

Interlocking Masonry: Panacea for Sustainable Low-cost Housing in Nigeria

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Abstract: This comparative study on masonry works examines the potentials of interlocking masonry over the conventional masonry work. It seeks to highlight the merits of interlocking blocks as a better alternative towards achieving a sustainable low-income housing in Nigeria. The study investigates 20 randomly selected building projects in 4 out of the 6 geo-political zones in Nigeria as case studies. Data for the study were collected through observations and interview schedules administered to practicing professionals in the building industry (Architects, Engineers, Quantity Surveyors, Builders and Contractors) from selected cities in Nigeria. Variables investigated include: masonry setting time, gangs of labour engaged together cost with a view to measure time, labour and cost expended on the 2 types of masonries used in these projects. Results from the survey were analysed in collaboration with the Quantity Surveying Department, Federal University of Technology, Akure. Findings from the field signifies shorter time of construction, reduced number of labour and cost of construction expended if interlocking blocks are used in housing construction as compared with the use of conventional blocks. The study further recommends that the material should be used as a replacement to conventional types in construction of low-cost housing in Nigeria.

Key words: Conventional, housing, interlocking masonry, low-cost, sustainable

INTRODUCTION

Housing industry is one of the most important sectors of the Nigerian economy. As a basic human need, that comes after air, water, food and clothing, it is necessary for human privacy, comfort and satisfaction. Housing is an essential indicator of national, economic, historical, cultural and technological development of any society and a social desideratum with a universal appeal. Housing is a basic human requirement affecting the largest number of people world wide. The building Industry accounts for nearly half of the GNP of most nations, Housing shortages in many developing countries have stimulated efforts to develop construction methods that use cheap and durable local materials. Limited research studies carried out in this direction on accelerated mortar-less masonry are concentrated on some foreign nations of the world except that of some experimental works on industrialized method of housing (Olusanya, 1996), cost efficient housing (Olusanya, 2001) together with the recent innovation and development of interlocking block making machine developed by the Nigerian Building and Road Research Institute (NBRRI), which is meant to be launched in every local government in Nigeria. In view of the above, this study therefore, intends to explore the option of dry construction for masonry works applicable to all types of blocks in use that will eliminate wastages in terms of materials, time and

cost associated with conventional construction methods in Nigeria. It seeks to recommend the use of interlocking blocks as alternative and cost-efficient masonry towards reducing cost and enhancing sustainability in housing, thus, encouraging standardisation of building materials in line with the current global campaign of International Standards Organisation (ISO) on building materials.

Housing problems in Nigeria: The problems of housing shortage grows deeper daily in many developing nations including Nigeria. Conceivably, a major trait of housing crisis notable in urban centres in most developing nations as observed by Ademiluyi and Solanke (1997) is that of inadequate supply relative to demand. Using various assumptions of urbanization rates, Olotuah (2000), estimated the following figures as summarised in Table 1.

Unfortunately, shortage of housing stock both in number and quality virtually abounds in every country particularly in the developing and third world countries, but this shortage is more acute in the urban centres. Omojinmi (2000) observed that people that sleep in indecent houses in urban Nigeria are more than people who sleep in decent houses. Thus, it is assertive to say that there is inadequacy of housing stock to cope with the ever-increasing population and available housing facilities in Nigeria (Arayela, 2002). The causes of this dearth in housing stock are numerous and also vary from country to country. But one cause, which centres on high

Table 1: Estimated housing need between the periods of 1990-2020

Income group	1990	2000	2020
Low-income	8,413,980	14,372,293	39,989,286
Medium-income	7,770,005	13,273,291	33,573,900
High-income	7,624,230	12,419,068	28,548,633

Source: Olotuah (2000)

construction cost is found to be present in all countries, albeit in varying degrees of exacerbation.

