COMPARATIVE COST STUDY OF HYDRAFORM INTERLOCKING AND CONVENTIONAL SANDCRETE BLOCKS IN NORTHERN NIGERIA

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Abstract
Hydraform interlocking block system is gradually gaining recognition and is increasingly used in most developing countries like South Africa, Zambia and Nigeria for low-income housing delivery. The block system has many advantages with regards to savings on the cost of construction, time of construction delivery, durability. The study found out through a questionnaire survey and analysis of cost efficiency from bills of quantities the comparative cost study of hydra form interlocking blocks and the conventional sandcrete blocks in low-income housing delivery in Kaduna metropolis of Nigeria. The study revealed that the use of hydraform blocks in low-income delivery is cost-efficient, but its application in low-income housing delivery in the chosen area of study is very low when compared to the conventional sandcrete blocks. The study recommends that professionals in the building industry should promote the use of hydraform interlocking blocks and similar sustainable alternative type of block in low-income housing to encourage it and awareness.

KEYWORDS: *Hydraform interlocking, conventional sandcrete Blocks, Comparative Analysis, Northern Nigeria*

INTRODUCTION

The cost of materials is a vital variable in any construction project, hence the maxim that the first cost estimate is always the one figure that the client remembers as observed by Ashworth and Hogg (2007).The modern building industry lays much emphasis on sophisticated building materials and techniques that are expensive and energy-consuming which makes the cost of building high and inadvertently beyond the reach of the low-income earner and also reducing the impact of mass housing delivery. Mantri (2009) averred that of the total construction cost, almost 65to 70% is devoted to the cost of materials involved in the building construction. Therefore, control over the cost of material components automatically reduces the cost of construction especially if economical material alternatives are taken into consideration. In the selection of building materials for any construction, some factors need to be taken into consideration such as the material impact on the environment which may arise from its embodied energy that is, the energy used in Production, emissions and other forms of pollution, their cost, social requirement such as thermal comfort, strength and durability, aesthetic characteristics and also the ability to construct quickly as observed by Adedeji (2012).

According to Hodge (2008), many investigations conducted indicated that laterite is suitable for producing bricks which can serve as a suitable alternative for sandcrete blocks, hence the introduction of hydraform interlocking blocks, a class of solid interlocking blocks (SIB) which are produced mainly from laterite clay stabilized with cement in a mix ratio of (1:20). These types of blocks are an improvement of the traditional adobe blocks or unfired laterite blocks which were prevalent in the 20th century. Varied interlocking blocks developed and available for use today include the Nigerian Building and Road Research Institute (NBRRI) interlocking block system, sparlock system, meccano, sparfil, haener and hydaform interlocking blocks.

The construction industry is concerned with the planning regulation, design, manufacture, fabrication, erection and maintenance of buildings and other structures. It is also responsible for effective housing delivery. Adedeji (2012), rightly argued that one major barrier to the realization of effective housing delivery in Nigeria had been the high cost of housing delivery. This is due to the rising cost in the country arising due to the high cost of building materials, rapid population growth in the urban areas, rapid urban growth and the low performance of the construction industry in the housing sector to meet this rising demand for low-income housing.

Recent research carried out by Raheem et al (2012), on comparative analysis of sandcrete hollow and laterite interlocking blocks as walling material observed that laterite interlocking blocks were denser and stronger than the sandcrete hollow blocks however laterite interlocking block is cheaper than sandcrete hollow block, both in terms of unit cost and cost per square meter. This factor under consideration had motivated the study.

JUSTIFICATION FOR THE STUDY

Nigeria with a population of about 166.2 million people (in 2012) has a housing deficit of about 17 million units (Olabode,2014). Therefore, there is a need for effective mass housing delivery in the country despite the rising cost of building construction and the growing challenges associated with housing delivery. The single-family house has not lost any of its' attractions, a well-planned owner occupier house can provide an environment adapted to the owner's personal way of life unrestricted by consideration for other people living in the building. Unlike a rented house, an owner-occupier house offers maximum freedom especially for low-income earners as observed by Jha and Sinha (2004).

