Architecture Research 2012, 2(5): 81-86
DOI: 10.5923/j.arch.20120205.03

Sustainable Housing Provision: Preference for the Use of Interlocking Masonry in Housing Delivery in Nigeria

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Abstract This paper reports a study on the preference level for the use of interlocking masonry over the conventional types in sustainable housing delivery in Nigeria. Globally, buildings are the largest energy consumers and greenhouse gases emitters, consuming over 50% in some cases. Common materials used for masonry works in housing delivery in Nigeria such as sandcrete blocks and burnt bricks impact high energy and greenhouse gases on the environment due to the production processes involved. Intelligent choice of building materials capable of reducing energy used in buildings is imperative towards achieving materials efficiency and cost reduction. In this study, a comparative survey was carried out empirically among selected professionals in the building industry from 4 out the 6 geo-political zones in Nigeria through the use of questionnaire, direct observations, and interview schedules. Analyses of Chi-square test for significance of differences between materials price rating and acceptability of interlocking masonry as well as level of willingness of respondents to use the selected materials for future projects were conducted. Findings signify shorter time of construction and reduced cost of construction expended when interlocking blocks are used. The study concludes that interlocking masonry is a good replacement to the conventional types in construction of housing in Nigeria.

Keywords Building Materials, Conventional Blocks, Housing Provision, Interlocking Blocks, Sustainable

1. Introduction

Building materials constitute the largest single input in housing construction. While Adedeji[1] observed that about sixty (60) per cent of the total housing expenditure goes for the purchase of building materials, Arayela[2] averred that the cost of building materials constitute about 65 percent of the construction cost. Ogunsemi[3] opined that building materials form the main factors that restricts the supply of housing and ascertained that they account for between 50-60 percent of the cost of buildings. Thus, Adedeji[4] rightly observed that one main barrier to the realisation of effective housing in Nigeria as revealed in successive government efforts has been the cost of housing in the country. He argued that in the early periods, shelter in Nigeria was easily affordable as building materials were sourced from man's immediate environment at affordable costs. Technology also was readily available with commensurate simple techniques. But contact with the outside world through interregional and international training of professionals in foreign countries as occasioned by colonization, brought changes to tastes and hence outlook to house forms. These changes rendered the undeveloped local building materials inadequate while there was an increased demand for exotic ones. Accordingly, Arayela[2] posited that the modern building industry lays much emphasis on sophisticated building materials and techniques that are expensive and energy consuming.

Though, housing delivery efforts have evidently been inhibited by prohibitive costs of building materials, this problem cannot be reasonably and reliably overcome by merely resorting to the use of locally available materials without due considerations to the applicable initiative, the cost of processing and sustainability of the local materials. One of the most important components of a sustainable building is the material efficiency. Correct selection of building materials can be performed by taking into account their complete life time (i.e. from cradle to grave ‖) and by choosing products with the minimal environmental impacts. For instance, González and Navarro[5] estimated that the selection of building materials with low environmental impacts can reduce carbon dioxide (CO_2) emissions by up to 30%. The use of renewable and recycled sources is widely encouraged as the life-cycle of a building and its elements can be closed[6]. The other factors that greatly affect the selection of building materials are their costs and social requirements such as thermal comfort, good mechanical properties (strength and durability), aesthetic characteristics and an ability to construct quickly. Ideally, the combination of all environmental, economic and social factors can give a clear description of a material, and thus helps in a decision making process regarding the selection of the materials

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Published online at http://journal.sapub.org/arch

suitable for buildings[7]. It is along this line that the building industry in Nigeria is evolving varied kinds of building system adapted to the local materials, environmental conditions, city developments and levels of techniques of building construction that are in use. One of such system is the adaptation of interlocking masonry into the building industry which forms the focus of this research.

