is essential to achieving all the Millennium Development Goals". Environmental sustainability is thereby said to mean meeting current human needs without undermining the capacity of the environment to cater for those needs over long term. Achieving environmental sustainability they argued "requires carefully balancing human

activities while maintaining a stable environment that predictably and regularly provides resources such as freshwater, food, clean air, wood, fisheries, and productive soils that protects people from flood, drought and pest infestations and diseases". Therefore environmental sustainability is necessarily a fundamental objective in the pursuit of the seven other Millennium Development Goals. Achieving environmental sustainability requires dramatic changes in the way societies and citizen manages biodiversity and the waste and bye-products of production and consumption. It also requires changes in consumption patterns themselves. Direct investment and structural changes are required at local, national, regional and global levels to address the underlying causes of environmental problems. Hence the recent global trend on research into alternative building materials with a bid to exploring possible usage of various agricultural and industrial wastes and bye-products can be seen in this light.

The main aim of building is to create an artificial micro climate which satisfies contemporary definitions of thermal comfort, air speed, temperature, radiation and humidity as well as protect occupants from harsh weather conditions and other environmental agents.

Advancement in modern technology and new building systems has brought to fore a wide range in choice of walling materials with bricks, sandcrete blocks, timber, glass and reinforced plastics taking the centre stage. The global trend in building material researches is that of search for alternatives with efforts mostly being directed at affordability of buildings without compromising its functional requirements and quality. New construction techniques and materials are now used giving consideration to cost, time and energy (American Encyclopaedia, 2007).

The use of plastics in modern constructions has been widely adopted in advanced countries; Nigeria like other developing countries is fast embracing this trend. Plastics have become an

important material for both construction and manufacturing of products used especially in landscaping because of their moisture and corrosion resistance, toughness, malleability and light weight. Plastics possess a variety of useful properties and they are lighter than many materials of comparable strength and unlike metals, plastics do not rust.

Polystyrene is an aromatic polymer made from the monomer styrene; a liquid hydrocarbon that is commercially manufactured from petroleum. It is normally a solid thermoplastic at room temperature but can be melted at higher temperature for moulding or extrusion and then solidified (American Encyclopaedia, 2007). Polystyrene as we know was used in wrapping mechanical and electrical products or used as disposal plates and other domestic uses (Alan, 1970); the same polystyrene has taken a new phase in the Construction Industry and is now being used in building structures. Polystyrene units have a variety of application in building components; it can be used in place of block work, which reduces the time required in erection (Citec Nigeria, 2006); it can also be used in form of slabs for floor decking; an arrangement very similar to hollow pot flooring techniques. Although, polystyrene is a new material, it is really making waves and is widely used by many organizations with varying approaches being adopted especially in wall construction. The need to verify the effectiveness of these alternative approaches serves thereby as the basis for this study. This paper therefore present the report of investigation carried out on two alternative approaches in use for polystyrene walling units in comparison with the conventional sandcrete blocks with a view to ascertain its efficiency. The specific objectives of the work are:

- Assessment of the compressive strength
- Determination of thermal conductivity and
- The assessment of the fire resistance of these samples.

REVIEW OF RELATED LITERATURES

Compressive Strength is the safe working strength of a material, which is the crushing force per unit area of the material. It is an important property of concrete and other masonry units and in general, the use to which units will be put is directly related to this strength. Thus some units may be used for exterior works while others will be confined to interior works (BS 5628, 1985; Barry, 1999). It is expressed in N/mm^2 or KN/m^2.

Thermal Conductivity is defined by Microsoft Encarta Dictionaries (2008) as "the measure of heat flow. It is the rate at which heat flows through a material between points at different temperatures, measured in watts per meter per degree". It is often represented by λk. According to Alan (1970), "it is a measure of heat transfer through a material from one surface to another surface. It is expressed as heat units transmitted in unit time (watts i.e. j/s) through unit thickness (m) of unit area (m^2) for unit temperature difference the surfaces (^oC)".

Fire Resistance of a material is defined as a the amount of heat (combustible) applied on a material, with respect to time which will damage the material or make it to smoulder in comparison with wood. In the words of Gage and Kirkbride (1980), "because of the inherent good fire resistance properties of concrete, concrete blockwork is an excellent fire resistant material for wall construction".