The intractable housing problems in Nigeria, particularly among the low-income groups addressed through many research efforts and government initiatives in finding solutions to them are yet to yield remarkable positive results. Some of the past efforts include subsidies as finance mechanism (Agbola, 1990), relevance of indigenous architecture in providing shelters for the poor in Nigeria (Suleman, 1995), housing the urban poor in an emergent state capital (Olotuah, 2000), the extensive works of Arayela (1995), on hitherto abandoned traditional building materials. Emerging dimensions increasing housing stock at reduced cost in Nigeria (Arayela, 2002), panacea for increasing housing stock at reduced cost in Nigeria (Arayela, 2003) towards a sustainable housing programme. The recurring problem of inadequate housing supply and urban environmental degradation in Nigeria (Arayela, 2004), lack of commitment to increase housing stock substantially, poverty, poor living conditions and low per capital income for the low-income (Nkogwu, 2001) together with previous governments attempts at increasing housing stock through direct involvement, there is still the need to explore deeper in the area of technology towards saving cost and time, to enhance better productivity in the construction industry. But, Olusanya (2001) attributes housing problems confronting Nigeria over the years to have acquired such proportions that threaten to overwhelm and undermine the very basic fabric of the urban society. It goes beyond the problem of materials for construction but as part of the larger problem of undeveloped (i.e., inefficient, unproductive) economy. Olusanya (2001) argued that the tendency to see the problem mainly in terms of the high cost of local raw materials substitution and or development of cheap alternative with the intention of reducing the cost of housing production to affordable level will be a simplistic view of what in reality is dependent upon a complex web of interdependent variables. Housing problems must thus be perceived in the larger context of industrial productivity rooted in the basic principle of development economics. Olusanya (1996) earlier submitted that there is the need for industrial capability for cost-efficient mass housing for meaningful housing delivery to be achieved. That the individualistic approach to housing delivery will never proffer solutions to the problem as the cost of

housing itself must be brought within the means of a significant segment of the working population if the capital available for mortgage financing is to have any meaningful impact. Realizing that all the conventional housing delivery systems have failed in achieving this objective, there is the necessity to evolve a radical and efficient approach to housing production adaptable to our current level of technological development.

Low-income class and private developers: National housing policy defined the low income group as all employees and self employed persons whose annual income as at year 2003 is ₦100,000:00 and below (i.e., the equivalent of salary grade level of 01-06 within the civil service). Interestingly, the national minimum wage is ₦44,000.00 per annum. Accordingly, the current GNDP per capita, at about US \$390, is below the level at independence 45 ago. About 57% of the Nigerian population now falls below the poverty line, which is on the average of US \$1 per day (Wahab, 2006). In reality, most employees, who work outside the public sector or outside the organized private sector as well as many self-employed Nigerians earn well below the national minimum wage. This, by implication indicates that about 70% of Nigerians fall into this category, which also forms the nucleus of the nation's economy.

The policy among others recommended strategies for improving, the housing situation for the low-income groups. These include the involvement of private and public massive investment in housing provision; encourage the establishment of cooperative societies for building construction and materials distribution and the provision of incentives by the federal government to financial and mortgage institutions for efficient financing of low-income housing. The current trend of development in the country where, private developers engage in commercial housing affordable for the few privileged ones in the society is mainly for profit making and not for the masses. Since, many of these developers operate on short-term loans, which must be recouped within a short period, the cost of such houses is extremely high and unaffordable to the low-income groups that are in need of them. The laudable housing policy of Obasanjo's regime in 1976, in which private sectors were compelled to build accommodation for their staff, thereby easing transportation and work efficiency should be reappraised and revisited.

Concept of sustainable development: The united nations conference on environment and development-the earth summit held in Rio de Janeiro in 1992, created an international framework for the sustainable development

of human settlements. In the conference, environmental issues and the natural environment became important guidelines for the realisation of adequate shelter in the century. Prior to Rio de Janeiro international awareness, the techniques of handling the relationship between ecology and the built environment had already become topical among governments and professionals. Architects, Planners, Environmentalists and Engineers were sensitised on issues such as energy consumption, use of environmental friendly materials and design concepts that reduce environmental impact. Besides, HABITAT (1996), the united nations conference on human settlements held at Istanbul in 1996 addressed the issues of sustainable human settlement development in an urbanising world focusing on issues such as human settlements that ensure productive life in harmony with nature, environmental protection, the protection of the world's natural resources, through limiting human impact on the natural environment among others. Thus, a sustainable development is that development, which while proffering solutions for the present needs will not jeopardise the ability of future generations to meet their needs. Thus, Maggie (1997) opined that designers response to these new demands, fall into two distinct approaches:

- The use of environmentally degradable construction materials such as earth, thatch and turf and the application of traditional and vernacular methods, which are in consonance with these materials or the use of organic forms and buildings with organic appearances that stimulate natural forms.
- High technology response such as the use of modern technology and materials that protect and conserve energy, recycling of waste materials in design of buildings and production of intelligent buildings that respond appropriately to environmental factors and forces.