2. Literature Review

2.1. Building Materials and Sustainable Housing Provision

The process of housing development should be based on sustainability principles, which could be applied in the conception, construction and use of the buildings. The goals of the process are to decrease the environmental costs incurred by inadequate constructive systems and solutions, minimizing the impacts on natural resources, and improving users' comfort[8]. Gilkinson & Sexton[9] defined sustainable housing as a form of affordable housing that incorporates environmentally friendly and community-based practices. It attempts to reduce the negative impact that homes can have on the environment through choosing better building materials and environmental design. Sustainable housing provision requires proper definition of housing needs, and the participation of the end users to ensure their satisfaction. The general goal of sustainable development is to meet the essential needs of the world's poor while ensuring that future generations have an adequate resources base to meet theirs. It is thus geared towards meeting the needs of the present generation without compromising the ability of future ones to meet their own needs[1]. It further includes the production of materials, which must use resources and energy from renewable sources instead of non-renewable ones. Sustainable building materials are environmentally responsible because their impacts are considered over the complete life time of the products. Sustainable building materials should pose no or very minimal environmental and human health risks[10]. They should also satisfy the following criteria: rational use of natural resources; energy efficiency; elimination or reduction of generated waste; low toxicity; water conservation; affordability. Sustainable building materials can offer a set of specific benefits to the owner of a building such as reduced maintenance and replacement costs, energy conservation, improved occupant's health and productivity, lower costs associated with changing space configurations, and greater flexibility in design[11].

Achieving sustainability in housing provision requires major societal changes, restructuring of institutions and management approaches. It requires the appropriate political will based on the conviction of the responsibility of government to its citizens, and the need to create humane and decent environment for dignified living[12]. In order to realise sustainable housing provision the housing needs of the Nigerian population have to be put into proper focus, and a coordinated programme to achieve this should be thoroughly worked out. With due consideration given to the input of the local communities, government may initiate aided self-help programmes and low-cost core housing units. It can also facilitate the acquisition of building materials, the cost of which constitutes about 60% of the entire cost of a building. Production of building materials of indigenous origin by private investors should be given logistic and material support by government

2.2. Interlocking Blocks and Energy Efficiency

Introduction of interlocking or "dry stack" mortarless masonry systems in masonry construction requires the development of efficient, easy to handle, and yet versatile blocks. Varied interlocking blocks developed for use include Sparlock system, Meccano system, Sparfil system, Haener system, and the Solid Interlocking blocks (SIB) or Hydraform blocks, which are an improvement over the traditional adobe bricks or unfired laterite blocks that were prevalent in the 20th century in some African countries[13]. Interlocking blocks can also be of cement and sand content only.

In Nigeria, the Nigerian Building and Road Research Institute (NBRRI) developed an interlocking block making machine meant to produce SIB types. The blocks have geometric size of 225 x 225 x 112 mm. This machine produces solid blocks of laterite composition mainly and stabilised with cement material of ratio 1:20[4]. The major environmental burdens associated with building materials (conventional and innovative types) include embodied energy of building materials and greenhouse emissions originated from each stage of their life-cycle. Embodied energy is defined as the amount of energy required to produce a material and supply it to the point of use. It is an important measure of the effectiveness of building materials in the environmental terms[7]. Embodied energy consists of: energy required for the manufacturing of building materials; energy associated with the transportation of raw materials to the factory and of the finished products to the consumer; energy needed for assembling various building materials to form a building. The results presented by Thormark[14] indicate that embodied energy in traditional building can be reduced by approximately 10–15% through the proper selection of building materials with low environmental impacts. Although the values of embodied energy can vary widely (sometimes by as much as 100%, depending on the number of factors like country, manufacturing processes, recycling technologies, methodology of analysis, fuel costs and destination), they can be considered as reasonable indicators of an overall environmental impact of building materials[15]. The usage of SIB in place of conventional fired ones can significantly reduce the energy use and also cut down CO_2 emissions. Interlocking blocks are manufactured by hydraulically compressing a soil and cement mixture (stabiliser) in a block-making machine

(Figure 1).

Figure 1. Hydraulic Machine developed by NBRRI, Lagos

The production process involves preparation of soil, preparation of mix, compression of mix, stacking and curing of blocks. The results of several studies (Harris, et al.[16], Anand & Ramamurthy[13]) showed that increase in durability and strength over conventional blocks and unfired blocks occurred when cement is added to stabilise solid interlocking blocks. In the production of the latter, a 4MPa block requires a 1:20 ratio of cement to soil for stabilisation. This means that for one bag of 50kg cement (+-33 litres) you will need about 10 wheelbarrows (+- 65 litres/wheelbarrow) of soil. This mix yields about 75 blocks, with engineering standards acceptable for wall construction.