Polystyrene is referred to by Microsoft Encarta (2008) "as synthetic polymer of styrene that is stable in various forms. The types as expressed by Maurine (1971) are expanded and extruded. **Expanded polystyrene** is a combustible material, which in fire, produces large quantities of noxious black smoke. It is a closed cell product which is unaffected by water, dilute acid and alkalis but is readily dissolved by most organic solvents. It is rot and vermin proof. Its thermal conductivity is in the range of 0.33-0.046w/mk. **Extruded polystyrene** is normally manufactured by a vacuum process although some is blown. It is slightly denser and

therefore stronger in compression than expanded polystyrene but has lower thermal conductivity. It also has a close cell structure with very low water absorption and vapour transmission properties and a thermal conductivity range of 0.025-0.027w/mk (Maurine, 1971). **Polystyrene beads** are the basic material of this housing system and despite the abundance of crude oil of which polystyrene can be gotten as a bye-product, the beads at the moment is still being imported into Nigeria from Europe, with Italy in particular having the highest number of usage in terms of housing construction using polystyrene panels (Cubic Homes, 2006; Citec Nigeria, 2006). The beads of certified quality according to the rules of the producer countries are suitably to be expanded by blowing agent with or without additives in order to grant the self-extinguishing or the improved behaviour in presence of fire if required. The beads which come in drums of 125kg or containers of 1000kg are either used directly as in-fill in sandcrete panels or moulded to polystyrene sheets/panels for installation in pre-fabricated wall panel systems.

MATERIALS AND METHODS

The **Polystyrene units** used for this study were obtained from two organisations in Federal Capital Territory (FCT), Abuja. Each organisation adopts different approach in the production of their walling units/panels. **Polystyrene Specimen A (PSA)** was produced using expanded polystyrene sheet with steel wire mesh placed round it as reinforcements (Fig.1) while 1:6 cement/sand screed is sprayed as the finished surface (Cubic Homes, 2006); **Polystyrene Specimen B (PSB)** on the other hand adopts the use of polystyrene beads placed as infill within a sandcrete panel during the casting process (Citec, 2006). The specimens were obtained as small wall panels of about 600mm square dimension. This was then cut/ prepared to requisite sizes as demanded by the various test procedures and the equipment available. This was after they have been properly cured as pre-cast units ready for installation on site.

The **Sandcrete blocks** used were 225mm hollow blocks obtained from a block factory situated beside the new Talba's Estate along the Kuta Road bye-pass in Minna. The blocks were produced from a 1:8 cement/sand dry mix. Water added to mix was said to be little applied by wetting while the blocks moulding and compaction was by mechanical means (i.e. machine moulded). The block samples obtained for test were those already cured for 28-days ready for site usage.

Determination of the functional requirements of polystyrene walling units was the emphasis of this study and in line with the study objectives; three major tests carried out on the samples were the compressive strength, thermal conductivity and fire resistance.

The **Compressive Strength Test** involves three samples tested for each specimen and an average of the computed values taken as the Compressive Strength value. The specimen sizes varied in line with convenience and availability; sizes adopted for test were 450x125x225mm (PSA), 250x90x150mm (PSB) and 450x225x225mm (SHB) given in LxBxH with B representing the wall unit thickness. The equipment and apparatus used for this test (i.e.2000 KN capacity ELE compression testing machine, flat 50kg weighing balance and duster for cleaning) were those available in the Civil Engineering Laboratory of the Federal University of Technology, Minna. The compressive strength is determined by the applied load at failure (N) divided by the gross area (mm^2) of the unit (i.e. surface area section perpendicular to the load). The samples were tested arranging them in equipment the same way as laid on site (i.e. for Sandcrete hollow blocks with their hollow cores vertical as to be laid on the site.

The **Thermal Conductivity Test** adopted the Lee-Disc Apparatus made of the followings: (i). Heat source (kerosene stove), (ii). Steam chamber (fabricated), (iii). 2Nos. thermometer and (iv). 2Nos. platted brass as shown in Fig.2. Same specimen sizes as adopted for compressive strength were used for the respective walling units (PSA, PSB, and SHB). The

heat source was used to heat water in the steam chamber so as to convert water to steam. The first platted brass was positioned at the outlet of the steam chamber with a thermometer fastened to it to read the initial temperature (t_1-i.e. temperature before the heat is passed through the specimen). The specimen was put under the first brass plate and another brass plate put under the specimen with the second thermometer fastened to measure the final temperature (t_2-i.e. temperature after heat is passed through the specimen). Steam produced from the boiling water was allowed to pass through the steam chamber until t_1 and t_2 becomes steady. The readings were taken at intervals of 30seconds and recorded accordingly. Three test readings were taken per sample implying an average of nine (9) tests results for each specimen gave the thermal conductivity value.