There is a rapid population explosion in the urban areas which has led to high demand for residential buildings. This problem of low-income housing delivery in Nigeria which was observed by Olukanyin (2012), is a significant problem and calls for immediate action as shelter is a basic and fundamental human requirement that affects the largest number of people. This is similar to that of many developing countries and has been attributed to the rapid urban growth and low performance of the construction industry in the housing sector to meet the demand for affordable housing.

Zakari and Akani (2013), in previous research, observed that a major factor to the housing problem is the inadequate application of technologies and the use of natural resources, hence the urge to find alternative materials to the existing conventional ones and the need to bring down the cost of construction especially for low-income housing as well as adopting easy and effective solutions for their repair and maintenance. This has necessitated the comparison of the cost associated with the production of walling units from the mixture of laterite and cement (interlocking block) to that of sand and cement (sandcrete block) and its' possible application for low-income housing in urban areas.

This study will be crucial in assessing the comparative cost benefits associated with the use of hydraform interlocking blocks and sandcrete blocks in low-income housing delivery in the country. This research seeks to identify the comparative cost benefits in the use of hydraform interlocking blocks and conventional sandcrete blocks in order to seek ways to reduce construction cost, especially for low-income housing

DATA AND METHODOLOGY

The data used for the study was collected through questionnaires, oral interviews and telephone calls to be administered on selected subjects in three categories, viz: owners, occupiers and producers of houses built with hydraform interlocking blocks in the chosen area of study. The data obtained for this study will be analysed using simple statistical methods which would be used to calculate frequency and severity indices which would enable the establishment of the relative importance index. Direct analysis of Bill of Quantities for walls built with hydraform interlocking block and that of sandcrete block would be compared.

LITERATURE REVIEW

CONCEPT OF MASONRY CONSTRUCTION

The concept of masonry construction according to Jackson and Dhir (1988), is principally for load-bearing and non-load bearing wall in which materials such as broken stones, clay blocks, solid and hollow concrete blocks are used. Barry (1996) defined a wall as a continuous vertical structure of bricks, stones, concrete, timber or metal thin in proportion to its length and height, which encloses and protects the building or serves to divide the building into compartments or rooms. Obande (1990) asserted that blocks used in masonry construction were classified as:

I. Light weight blocks, made from light aggregates such as sawdust, foamed slag.
II. Dense weight blocks. made from dense aggregates such as natural sand and crushed rock

SANDCRETE BLOCKS

A sandcrete block according to British standard 2028 is defined as a walling unit exceeding the length, width or height for bricks in BS 3921 which are designed to be laid not more than 337.5mm long, 225mm wide and 112.5mm high as distinct from a building block. Nash (1983), as cited in Obande added the height of a block must not exceed either its length or six times its thickness. Obande (1990), posited that sandcrete blocks which are sometimes referred to as concrete blocks are made from a mixture of hard durable and clean sand, cement and water. On setting and hardening, the blocks attain sufficient strength to be used as walling units. He further added that sandcrete blocks are categorized as dense blocks which according to BS 882; 1983, are made from dense aggregates which include natural sand and crushed rocks. Hollow and solid blocks can be produced from such aggregates with varying densities ranging from 1920kg/m3 to 2080kg/m3 and are suitable for general use in load bearing and non-load bearing walls including works below ground level damp proof course.

