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HOUSING ECONOMY: USE OF INTERLOCKING MASONRY FOR LOW-COST STUDENT HOUSING IN NIGERIA

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Abstract
This paper examines the overriding benefits of interlocking masonry over the conventional types in housing delivery in Nigeria. The study summarises and interprets the findings from an empirical survey of students' housing projects in selected institutions in South-western Nigeria and Abuja, the capital city of Nigeria through case studies, interview schedules, and observations. Professionals like architects, engineers, quantity surveyors and building contractors involved in the designs and supervision of these projects were interviewed to obtain their views on the subject. Research variables investigated include: size of buildings; number of labourers engaged in masonry works; cost of masonry works; curing and setting time for concrete blocks; productive hours of labourers employed; and willingness to use these materials. Some selected buildings observed in the field that have been constructed using mortarless masonry construction systems are presented next. Data obtained from the field through observations and interview schedules were analysed and compared with both descriptive and inferential statistics. Analysis of results revealed the following: a high preference of professionals for the use of interlocking masonry over the conventional methods; faster construction time; labour and material cost savings with interlocking blocks. The limitations of the use of interlocking blocks for housing projects were also observed. This paper recommends the use of the accelerated dry masonry system in housing projects and concludes that interlocking masonry is a good replacement for the conventional types of construction used in student housing projects in Nigeria.

Keywords: economy, housing, conventional blocks, interlocking blocks, Nigeria

INTRODUCTION

The rising cost of housing is a concern to governments and citizens of many nations particularly for the low-income classes that constitute the nucleus of developing nations' economies. Housing programmes for the low-income earners in both public and private sectors are neglected leaving many citizens in distressed conditions. The celebrated mass housing programmes for the low-income families by the corporate and private investors (1987-to-date) are unaffordable to this class of people while government efforts in this direction have yielded little or no fruits. Fasakin (2006) opined that the facile notion of engaging profit-motivated and commercially oriented private property companies in the mass production of houses for the poor is flawed. Hence, Agbola (2005) corroborated that this approach is unworkable due to the high cost profiles of private sector-produced houses and should be dismissed. Consequently, Olotuah (2009) asserted that the result is manifested in the paucity of housing; growing numbers of over-crowded homes; low production/inefficiency of many workers; and mounting pressures on infrastructural facilities, particularly in cities, contributing to a rapidly deteriorating environment.

Similarly, Adedeji and Folorunso (2009) pointed out that the rising students intake into many schools of higher learning in Nigeria without a corresponding update of the required infrastructures for training in some of these institutions is a matter of growing concern to major stakeholders in the profession. Enrolment in Nigerian universities continues to increase due to population growth while educational resources continue to decline. This is reflected in the data presented in Table 1. Data presented in the table are obtained from Wikipedia on the students' population of some universities that have been selected as case studies.

Table 1
Students' population in selected universities vs. low percentages accommodated on the campus of each institution

S/No	Institution	Students' population	Students' population accommodated	Percentage of students accommodated on the campus
1	University of Abuja	15000	3300	22%
2	University of Lagos	40000	11 200	28%
3	Obafemi Awolowo University, Ile-Ife	30000	7680	25.6%

4	Federal University of Technology, Akure	10200	2040	20%
5	Ambrose Alli University, Ekpoma	13740	2377	17.3%

Source: Field survey, (2008)

In 1980, total students' enrolment in universities in Nigeria was 72, 425 but by1990, it had soared to 180,871, an increase of 246%. In 2007, the total enrolment of students in higher institutions in Nigeria was put at 1, 556, 285 while that of staff was 151, 785 (DLCF, 2007). Besides, the issues of under-funding and over-reliance on government funds, in the face of rising students' enrolment numbers, are a major bane to educational development in these institutions. Students' population explosions over the past 17 years have not been matched by a corresponding expansion or the construction of new residences to house these students.

An inquiry into the reasons for poor performances of many Nigerian students in academics was attributable to facilities and conditions prevalent in the universities. Principally, residences are in dire need of attention. The *Preliminary Survey of Students' Accommodation* compiled by the National Universities Commission (NUC) reveals that the provision of hostel accommodation in Nigerian universities is below 30% average of the students' population (NUC, 2008).