The **Fire Resistance Tests** adopted same specimen sizes as in the compressive strength test for PSA, PSB, and SHB while for wood (WD), 50x100mm hardwood timber was adopted. The apparatus used were (i). Acetylene gas; (ii). Oxygen gas; (iii). Stop watch and weighing balance. The nozzle was connected to two (2) hose pipes, one for Acetylene gas and the other Oxygen gas. It was positioned at a distance of 25mm from each specimen and heat applied through the flame from the nozzle at a point, until the composite material (i.e. the specimen) shows sign of failure either as crack, smoulder, or a hole through the surfaces (Fig.3). The time and temperature at which this failure occurred was recorded with the average of two repeated tests giving the fire resistance test result.

RESULTS AND DISCUSSION

Compressive Strength

Table 1 shows the result of compressive strength test while calculation for the surface area of block resisting the load applied and the actual volume of the sandcrete hollow block is as followed:

Table 1: Compressive Strength Test Result

Samples	Dimension L×b×h(mm)	Area(mm^2)	Crushing force (N)	Weight (kg)	Density ($kg/m^{3)}$	Average density (kg/m^3)	Compressive strength (N/mm^2)	Average compressive strength (N/mm^2)
PSA 1	450×125×225	101250	21000	23.42	1850.5	2049.58	0.207	0.217
PSA 2	450×125×225	101250	22050	27.00	2133.3		0.218	
PSA 3	450×125×225	101250	22950	27.40	2164.9		0.227	
SHB 1	450×225×225	63750	45000	24.28	1065.8	1034.33	0.706	0.622
SHB 2	450×225×225	63750	47950	23.12	1014.9		0.752	
SHB 3	450×225×225	63750	26000	23.29	1022.3		0.408	
PSB 1	250×90×150	37500	110000	6.86	203.3	209.19	2.933	3.333
PSB 2	250×90×150	37500	135000	7.22	213.9		3.600	
PSB 3	250×90×150	37500	130000	7.10	210.4		3.467	

Area of sandcrete block = $(450\times225-2(150\times125)) = 63.75\times10^{-3}m$ **= 63750mm^2**

Volume = $225(450\times225-2(150\times125))$ = **$14.344\times10^{-3}m^3$**

The results reflect that PSB has the highest compressive strength value of **3.33N/mm^2,** followed by the Sandcrete Hollow Blocks (SHB) with a value of **0.62N/mm^2** while the least compressive strength value is that of PSA giving **0.22N/mm^2.** PSB which had the highest compressive strength value was noted to have been produced and hydrated for more than one year, and this may be what accounts for the relatively high compressive strength value. The true reflection of compressive strength of polystyrene walling unit as at the 28-day is therefore adjudged as the value gotten from PSA which is rather too low for a load bearing wall.

Thermal Conductivity

Table 2: Result of Thermal Conductivity Test

Samples	Test No.	T_1(^{o}c)	T_2(^{o}c)	Time (secs)	T_1-T_2 (^{o}c)	Thermal conductivity (w/mk)	Av. Thermal Conductivity (w/mk)
PSA 1	1st test	31	10	30	21	0.0049	0.0048
	2nd test	30	9.5	60	20.5	0.0048	
	3rd test	30	9.5	90	20.5	0.0048	
PSA 2	1st test	31	10	120	21	0.0049	0.0049
	2nd test	30	9	150	21	0.0049	
	3rd test	30	9	180	21	0.0049	
PSA 3	1st test	30	10	210	20	0.0043	0.0045
	2nd test	29	9	240	20	0.0047	
	3rd test	29	9	270	20	0.0045	
PSB 1	1st test	43	12	300	22	0.0059	0.0056
	2nd test	32	10.5	330	21	0.0056	
	3rd test	30	10	360	20	0.0052	
PSB 2	1st test	33	11	390	22	0.0059	0.0058
	2nd test	32	10	420	22	0.0059	
	3rd test	32	10	450	21	0.0056	
PSB 3	1st test	30	10	480	20	0.0052	0.0053
	2nd test	29	9	510	20	0.0052	
	3rd test	29	8.5	540	20.5	0.0055	
SHB 1	1st test	32	10	570	22	0.083	0.0813
	2nd test	30	9	600	21	0.079	
	3rd test	30	8	630	22	0.082	
SHB 2	1st test	30	10	660	20	0.076	0.0757
	2nd test	29	8	690	21	0.079	
	3rd test	29	8	720	22	0.072	
SHB 3	1st test	31	10	750	21	0.079	0.0787
	2nd test	30	10	780	20.5	0.078	
	3rd test	30	9	810	21	0.079	

The results of thermal conductivity test (Table 2) reflects an overall average values of 0.0047w/mk and 0.0056w/mk for PSA and PSB respectively; while the SHB has an overall average value of 0.0079w/mk. This thereby implies that the Polystyrene walling unit has lower thermal conductivity values than the 225mm Sandcrete Hollow Blocks and will therefore enhance better comfort for the building occupants especially in temperate regions like ours.