Barden and Tuuli (2004), posited that sandcrete blocks can be produced from cement and sharp sand in a mix ratio ranging from (1:6), (1:8) to as weak as (1:19). It can be machine molded or hand molded manually using hand molds. A simple machine can make up to 1600 blocks in an eight-hour shift. The cast blocks can be cured using steam or water spray for at least 14 days and dried for 4 weeks before being used. All the initial shrinkages should have taken place. The blocks could be molded in solid, hollow and cellular forms with a variety of sizes ranging from:

a) 450 x 150 x 75
b) 450 x 150 x 100
c) 450 x 225 x 75
d) 450 x 225 x 150
e) 450 x 225 x 225

Stutz (1986) further added that after the curing period the bricks should be stacked in such a way that air could circulate between the blocks.

COMPRESSIVE STRENGTH

Stutz (1986) identified the range of compressive strength of sandcrete blocks tested by BS 6073 part 2 which were found to vary from 2.8N/mm2 to 35N/mm2. But from considerations of cost the normal practical upper limit is about 20N/mm2 and most commonly used blocks fall within a much smaller strength band of 3.5N/mm2 to 10N/mm2. Zakari and Akani (2013), also observed that sandcrete blocks were found to be durable in compressive strength, density, permeability as well as porosity.

Orjinta (2008), further added that the measured strength in Nigeria was found to be between 0.5N/mm2 and 1N/mm2 which is well below the 3.5N/mm2 that is legally required. This may be due to the manufacturers to keep the price low.

HYDRAFORM INTERLOCKING BLOCKS

Hydraform solid interlocking block was first introduced by Hydraform international company in South-Africa in the year 1988. This was to design and market quality soil-cement stabilized building blocks that could be stacked together without the use of cement mortar. According to Hydraform (2005), the blocks have a male and female profile on the face that works as lock and key on four of the six sides of the block, which eliminates the use of cement mortar and makes them self-aligning. The concept of interlocking blocks is based on the following principles: firstly, blocks are shaped with projecting parts which fit exactly into the depressions in the blocks placed above such that they are automatically aligned horizontally and vertically which thus makes laying of the blocks possible without special masonry skills. Secondly, this block can be laid dry, no mortar required and a considerable amount of cement can be saved.

MANUFACTURE OF HYDRAFORM INTERLOCKING BLOCKS

According to Arayela (2005), as cited in Adedeji, hydraform interlocking blocks are produced by hydraulically compressing laterite and cement mixture in the ratio (1:20). The blocks have a geometric size of (225 x 112 x 225). The processes involved in the production include;

- Preparation of soil.
- Preparation of mix.
- Compression of the mix.
- Stacking and curing of blocks.

Hydraform interlocking blocks can be manufactured on site and dry stacked reducing the embodied transport and curing energy significantly to around 0.635 mj/kg. The product contains a small percentage of cement, which stabilizes it and largely accounts for its embodied energy component (Hydraform, 2005).

Hydraform blocks are three times as efficient as concrete and almost twice as efficient as fired clay bricks in terms of thermal insulation. Hodge (2008), opined that laterite is suitable for producing bricks and the laterite to be used must be properly crushed and large lumps removed by sieving with an 8 – 10mm mesh sieve after which the laterite is kept in temporary small heaps to dry and ready for mixing.

PREPARATION OF MIX

The hydraform interlocking blocks require a cement to laterite mix of (1:20), Adedeji (2012). This means that one bag of cement (50kg) which is about 33 liters will require about ten wheel barrows (65 liters) of laterite soil which will yield 75 blocks with acceptable engineering standard for wall construction. The cement and laterite mix can be hydraulically compressed in a hydraform block making machine or manually compressed using hand molds to produce efficient, easy to handle and versatile solid interlocking blocks. Adedeji (2012) is of the opinion that the block strength can be affected by the cement content, quality, curing duration and soil type. The newly manufactured blocks must be cured for a minimum of seven (7) days and stacked on a horizontal platform to dry. The blocks can be covered to prevent rain.

Non- Contributory Activities Associated with the Use Of Hydraform Interlocking Blocks in Building Construction

Adedeji (2012) outlined some non- contributory activities associated with the use of hydraform interlocking blocks which include:

- Sorting of blocks.
- Taking of blocks.
- Breaking of blocks.
- Laying of blocks.