Figure 2. Stacking of Solid Interlocking blocks in a project site

In Solid interlocking blocks, substantial cost savings can be achieved due to elimination of bedding mortar in the superstructure (except in ring beams and in high gables) accelerates construction, thereby reducing workmanship and cost. Hydraform blocks are three times as efficient as concrete and almost twice as efficient as fired clay bricks in terms of the thermal insulation they offer**.** Attractive, face brick finishes (in a variety of natural colours derived from the soil found at individual sites) is also possible with the use of the material[17]. However, Adedeji[17] observed that block strength is affected by cement content quality, curing duration (7 days minimum) and soil type. Moreover, energy input of interlocking blocks are comparable to that of unfired clay bricks, which their total energy input was estimated of 657 MJ/ton as opposed to 4,187 MJ/ton for the common fired bricks, while an equivalent output of CO_2 emission was 41 kg CO_2/ton compared to 202 kg CO_2/ton for traditional bricks in mainstream construction[18],[19].

Concrete and cement products are the most widely used for construction of foundations, structural frames, floors, roofs, and prefabricated elements in Nigeria and many parts of the globe[20]. Globally, more than 10 billion tons of concrete are produced annually[21]. Concrete is a durable material with excellent mechanical properties. It is adaptable to different climates, relatively fire resistant, widely available and affordable. Concrete can be moulded almost into any shape and can be designed to satisfy almost any performance requirements[21]. It can be reinforced with either steel or fibres. Moreover, recycled materials can be incorporated into the concrete mix, thus reducing consumption of raw materials and disposal of waste products. The use of admixtures-materials added to concrete-becomes very popular as the final composite can have better durability and gains some specific unique properties[10]. In spite of these advantages, concrete unfortunately has an enormous negative impact on the environment. It is estimated that cement and concrete industry generates up to 7% of global anthropogenic CO_2 emissions, and it is set to increase dramatically in the coming decades as the Earth's population grows[10]. Apart from the emissions related to the combustion of fossil fuels, there is a release of CO_2 associated with unavoidable de-carbonation of limestone (raw material)[22]. Concrete manufacturing is responsible for generating not only carbon dioxide but also other air pollutants like carbon monoxide (CO), sulphur (IV) oxides (SO_2), nitrogen (IV) oxides (NO_2), hydrogen chloride (HCl), volatile hydrocarbons and particulate matter. Production of concrete causes depletion of non-renewable mineral and water resources required in extremely large quantities.

Concrete industry must, therefore, take urgent actions in order to reduce the emissions of CO_2 and other air pollutants; to reduce the use of energy; to cut down the use of natural resources (including water); and to minimize the amount of waste generated. One of the effective ways to deal with negative environmental impact of concrete is to reduce the total volume of this material needed for a certain construction process by enhancing its performance[12].

3. Materials and Methods

The research method was an abridged form of a parent research carried on materials preference options for sustainable low-income housing in selected cities in Nigeria in 2007. A multi-stage sampling technique was adopted in selecting the zones and the cities. The stages of the multi-stage sampling technique employed were; (i) adoption of the original six geo-political zones and random selection of 4 zones out of the six zones; (ii) random selection of one State per zone and (iii) specific selection of State capitals in the surveyed zones as they were adjudged to be the most urban. A town was randomly selected from each of the geopolitical zones as follows Abuja, (North-central zone); Port-Harcourt (South-south zone), Lagos (Southwest zone) and Enugu (Southeast zone). Data were obtained through observations from case studies. Also, a well-structured questionnaire, which was designed to investigate 25 variables on housing materials, was used to elicit opinions of professionals and clients on the use of these materials. The variables were structured in question form and responses were required in pre-coded alternatives given. Research assistants, who had earlier been trained by the author, administered questionnaires to selected professionals in the building industry. The selected professionals (Architects, Engineers, Quantity Surveyors and Builders) distributed over four out of the six geo-political zones in Nigeria expressed their opinion on the acceptability and willingness to use this material as a replacement for the conventional sandcrete blocks. Questionnaires were administered to two hundred respondents in the four geo-political zones as shown in Table 1.