The economic, practical and ecological fits of new constructive system are factors that come to contribute to the idea of sustainability. New masonry approaches for raw material stocks and their production make possible the decrease of costs associated to the quality growth, particularly on the housing segment (Gallo *et al.*, 2002). Sustainability in planning and architecture has become a factor in building as economic-ecological capital can no longer be ignored in the calculation of building cost to the society. The environment must no longer be ignored, but the society is required to reinvest in ecology through renewable technologies to make good depredation resulting from adverse environmental impact of buildings and structures (Ogunsote and Ogunsote, 2002; Sa'ad, 1998).

A sustainable society restores, preserves and enhances nature and culture for the benefit of all humans, present and future. A diverse and healthy environment is intrinsically valuable and essential to a healthy society. Buildings and the built environment play a major role in the human impact on the natural environment and on the quality of life. Sustainable design integrates the consideration all of resources including energy efficiency, comfortable residential buildings and materials, ecologically and socially sensitive land use and aesthetic sensitivity that inspires firms and ennobles. Sustainable design can significantly reduce adverse human impacts on the natural environment, while simultaneously improving quality of life and economic well-being.

Types and strength of interlocking blocks: Most of the commercially, available interlocking blocks vary in geometrical shapes, materials, dimensional characteristics and invariably are proprietary systems. These can be categorized 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 in Fig. 1.

- Structural efficient hollow block.
- Solid interlocking block.
- Hollow interlocking block.

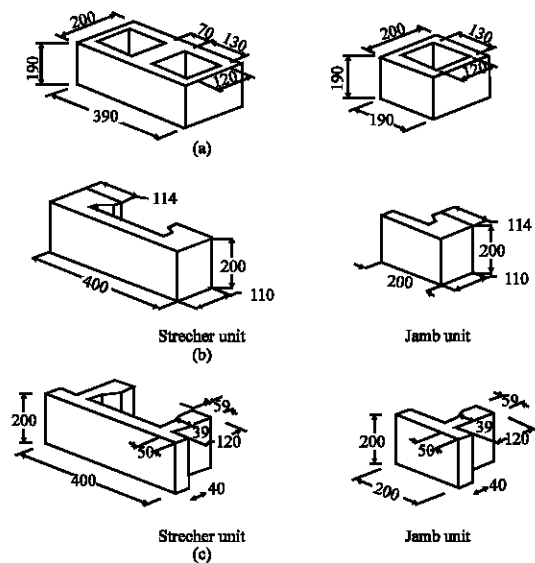


Fig. 1: Dimensional details of masonry units. Source: Anand and Ramamurthy (2003)



Plate 1: Stacked solid interlocking blocks in obasarjo's housing estate, Ado-Ekiti. Source: Field Survey (2007)



Plate 2: Solid interlocking blocks used in construction of analytical and materials laboratory, NBRRI, Ota, Ogun State Nigeria. Source: Field Survey (2007)

Advantages of interlocking blocks: The development of interlocking blocks shows some overriding merits over the conventional types. Elimination of bedding mortar accelerates construction, thereby reducing cost, variation due to workmanship and moisture penetration. The absence of bedding mortar also eliminates the biaxial lateral tensile stresses in masonry units, which initiate early splitting at a lower stress level than its compressive strength, present in conventional masonry subjected to axial compression.

Interlocking blocks produced with stabilised laterite soil have been tested to be bullet proof, of thermal and fire resistant, suitability of use, of very good appearance and can be handled easily by unskilled labour. Interlocking mortar-less is a break through walling solution using simplified technology, which challenges the present day practices from their very core. These walling materials have such characteristic, which include easy manufacturing, easy assembly, very cost-effective, low maintenance and unmatched aesthetics. In 2002, the NBRRI developed a solid interlocking block machine for the production interlocking blocks and show-cased it in every local government in Nigeria in order to create awareness and ensure public patronage. Examples of such blocks produced by the machine in shown in Plate 1 and 2.

Limitations of interlocking blocks: Elimination of bedding mortar requires stringent dimensional tolerance for the blocks to ensure uniform load transfer between layers. Manufacturing costs of interlocking blocks are marginally higher and specially shaped blocks are required for the jamb and corner units. Early planning and careful detailing is essential. Systems that do not have a complete geometric interlocking mechanism require external bracing during construction.

MATERIALS AND METHODS

This research was carried out in four randomly selected geo-political zones out of the six existing in Nigeria. A multi-stage sampling technique was adopted in selecting the zones and the cities. The stages of the multi-stage sampling technique employed were; adoption of the original 6 geo-political zones and random selection of 4 zones out of the 6 zones; random selection of one state per zone and 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). Two sets of data were collected for this study.