Indeed, it is the practice in most universities to allocate accommodation only to first and final year students. Other students either 'squat' with the lucky ones who have secured accommodation, thus exacerbating overcrowding, or seek even less adequate accommodation at high rates in the neighbourhood. Sometimes they have to travel more than 10 km to get to classes. Nowadays, mediocre educational standards, deplorable academic performance and poor moral behaviour are synonymous with the average Nigerian student. A major contributing factor to this situation is the inadequacy of student accommodation, although other infrastructure deficiencies bear equal blame.

Some entrepreneurs have taken advantage of the acute hostel shortage. Buildings within the vicinity of university campuses are either being renovated or constructed to accommodate students. Yet such accommodation lacks the basic atmosphere requisite for achieving an effective, value-adding university education. Besides, they are expensive, and do not provide basic amenities, e.g. students spend a considerable amount of time fetching water; an unwelcome distraction, when they should be concentrating on their studies. Rent paid can be as high as 55 000 naira ($343.75) per student per year (Wikipedia, 2008).

The above pictures depict that the gap between housing needs and provisions for low-income groups and particularly student housing in Nigeria is widening due to undeveloped local technology, lack of industrialised methods of housing construction (Olusanya, 2003) and untapped indigenous building materials (Arayela, 2004). Other causative factors include capital-intensive technology in production of local building materials (Adedeji, 2010); lack of commitment to increase housing stock substantially; poverty and poor living conditions; low per-capita income (Nkwogu, 2001); some restrictive government rules and regulations coupled with high building standards inherited from the Western world; and high construction costs (Wahab, 2006).

Apart from the dearth of general housing, which is due to many factors, the conventional methods of using wet masonry in construction of buildings is plagued with enormous waste, which can be avoided with intelligent applications. The use of plastering mortar for coating walls in masonry works further adds significant cost to the total cost of a building, which is already high for low-income earners. A more rational construction process can be implemented with the introduction of technologies that will allow the elimination of mortar; will reduce labour costs; and will shorten the period of time taken to complete the structure. Adedeji (2007) asserted that this new initiative, which is possible through the use of interlocking masonry, has the advantage of saving time and labour, reducing cost and wastages, thus enhancing sustainable and accelerated housing delivery.

ORIGIN AND TYPES OF INTERLOCKING BLOCKS

The construction industry is acknowledging the strong need to accelerate the masonry construction process, as the traditional method is labour intensive, and hence slower, due to the presence of a large number of mortar joints. Early attempts have been made to increase the size of masonry units (blocks instead of bricks), thereby reducing the number of mortar joints. Anand and Ramamurthy (2003) pointed out the need for further acceleration in the rate of construction occasioned by the elimination of bedding mortar and thereby leading to the development of non-conventional methods of masonry construction techniques, one that adopted special interlocking blocks. Interlocking blocks differ from conventional blocks in that the units are assembled together using geometrical features incorporated in the unit without the aid of mortar.

Varied interlocking blocks developed for use include the Sparlock system, the Meccano system, the Sparfil system, the Haener system, and the solid interlocking blocks which are an improvement over the traditional adobe bricks that have been prevalent in the 20th century in some African countries (Anand and Ramamurthy, 2003). Most of the commercially available interlocking blocks vary in geometrical shapes, materials, dimensional characteristics and invariably are proprietary systems. These can be categorised as blocks, which ensure complete (vertical and horizontal) or only partial (vertical) interlocking. To enhance the lateral resistance, plain or reinforced grouting as well as surface bonding (with structural grade fibre glass and resin) is adopted. The dimensional details and isometric are shown below:

a. Structurally efficient hollow concrete blocks
b. Hollow interlocking concrete blocks
c. Solid concrete interlocking blocks

Two promising interlocking blocks designated as the H-Block (modified hollow interlocking block) and the WHD block were developed at Drexel University, Philadelphia, PA, USA (Harris et al., 1992). Also, solid-interlocking blocks were first developed in the USA (1991) and hollow-interlocking block systems were developed as part of the efforts towards improving productivity of conventional and interlocking masonry (Anand and Ramamurthy, 2000).