Table 1. Distribution of Questionnaires Type 'A within the Study Area

S/No	Geopolitical zone	Town	No of Questionnaire	No of Responses
1	South West	Lagos	50	40
2	North	Abuja	50	32
3	South South	Port Harcourt	50	28
4	South East	Enugu	50	20
Total			200	120

Descriptive statistics such as frequency distributions and pie-chart were utilised for the analysis of socio-economic data while Chi-square (c2) was used to test bi-variate relationships and determine the superiority of the selected materials in terms of cost-efficiency over the conventional type. The chi square model used is given as:

$$c2 = \sum_{i=1}^{n} \frac{\left(O_i - E_i\right)^2}{E_i} \quad (3.1)$$

Where
O_1= observed frequency
E_1= expected frequency
n= number of category

4. Findings and Discussion of Results

Observations from case studies on comparative cost of interlocking blocks with conventional types were obtained from the four (4) selected locations. Prices of interlocking blocks and conventional blocks were also obtained from the market. While conventional sandcrete blocks (225 x 225 x 450) sells at ₦120.00, interlocking block (225 x 112 x 225) mm sells at ₦25.00 as at October, 2007. Taking into consideration that conventional block requires the use of mortar for the laying of the blocks and associated non-contributory activities that affect its cost and the net output. Some non-contributory activities associated with the use of conventional sandcrete blocks include: sorting of blocks, taking of blocks, breaking of blocks, laying of blocks, levelling of blocks, taking of mortar, mixing of mortar, laying of mortar, spreading of mortar and waiting for materials. These activities together with the use of mortar are eliminated in the operation of interlocking blocks[13]. Besides, interlocking blocks offer several advantages such as design flexibility, reduced construction time, environmental friendly and solution to space shortage. This resulted to the significant cost savings observed with the use of interlocking blocks in the study area. Though four (4) units of interlocking blocks will combine to make a unit of the conventional block, the cost of 4 units of interlocking blocks is still lesser than that of a corresponding conventional masonry. Also, interlocking blocks are designed and produced in varied sizes in such a way that it does not require cutting into sizes during setting operations. This further reduces the time for setting operation and eliminates associated wastages.

Figure 3. Interlocking Masonry at the finishing stage of a housing project

The production of SIB does not require firing as in the case of burnt bricks nor expensive factory processes associated with cement products. Hence, energy consumption is reduced considerably. Besides, the cost of using interlocking blocks in construction is lower than that of conventional blocks as its operation does not require special skilled labour as it is in the case of conventional blocks. It was also observed that while a gang of 1mason + 1 labour could achieve a productive hours 6.5m^2/h with interlocking masonry, a gang of 1mason + 1 labour could only achieve a productive hours 1.55m^2/h with conventional masonry. This further corroborates an observation made by Anand & Ramamurthy[13] on a study carried out on comparison of output from different types of masonry works, where a crew of one person, achieved the productivity of 4.1 m/h with the use of hollow-interlocking blocks.

The results obtained from the various zones were not significantly different from each other, implying that the locations of the selected projects did not significantly affect the willingness of respondents to use these materials.

Consequently, respondents favoured the use of interlocking masonry in housing construction based on its shorter time of construction, reduced cost, high energy efficiency and high acceptability index as against the use of the conventional types.

4.1. Respondents' Willingness to Use Interlocking Blocks

The tendency towards the preference for the use of interlocking-blocks masonry was further studied when testing the opinions of respondents about the willingness to use the material in Figure 4.