Data for the research were collected with the use of interview schedules, observations, photo prints and through visits to construction sites, research institutes and institutions involved in the use of Interlocking blocks materials within the study area. The major materials investigated were interlocking blocks and conventional sandcrete blocks. Data collected included information on size of buildings, cost, labour, rate paid per gang and productive hours from 31 selected buildings from the study area for comparative analyses with the conventional type. Photographic surveys of projects, which exhibited excellence in the use of interlocking masonry were also taken and carefully observed during the course of data collection. During the interviews, information on projects size, specification of materials used, number of labour engaged and cost of interlocking masonry, time expended for these operations and associated problems with these materials were collected.

RESULTS AND DISCUSSION

The findings presented in this research were derived directly from responses obtained from empirical survey

using questionnaires and field observations on the subject. Accordingly, comparative cost analysis of 20 samples of projects, that experimented the use of interlocking blocks were carried out for elaboration on the advantages of dry construction method, coupled with photographic surveys of relevant projects for illustrations.

Data obtained on sizes (area) of buildings, wages rate paid per day to a gang of labour in different localities, number of labour engaged and the cost of masonry works using the 2 types of blocks each for the buildings were further analysed in collaboration with the Department of Quantity Surveying of Federal University of Technology as shown in estimates of sampled Projects 1-2 and Table 2.

Estimates of sampled projects 1-2

Sampled project 1:

Masonry type (interlocking):

Area = 286 m², Productive hours 6 m² h⁻¹
 286 m² @ 6 m² h⁻¹ of 1 mason + 1 labour.
 Number of man hour = 286/6 h = 48 man hour for 1 mason + 1 labour.

Number of days = 48/8 of 1 mason + 1 labour = 6 days.

If the cost of 1 mason + 1 labour = ₦2,300 per day.

Labour cost for 6 days = 6 × ₦2,300 = ₦13,800.

Labour cost for wet masonry = ₦13,800.

Masonry types (Conventional):

Area = 286 m², Productive hours 1.5 m² h⁻¹.

286 m² @ 1.5 m² h⁻¹ of 1 mason + 1 labour.

Number of man hour = 286/1.5 h = 190.6 man hour for 1 mason + 1 labour.

Number of days = 190.6/8 of 1 mason + 1 labour = 24 days.

If the cost of 1 mason + 1 labour = ₦2,300 per day.

Labour cost for 24 days = 24 × ₦2,300 = ₦55,200.

Labour cost for wet masonry = ₦55,200.

Cost saving for building A = 55,200 - 13,800 = ₦41,400.

Percentage of cost saving = 41400/55200 = 0.75.

Percentage cost saving = 75% reduction from the cost of the conventional blocks.

Block setting time

Conventional type:

Number of blocks = 286 × 10 = 2860 blocks.

1 mason + 1 labour = 23 days.

Interlocking type:

Number of blocks = 286 × 20 = 5720 blocks.

1 mason + 1 labour = 6 days.

Time saving using interlocking blocks = 23-6 (days) = 17 days.

Percentage of time saving = 17/23 = 75% reduction in time saving.

Sampled building 2

Masonry type (interlocking):

Area = 143 m², Productive hours 6.2 m² h⁻¹.

143m² @ 6.5m² h⁻¹ of 1 mason + 1 labour.

Number of man hour = 143/6.5 h = 22 man hours for 1 mason + 1 labour.

Number of days = 22/8 of 1 mason + 1 labour = 2.75 days.

If the cost of 1 mason + 1 labour = ₦2,500:00 per day.

Labour cost for 2.75 days = 2.75 × ₦2,500 = ₦6,325:00.

Actual cost = ₦6,875:00.