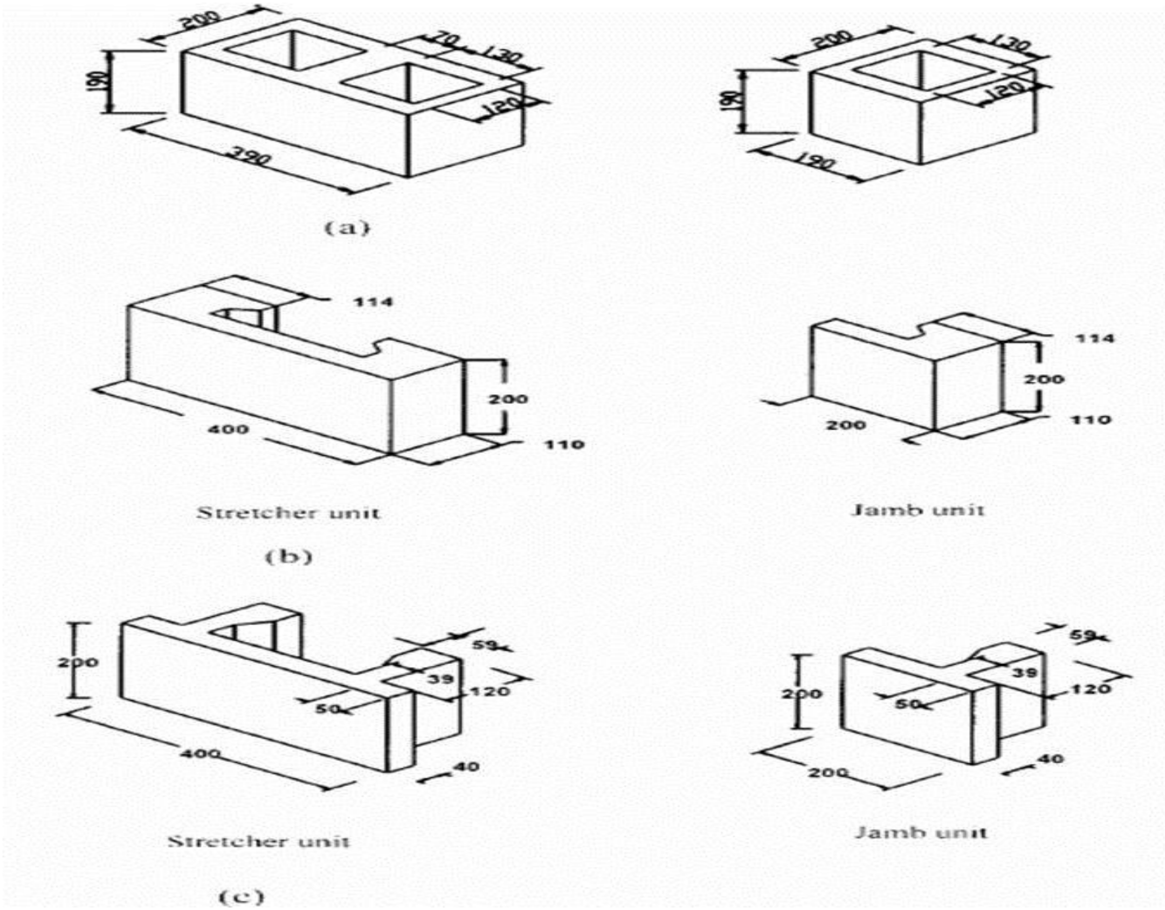

Figure 1: Dimensional details of masonry units (Source: Anand and Ramamurthy, 2003)

The solid interlocking block of laterite composition, stabilised with cement (Figure 2) was developed by the Nigerian Building and Road Research Institute, NBRRI (Adedeji, 2007). The main aim of this development was, in the first place, to equal or exceed the structural performance of conventional masonry systems, and secondly, to provide a more economical and rational solution for the masonry system, thus, leading to more competitive designs.