He further stated that the above listed activities promote:

- Design flexibility.
- Reduced construction time.
- Environmental friendliness.
- Solution to space shortage.
- Considerable low energy consumption.

Adedeji (2012), observed the following Comparison of output between hydraform interlocking blocks and sandcrete blocks.

Table 1

BLOCK TYPE	OUTPUT M2/HR
1mason and 1 labour sandcrete block	1.55m^2 per hour
1mason and 1 labour hydraform block	6.5m^2 per hour

According to Adedeji(2012), if 6.5m^2 could be produced in 1hour, then in 8 hours period, (8 x 6.5=52m^{2}per day), he further stated that 4 hydraform blocks are equivalent to 1 sandcrete block, therefore; If 10 sandcrete blocks make 1m^2, then 40 hydraform blocks will make 1m^2.

BENEFITS OF HYDRAFORM INTERLOCKING BLOCKS

Hines (1992), Gate (1995) and Olusanya (1991 and 2005), observed that interlocking blocks offer several potential benefits that could improve the overall effectiveness of a wall, which are mentioned below:

- It makes it possible to eliminate the use of mortar for laying the blocks.
- The material laterite is very good in various weather changes, it makes the house cool during hot and cold weather.
- It does not require the need for a high waged skilled labour.
- The materials required for the production and construction are locally available in most regions.
- It reduces construction time as the activity with mortar has been eliminated.
- It is suitable for construction of multi-story buildings as the strength is higher than that of conventional sandcrete blocks.
- It is maintenance free.
- The block material is structurally stable and durable, it requires little or no wetting for the mortar to cure, therefore speeds up construction.
- It can be produced locally with both manual and mechanical block making machine.

Gate (1995) as cited in Olukanjin, describes the demerits of interlocking blocks as follows:

- The technology is new and not well known thereby making people reluctant to apply it.
- Certain amount of training is required to ensure proper alignment of the blocks.
- The joints are not entirely resistant to wind and rain penetration, it is usually necessary to plaster the interior wall.

LOW-INCOME HOUSING SITUATION IN NIGERIA

Housing is universally accepted as the second most important human need after food; hence the Nigerian state is enjoined by section 16 (i) (d) of the 1999 constitution under the fundamental objectives and directive principles of state policy "to provide suitable and adequate shelter for all citizens". Housing is one of the basic needs for human existence and represents not only the largest non-food household expenditure, but also the most valuable and main capital asset possessed by most low-income households (Datta and Jones, 1999; Fergusion and Haider, 2000), yet not many people can provide for themselves because of limited means. Agbola (2005), posited that the house is an institution created for a complex set of purposes beyond provision of shelter. He further opined that it is a social unit of space where every human being resides irrespective of age, sex and status differences. This fact had not been lost to Government, according to Arayela (2005), under the third National Development plan (1975 - 1980); the Federal Government of Nigeria proposed to build 202,000 housing units all over the country comprising 8000 units in each of the then nineteen state capitals with the exception of Kaduna and Lagos states which were allotted 4000 and 46,000 additional units respectively, which were not realized.

In spite of the intention, Agbola (2005) noted that the period of Third National Development Plan was when housing units became more scarce and costly, relative to income and as such described the period as an abysmal failure. Arayela (2002), also opined that there is inadequate housing stock to cope with the ever-increasing population and available housing facilities in Nigeria.