Fire Resistance Test

The fire resistance test (Table 3) revealed that PSA failed at an average time of 24.5minutes, 808.52^{o}C temperature while the PSB failed at an average time 15.5minutes and a temperature of 743.43^{o}C. The SHB also failed at an average time of 17minutes, and a 757.17^{o}c temperature. **Table 3: Result of Fire Resistant Test**

Sample	Temperature(^{o}C)	Time (Min)	Av. Time (Min)
PSA 1	808.52	24	24.5
PSA 2		25	
PSB 1	743.43	16	15.5
PSB 2		15	
SHB 1	757.17	17	17
SHB 2		17	
WD 1	561.03	4	4.5
WD 2		5	

Expanded polystyrene in its natural form is a combustible material and so also is wood, but from the test results it was observed that wood (WD) failed at a temperature of 561.03^{o}c, an average time of 4.5minutes which reflects that the polystyrene walling units has a better resistance to fire than timber, because of the additional materials used in it's finishing for

construction. Their performance is found to be comparatively in the same range with 225mm Sandcrete Hollow Blocks.

CONCLUSION

The result and discussion above indicates that the polystyrene walling units were found to have high resistance to fire; they are poor heat conductors and thereby fit well as alternative walling material especially as internal walls. Adopting them as an alternating walling material will have a positive effect on the market value of other walling materials as it will increase competition in terms of usage and also tends to influence the quality of other walling materials. Manufacturers will always aspire to conform to the technological advancement in the properties posed by polystyrene.

The need for extra cost on insulating materials on walls and internal cooling of the building will be limited if not completely eliminated. It will also be a right attitude at a productive utilisation of the available bye-product of our Petroleum Industry if properly harvested. Growth and local production of polystyrene beads ought to be encouraged through appropriate policy formulations for this will be a step in right direction of **environmental sustainability** of the Millennium Development Goals.

REFERENCES

Alan, E. (1970): Mitchell's Building Construction Series, Batshford Ltd., London, pgs.38-60.

American Concise Encyclopaedia (2007): American Concise Encyclopaedia.

Barry, R. (1999): The Construction of Buildings, Blackwell Science, London, pg. 41.

British Standard Institution (1985): British Code of Practice for Use of Masonry, BS 5628:

Part 3- Materials and Components, Design and Workmanship, BSI, London.

Citec Nigeria Ltd. (2006): Technical Manual.

Cubic Homes Ltd. (2006): Technical Manual.

Encarta English Dictionary (2008): Website: www.microsoft encarta.com.

Gage, M; and Kirkbride, T. (1980): Design in Blockwork (3rd ed.), the Architectural Press Ltd., London.

Maurine, (1971): Plastics, Batellier, New York, pgs 23-56.

Melnick, D; McNeely, J; Navarro, Y. K; Schmit-Traub, G. and Sears, R. R. (2005):

"Environment and Human Well-Being: A Practical Strategy (Summary Version)", UN Millennium Project (Report of Task Force on Sustainable Development), 40 pp.

UNDP (2005): "About the Millennium Development Goals: Basics", a publication of the United Nations Development Programme (UNDP).

APPENDIX

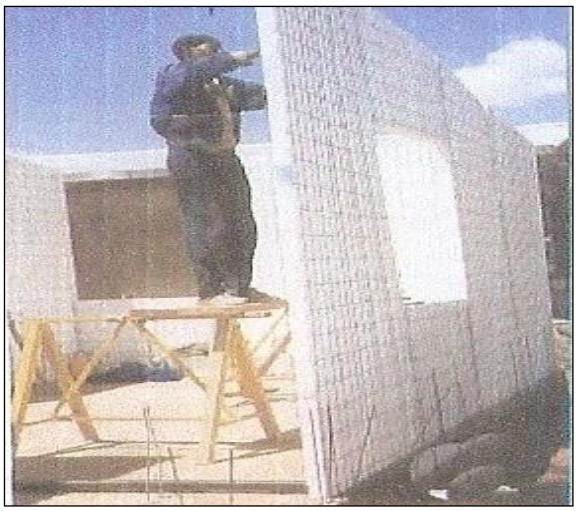

Fig. 1: A Polystyrene Panel Installation with Wire Mesh Reinforcements.

Fig. 2: Lee Disc Apparatus

Fig. 3: Fire Testing Process