Figure 2: Curing and stacking of interlocking blocks (Source: Researcher's field survey, 2007)

Advantages of interlocking blocks

The development of interlocking blocks (solid interlocking laterite blocks) shows some merits over the conventional types. First, substantial cost savings can be achieved due to elimination of bedding mortar in the superstructure (except in ring beams and in high gables), thereby reducing workmanship. In this system freely-available subsoil is the main raw material and the blocks do not require costly burning; transport costs are minimised since production of Hydraform blocks takes place on site in hydraulic block machines, available from Hydraform International (Pty) Ltd., headquartered in Johannesburg, South Africa. In addition, speed of construction is a valuable feature of the system, which is much faster than other building methods. A mason can lay up to 800 Hydraform blocks (21 m^2 of walling) per day. Moreover, owing to laterite composition of the material, it is environmentally friendly as blocks are produced under high compression from subsoil, without the need for the fuel-wood used to burn bricks, hence the process is sustainable. Sustainable building materials are environmentally responsible because their impacts are considered over the complete lifetime of the products. Such materials should not constitute environmental and human health risks. Other criteria for selection include rational use of natural resources; energy efficiency; elimination or reduction of generated waste; low toxicity; water conservation and affordability (Calkins, 2009). Moreover, simplicity exemplifies the use of the material. Both the production of blocks and the erection of walls are simple processes; relatively unskilled labour may be used to carry out both processes, operating under Hydraform-trained supervision. Excellent thermal capacity (the ability to absorb and hold heat) is one of the main features of these Hydraform blocks, as they 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 subsoil found at individual sites) are also possible with the use of the material. The interior walls may or may not be plastered, painted or sealed.

RESEARCH METHODOLOGY

The data presented in this report were obtained from research conducted on materials characteristic of students' housing and the building technology used in selected institutions in Nigeria. Major materials investigated were interlocking blocks and sandcrete blocks used for construction of housing projects. Twenty housing schemes in Nigeria, including student residences on some university campuses that had been constructed with the interlocking blocks, were selected as case studies and compared with other similar projects constructed with conventional sandcrete blocks. Some of the hostels include Citec hostel at the University of Abuja; Fajuyi hall (extension) at the Obafemi Awolowo University (OAU), Ile-Ife; Utility hostel at the University of Lagos, Lagos; hostels for male students at Ambrose Ali University (AAU), Ekpoma and Abiola and Jibowu hostels at the Federal University of Technology, Akure (FUTA), among others.

The main research instruments for data collection were interview schedules and observations from selected case studies. The interview schedule, designed to investigate 25 variables on housing materials, structured in question form and written in English, was targeted to elicit responses from clients and professionals in the building industry on the use of these materials. The addresses of these professionals were obtained from the Physical Planning Unit of their respective institutions. The selected professionals (architects, engineers, quantity surveyors and builders) commissioned by these institutions to design and supervise the construction of these projects, presented their opinions on the subject. Research assistants, who had earlier been trained by the author, administered the research instruments.

The interview schedule collected information on name and addresses of projects; sizes of buildings in square metres; storey heights of buildings; types of materials used; availability of materials; cost of materials for walling; proficiency of labour in handling materials; number of labourers engaged in masonry operations; number of hours expended on masonry works; amount paid to a labourers on masonry works; and estimated man-hours required for completion of the masonry works for each of the projects. Projects covered by these interviews were housing projects constructed with interlocking blocks within the past three years and costsrangingbetweenUS$553 andUS$2340.