METHODS OF DATA COLLECTION

The collected data from the questionnaires and oral interviews were analyzed using simple descriptive statistics and importance indices. The number of respondents in the various categories, highest qualifications, years of experience, number of projects that hydraform interlocking blocks were used, status of occupancy were obtained. The data were analyzed with the aim of establishing the relative importance of the various factors:

Relative importance index = $\sum_{i=1}^{4} ai\ xi/4 \sum_{i=1}^{4}$ xi

Where

ai = constant expressing the severity given to i.

xi = variable expressing the frequency of the response for I = 1, 2,3,4 and illustrated as follows;

x1 = frequency of the slightly important and corresponding to a1

x2 = frequency of the somewhat important and corresponding to a2 = 2

x3 = frequency of the average important and corresponding to a3 = 3

x4 = frequency of the very important and corresponding to a4 = 4

The frequency and severity indices would enable the establishment of the relative importance indices, which according to Waziri et al (2014), is a product of the summation of the frequency index(x1) and severity index (a1) divided by the summation of the frequency index which represents the number of cases considered mathematically put as follows:

Relative importance index (RII) = $\sum$ (xi ai)/ $\sum$xi

Where:

RII= relative importance index

Xi = frequency index

Ai = severity index

∑xi = summation of frequency index

The relative importance indices arrived at in each of the three respondent categories for each of the items were ranked and thus enabled the establishment of the most important advantages of hydraform interlocking blocks as compared to the conventional sandcrete blocks for each of the three(3) categories of respondents.

A summary and comparison of the relative importance indices and rankings of the three(3) categories of respondents and also the bill of quantities (BOQ) showing practical comparison of the economic cost of using hydraform interlocking blocks and the conventional sandcrete blocks in the construction of walls for a two bedroom bungalow were undertaken on a combined basis to have a combined perspective of the categories of respondents. The results enabled the determination of the comparative cost advantages of hydraform interlocking blocks and the conventional sandcrete blocks in low income housing delivery.

DATA PRESENTATION, ANALYSIS AND DISCUSSION OF RESULTS

PRESENTATION AND ANALYSIS OF BILL OF QUANTITIES

Bill of Quantity for superstructural works for a proposed two bedroom bungalow

Using sandcrete hollow blocks size 450x225x225mm.

S/NO.	DESCRIPTION	QUANTITY	UNIT	RATE(₦)	AMOUNT (₦)
1	F10,230mm thick sandcrete hollowblock wall in cement mortar (1:6), laid in stretcher bond, vertically.	139	M^2	3,263	453,557

	Surface finishes 15mm thick cement- sand (1:4), one coat internal rendering on sandcrete blockwork, wall width > 300mm. Cement-sand(1:4),one coat external rendering on block work, wall width > 300mm.	207 103	M^2 m^2	1,150 1,150	238,050 118,450
3	M60,Painting and clear finishing internally Prepare and apply one mist coat and two full coats of sandtex vinyl matt standard quality emulsion paint internally rendered walls. M60, painting and clear finishing externally. Prepare and apply one prime coat and one full coat of sandtex weather shield quality textured paint externally on rendered walls.	207 103	M^2 M^2	614.28 833.20	127,156 85,820
4	E30 high tensile steel reinforcement to BS for 4449 for insitu concrete. Bar, 16mm diameter Bar, 10mm diameter	0.03 0.02	Tone Tone	201,000 201,000	6,030 4,020

5	E05,reinforced vibrated insitu concrete mix grade 20-10mm aggregate as described to; Lintels	1.26	M^3	24,571	30,960
6	E05,reinforced vibrated insitu concrete mix grade 25-12mm aggregate as described to; columns	0.95	M^3	27,168	25,810
	E20, formwork class F3 for insitu concrete to;	42.46	M	1,159	49,211
	Sides and soffit of lintel Vertical sides of columns	36	M	1,159	41,724
				Total carried to summary	**1,180,788**

SUMMARY

Super structural works: ₦ 1,180,788.00

add

10% contingency: 118,078.8

₦1,298,866.80

Add

Profit and overhead at 25%: 324,716.67

₦1,623,583.50

Add V.A.T (5%): 81,179.175

Grand Total ₦ 1,704,762. 68

Bill of Quantity for super structural works for a proposed two bedroom bungalow using hydraform interlocking blocks