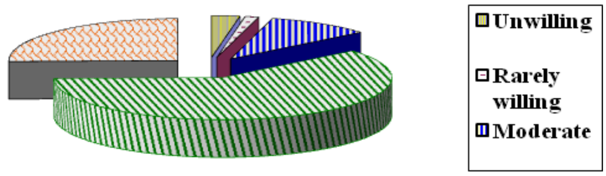

Figure 4. willingness to use interlocking blocks

Majority of the respondents (83.4%) were willing to use the products. Only 6.6% claimed that they were not willing to use this material for construction. These respondents were unwilling to use the material based on the fact that the material is not popularly used in the building industry in Nigeria. Few developers and individual home owners in the study area exhibited the use of the material. Ten percent of the respondents were undecided on the choice of masonry they could use for house construction. The decision of this group may be affected positively toward the use of interlocking blocks as the material becomes more popular in the building market. Industrial production of the product can also facilitate reduction of cost and its acceptability.

4.2. Chi-Square Test for Significance of Differences Between Materials Price Rating and Acceptability of Interlocking Masonry

Chi- square model was used to test for association between the materials' price rating and acceptability of inter-locking masonry by the respondents. The respondents' opinions on materials price rating were found to depend on their acceptability of interlocking masonry.

Based on the result in Table 2, there is association between acceptability of interlocking masonry and price of materials. The c2 results shown in the table indicated a significant level (P≤0.05) for the variables used to assess acceptability and material price rating. This implies that the high acceptability preference shown by respondents for the material was dependent on the cost efficiency of the material over the conventional sandcrete blocks used for housing in the study area. Added to this, could be the other advantages of interlocking blocks discussed earlier. Majority of the respondents would want to use SIB as a better alternative to the conventional blocks.

Where:

V E = Very Expensive; E = Expensive; M C = Moderately Cheap; Cheap; V C = Very Cheap;

NA = Not Acceptable; Rarely Acceptable; Moderately Acceptable; Acceptable; Very Acceptable.

Since the c2 result showed a significant level of association between material price rating and acceptability of interlocking blocks based on comparative cheaper cost of the material in the locality of respondents, the material is therefore recommended for use as a better alternative to conventional blocks in housing delivery in Nigeria.

Table 2. Measures of Association between Materials Price Rating and Acceptability of Interlocking Blocks

Cross tab			Acceptability of Interlocking Blocks					T
			N A	R A	M A	A	V A	
Materials Price Rating	V E	O E	1 1. 0	3 7.9	5 6.3	14 14 .6	15 8. 2	3 8 3 8
	E	O E	1 1. 3	12 10.4	7 8.3	25 19 .2	5 10 .8	5 0 5 0
	M C	O E	1 0. 7	10 6.0	7 4.8	7 11 .1	4 6. 3	2 9 2 9
	C	O E	0 0	0 0.2	0 0.2	0 0. 4	1 0. 2	1 1
	V C	O E	0 0. 1	0 0.4	1 0.3	0 0. 8	1 0. 4	2 2
Total		O E	3 3. 0	25 25.0	20 20. 0	46 46 .0	26 26 .0	1 2 1 2

5. Conclusions

The goal of this paper is sustainable housing provision through the adaption of interlocking blocks for housing delivery in Nigeria. This paper examines factors for the preference of interlocking masonry over the conventional type in construction of housing in Nigeria. Though the survey covered 4 out of 6 geo-political zones in Nigeria, the respondents' opinion on the variables investigated did not show significant differences from one location to the other but in the willingness of respondents to use interlocking masonry as a better alternative to conventional masonry. This is predicated on the cost-efficiency, shorter period of setting, design flexibility, environmental friendliness and energy efficiency of the material. The field data obtained from four different locations were analysed, which showed 83% respondents' preference for the use of interlocking masonry as against the use of the conventional type. The analysis of measure of association and their significance of interlocking-blocks masonry based on variables such as material price rating and acceptability / willingness of respondents indicated results of significance level at ($P \leq 0.05$) of the association of variables measured. Thus, the result of the research has strongly indicated that interlocking blocks are preferred as better alternatives to conventional sandcrete blocks and should therefore be used as replacement for the former in housing delivery in Nigeria. This will facilitate cost efficiency and make housing provision sustainable.

ACKNOWLEDGEMENTS

SAP Productions wishes to acknowledge all the contributors for developing and maintaining this template.

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