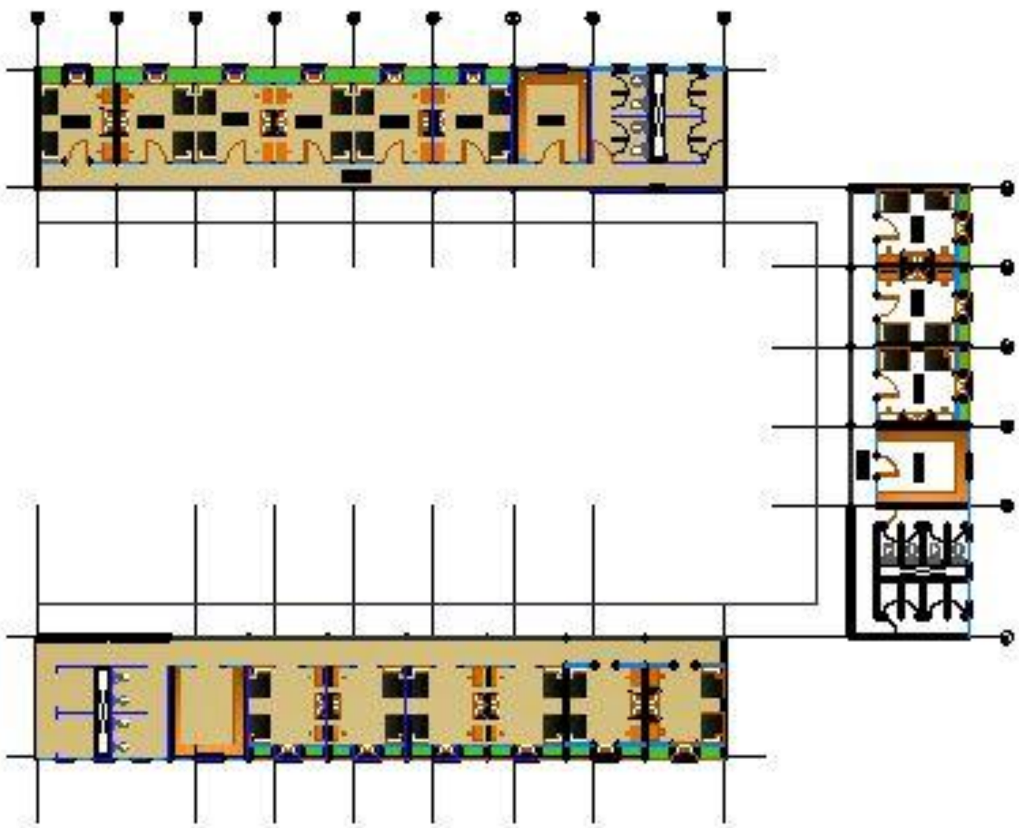

Figure 3: Plan of Citec Hostel, University of Abuja, Nigeria (Source: Researcher's sketch, 2010)

While measurements of these drawings together with cost estimates were taken from the architectural drawings, cost estimates of masonry works of these buildings were based on data obtained from the field for interlocking blocks and compared with cost estimates of the same building using the conventional masonry walls. All the projects were aimed at minimising the cost of construction and accelerating the setting time for masonry works.

FINDINGS AND DISCUSSION OF RESULTS

In this section, data from the field on the 20 sampled buildings were estimated, analysed and discussed as shown below. Results of the two materials were further compared and the results are shown in Table 2.

Cost estimates of interlocking/Hydraform blocks

4MPa machine requires 1:20 ratio = 1 bag of cement with 10 wheelbarrows = 75 blocks

$1m^3$ of soil = 105 blocks

10 ℓ of diesel = 1300 blocks = 1100

A team of 7 men can produce ± 1 500 blocks per 8 h shift

A block-layer can lay 800 blocks per day = 21 m^2 of walling

Going by the size 220mm x 115mm x 240mm

3.5 m^3 of soil	=	368 blocks	=	1 labourer = $10
5 bags of cement @ $12			=	$60
Labour in moulding		368 blocks	=	$10
Diesel used	=	1.03 ℓ/ block	=	$2.55
Total			=	$82.55
Cost/block	=	82.55/368	=	$0.22