S/NO.	DESCRIPTION	QUANTITY	UNIT	RATE (₦)	AMOUNT (₦)
1	BLOCKWORK 225X112X225mm thick hydraform interlocking blocks, placed straight to interlock, vertically.	139	M^2	697	96,883
	Hire rate for single engine hydraform interlocking block making machine with a minimum output of 1500				

	blocks minimum per day. (139m x 52m =7,228 blocks) 7,228 requires(7228/1500= 5 days)	5	number	16,000	80,000
2	E30 high tensile steel reinforcement to BS for 4449 for insitu concrete. Bar, 16mm diameter Bar, 10mm diameter	0.03 0.02	Tonne Tonne	201,000 201,000	6,030 4,020
3	E05,reinforced vibrated insitu concrete mix grade 20-10mm aggregate as described to; Lintels	1.26	M^3	24,571	30,960
4	E05,reinforced vibrated insitu concrete mix grade 25-12mm aggregate as described to; columns E20, formwork class F3 for insitu concrete to; Sides and soffit of lintel Vertical sides of columns	0.95 42.46 36	M^3 M M	27,168 1,159 1,159	25,810 42,211 41,724
				Total	**327,638**

SUMMARY

Super structural works: ₦ 327,638.00

add

10% contingency: ₦32,763.80

₦360,401.80

Add

Profit and overhead at 25%:₦90,100.45

₦450,502.25

Add V.A.T (5%): ₦ 22,525 .11

Grand total ₦473,027.36

RESULTS FROM THE ANALYSIS OF BILLS PRESENTED

From the above computation and analysis of Bills of Quantities presented, it was found that the two alternatives; the conventional sandcrete blocks and hydraform interlocking blocks, had a total construction cost of ₦ 1,704,762.68K and₦473,027.36K respectively. The results obtained also shows that the use of hydraform interlocking blocks in low income housing saves cost of construction when compared to the conventional sandcrete blocks.

CONCLUSION

The study has examined the comparative cost of hydraform interlocking blocks and the conventional sandcrete blocks in low-income housing delivery in order of questionnaires distributed to low-come households built with hydraform interlocking blocks and also a cost analysis of the two alternatives obtained from bills of quantities presented. It was then possible to compare the cost associated with the two block alternatives. The study reveals the economy in the use of hydraform interlocking blocks when compared to the conventional sandcrete blocks and could be used in low-income housing delivery. It was found out from the study that few households were built with hydraform interlocking blocks when compared with households built with the conventional sandcrete blocks in Kaduna metropolis despite their many benefits. This observation signifies a low level of awareness in the use of hydraform interlocking blocks in the chosen area of study.

RECOMMENDATIONS

From the review of literature and conclusion reached;

- The professionals in the building industry should encourage the use of hydraform interlocking blocks as an alternative building material in low-income housing delivery.
- The study recommends sensitization in the use of alternative sustainable materials for building construction.
- During the construction process, the following should be ensured, adequate consultant supervision, involvement of competent contractors, adequate project coordination, use of standard materials and adequate project coordination.
- Similarly, during the design stage, the following should be ensured: coordinated drawings, sufficient detailing, proper supervision, specification to be issued by the design team and proper communication.
- The Federal Government should regulate the product of the building industry, especially houses, using appropriate laws and enforce it on contractors to employ quality assurance experts to fairly big contractors.
- The Nigeria Institute of Building (NIOB) should set-up a site management education scheme charged with the responsibility of organizing workshops for site personnel on regular basis.
- Penalty should be attributed to any defective work caused by a worker so as to serve as a deterrent for such work by workers.
- Construction professionals within the area of the study should further their studies in order to acquire advance approach that can ensure proper quality management.
- Government should set-up an advisory committee on technical education to advice and gives assessment and progress to technical education from time to time.

- Government should sponsor construction professionals to workshop and seminars on how to improve their profession and handling of new innovations.

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