Cost/m² of Hydraform blocks

3300mm x 4000mm	=	13.2 m^2 or 528 blocks
528 blocks @ $0.22	=	$116.16
2 unskilled labourers laying the blocks	=	$20.00

$$\text{Cost/m}^2 = \frac{\$136.16}{13.2m^2}$$

$$= \underline{\mathbf{\$10.32/m^2}}$$

Cost estimates of conventional blocks

132 blocks @ 0.93	=	\$123.20
Labour in laying	=	\$30.00
Mortar for jointing and bedding	=	\$31.00
Plastering	=	\$54.00
Painting	=	\$52.00
Cost/m^2	=	\$290.20/13.2 m^2
	=	**\$21.98/m^2**
Cost savings	=	**\$(21.98 -10.32) = \$11.66**
% Cost savings	=	**53.07%**

Estimates of sampled projects

Masonry type (Interlocking A)

Area of building = 143m^2, and productive hours = 6.5m^2/h

143m^2 @ 6.5m^2/h of 1mason + 1 labourer

Number of man-hours = 143/6.5h = 22 man-hours for 1 mason + 1 labourer

Number of days = 22/8 of 1 mason + 1 labourer = 2.75 d

If the cost of 1 mason + 1 labourer = \$16.00 per day, then

Labour cost for 2.75 d = 2.75 x \$16 = \$44.00, and

Actual cost = **\$44.00**

Masonry type (Conventional B)

Area = 143m^2, and productive hours = 1.5m^2/h

143m^2@ 1.55m^2/h of 1mason + 1 labourer

Number of man-hours = 143/1.55h = 92.26 man-hours for 1 mason + 1 labourer

Number of days = 92.26/8 of 1 mason + 1 labourer = 11.53 d

If the cost of 1 mason + 1 labourer = \$16.00 per day, then

Labour cost for 23 d = 11.53 x \$16.00 = \$184.48, and

Actual cost = **$184.48**

Cost savings on Building A over Building B = $184.48 – $44.00 = **$140.48**

% of cost saving = 140.48/184.48 = 0.7615

Reduction in cost (percentage saving) = **76.15%**

Block setting time:

Conventional type

Number of blocks = 143 x 10 = 1430 blocks

1 mason + 1 labourer = 11.53 d

Interlocking type

Number of blocks = 143 x 20 = 2860 blocks

1 mason + 1 labourer = 2.88 d

Time saving using interlocking blocks = 11.53 – 2.88 (d) = 8.65 d

% of time saving = 8.65/11.53= 75.02% reduction in time (percentage saving)

Similar calculations were carried out in respect of the other selected buildings.

Comparative analysis of cost of masonries of selected projects

Data were obtained on the twenty (20) selected studenthostels constructed with interlocking blocks as shown in Table 2. These students' housing schemes are owned by federal and state governments. The selected students' hostels at the University of Abuja, and the Federal University of Technology, Akure (FUTA), among others, constructed with the interlocking blocks, were selected as case studies and compared with other similar projects constructed with conventional sandcrete blocks in these institutions.

Table 2

Comparison of selected data from executed project sites

			Dry masonry			Wet masonry		
S/N	**Area (m^2)**	**Rate ($)**	**Cost($) (in 1000)**	**Labour(No per gang)**	**Pro. Hr. m^2/h**	**Cost($) (in1000)**	**Labour (No per gang)**	**Pro. Hr. m^2/h**
1.	143	16.00	0.553	3	6.5	1.383	12	1.55
2.	384	20.00	1.664	8	6.0	3.712	30	1.40
3.	292	20.00	1.265	5	6.7	2.823	25	1.45
4.	286	16.00	1.096	6	6.0	2.668	23	1.55
5.	184	14.60	0.797	4	6.0	1.779	16	1.47
6.	248	18.60	1.074	5	5.8	1.731	19	1.52
7.	175	16.00	0.758	3	6.8	1.692	14	1.62
8.	352	20.00	1.525	7	6.6	3.403	28	1.60
9.	164	20.00	0.710	4	5.8	1.585	12	1.71
10.	420	2000	1.820	8	6.4	4.060	30	1.75
11.	165	16.60	0.715	3	6.5	1.595	12	1.42
12.	452	21.30	1.958	9	5.6	4.369	32	1.65
13.	354	18.60	1.534	7	6.4	3.422	30	1.50
14.	235	18.00	1.018	6	5.0	2.272	17	1.78
15.	259	16.60	1.122	6	5.2	2.504	20	1.64
16.	540	21.30	2.340	10	6.8	5.220	21	1.65
17.	484	18.60	2.097	10	6.0	4.679	36	1.68
18.	292	2000	1.698	7	6.8	3.789	29	1.70
19.	420	2000	1.820	8	7.0	4.060	31	1.72
20.	154	16.00	0.667	3	6.5	1.489	12	1.64

Source: Field Survey, (2010)

Variables investigated included sizes (area) of buildings in square metres, rate paid to a gang of labourers, labour engaged (number per gang), productive hour of masonry operation and the cost of masonry works for the materials. These variables were compared with similar projects constructed with conventional sandcrete blocks under similar conditions.

From Table 2, sizes of buildings, rates paid to a gang of labourers on a particular project are the same. In the case of Project No.1 with a masonry size of 143 m^2 (Table 2), it took 1 mason and 1 helper almost 3 d to erect the masonry work, while 1 mason and 1 helper will require 11.53 d to complete a similar operation using sandcrete blocks. It can be observed that cost savings of masonry works using interlocking blocks is $830 or 60% of cost of using conventional sandcrete blocks for the same project. Besides, while fewer men were engaged in carrying out the masonry operation, the productive man-hours observed are much higher (4: 1) with the use of interlocking blocks as compared with sandcrete blocks. Similar results were obtained for other projects given in Table 2.

Bungalows designed with modular coordination formed the hostel accommodation for students constructed by the University of Abuja. Sub-structures of buildings were of conventional strip foundations up to the floor slab. In superstructures, walls were load-bearing, supported with frames of columns and beams. The cost advantages of using interlocking blocks were achieved due to the elimination of indirect and non-contributory operations, which were more pronounced in conventional masonry, as they were unnecessary for its construction.

Figure 4: Solid interlocking blocks used for construction of a housing unit at one the selected sites (Source: Field survey, 2010)

This further corroborates an observation made by Anand and Ramamurthy (2003) on a study carried out to compare different types of masonry works, where a crew of one person achieved the productivity of (4.1 m^2/h) with the use of hollow-interlocking blocks.

Limitations of interlocking blocks

In Nigeria, masonry works of housing projects are mostly constructed with sandcrete blocks, which are very popular in the building market. Interlocking blocks are used on request, as there is no mass production; hence the material is not commonly available in the market. This makes the production costs of interlocking blocks marginally higher than that of conventional blocks. Besides, elimination of bedding mortar requires stringent dimensional tolerance for the blocks to ensure uniform load transfer between layers, while specially shaped blocks are required for the jamb and corner units. Early planning and careful detailing is therefore essential. Systems that do not have a complete geometric interlocking mechanism require external bracing during construction. Holes that can allow water, ants and reptiles into the building are often observed at corners and intersections, though these can be filled up with mortar.

RECOMMENDATIONS AND CONCLUSION

The paper reviewed a subjective appraisal of the success and failure of the application of interlocking masonry for student housing at universities in Nigeria. Although the study revealed unparalleled advantages of interlocking-block masonry in terms of short time of operation, lesser labour and reduced cost of construction, its usage in the construction of houses in Nigeria is still very low. This is partly due to the low level of awareness on the part of professionals and the public coupled with its non-availability in the market. In view of this, public agencies and stakeholders in the building industry should give interlocking-block masonry wider publicity and ensure mass production of the materials to make it available in the market for users. Interlocking-block masonry should be used in public housing projects to demonstrate government's sincerity and to create awareness within the Nigerian population. More research studies should be carried out on the application of the materials for housing projects in order to improve on the weaknesses observed in its usage.

Analysis of comparative advantages between interlocking-block masonry and conventional-block masonry showed that interlocking-blocks as an alternative masonry material are suitable for construction of housing units and are cheaper than the conventional blocks. The solid interlocking-block masonry system could become a potential alternative to mortar-bedded masonry as it accelerates the construction process and also exhibits better structural performance. All these strategies will go a long way to ameliorate the problem of housing finance and materials for low-cost institutional housing in Nigeria.

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