Table 2: Selected data from executed project sites used for regression

Area (m ²)	Rate (₦)	Dry masonry			Wet masonry		
		Cost ₦ (in 1000)	Labour (No per gang)	Pro. Hr. m ² h ⁻¹	Cost ₦ (in 1000)	Labour (No per gang)	Pro. Hr. m ² h ⁻¹
384	3000	249.6	8	6.0	556.8	30	1.40
143	2300	83.0	3	6.5	207.4	12	1.55
292	3000	189.8	5	6.7	423.4	25	1.45
286	2300	164.4	6	6.0	400.2	23	1.55
184	2200	119.6	4	6.0	266.8	16	1.47
248	2800	161.2	5	5.8	259.6	19	1.52
175	2400	113.8	3	6.8	253.8	14	1.62
352	3000	228.8	7	6.6	510.4	28	1.60
164	3000	106.6	4	5.8	237.8	12	1.71
420	3000	273.0	8	6.4	609.0	30	1.75
165	2500	107.3	3	6.5	239.3	12	1.42
452	3200	293.8	9	5.6	655.3	32	1.65
354	2800	230.1	7	6.4	513.3	30	1.50
235	2700	152.8	6	5.0	340.8	17	1.78
259	2500	168.4	6	5.2	375.6	20	1.64
540	3200	351.0	10	6.8	783.0	21	1.65
484	2800	314.6	10	6.0	701.8	36	1.68
292	3000	254.8	7	6.8	568.4	29	1.70
420	3000	273.0	8	7.0	609.0	31	1.72
154	2400	100.1	3	6.5	223.3	12	1.64

Source: Field Survey (2007) in collaboration with department of quantity surveying, federal university of technology, Akure

Masonry types (conventional):

Area = 143 m², Productive hour 1.5 m² h⁻¹.
143m² @ 1.55 m² h⁻¹ of 1 mason + 1 labour.
Number of man hour = 143/1.55 h = 92.26 man hours for 1 mason + 1 labour.
Number of days = 92.26/8 of 1 mason + 1 labour = 2.75 days.
If the cost of 1 mason + 1 labour = ₦2,500:00 per day.
If the cost of 1 mason + 1 labour = ₦2,300 per day.
Labour cost for 23 days = 11.53 × ₦2,300 = ₦26,524.19.
Actual cost = ₦26,524.19.
Cost saving for building B = 26,524.19 - 6,875 = ₦19,649.19.
Percentage of cost saving = 20,199.19/26,524.19 = 0.7408.
Percentage cost saving = 74.08% reduction from the cost of the conventional blocks.

Block setting time

Conventional type:

Number of blocks = 143 × 10 = 1430 blocks.
1 mason + 1 labour = 11.53 days.

Interlocking type:

Number of blocks = 143 × 20 = 2860 blocks.
1 mason + 1 labour = 2.88 days.
Time saving using interlocking blocks = 11.53 - 2.75 (days) = 8.78 days
Percentage of time saving = 8.78/11.53 = 15% reduction in time saving.
Similar calculations were carried out in respect of the other selected buildings.

Source: Field survey in collaboration with Department of Quantity Surveying, Federal University of Technology, Akure.

Respondents opinions on comparative cost of Interlocking blocks with conventional sandcrete blocks were obtained from the 4 selected locations. Prices of interlocking blocks and conventional blocks were also obtained from the market. While conventional sandcrete blocks (225 × 225 × 450) sells at ₦120.00, interlocking block (225 × 112 × 225) mm sells at ₦25.00 as at January 2007. Taking into consideration that conventional blocks requires the use of mortar for the laying of the blocks and associated non-contributory activities that affects its cost and the net output, these activities together with the use of mortar are eliminated in the operation of interlocking blocks. Though, 4 units of interlocking blocks will combine together 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. 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. 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.

Table 2 shows the summary of the comparative values of the estimates of selected data for both interlocking and conventional blocks prepared in conjunction with the Department of Quantity Surveying, Federal University of Technology, Akure.

The analysis presented in estimates of sampled Projects 1-2 and Table 2 shows that though the buildings were of the same sizes with equal rates paid to workers, the labour gang required for the conventional blocks were more in number compared to that of the interlocking blocks. Consequently, the cost of operation of conventional blocks is significantly higher than the recommended material. While, the productive hour of dry masonry is higher, the cost and number of servers involved in the masonry operations reduced significantly as compared with that of conventional masonry.

- It was observed that interlocking masonry have shorter period of setting.
- With the elimination of mortar from the stacking operation of interlocking masonry, together with the contributory activities associated with conventional masonry, labour is reduced and the productive hour is increased considerably in the former.
- There is overall reduction in cost of masonry works (65% lesser on the average) with the use of interlocking blocks for construction of a housing unit as compared with the use conventional sandcrete blocks for the same project.

In general, it was also observed that while a gang of 1 mason + 1 labour could achieve a productive hours 6.5 m² h⁻¹ with interlocking masonry, a gang of 1 mason + 1 labour could only achieve a productive hours 1.55 m² h⁻¹ with conventional masonry. These results were not significantly different from each other from one location to the other.

**RECOMMENDATIONS AND
POLICY STATEMENTS**

Accelerated dry masonry system is advocated for in housing projects as an alternative method cheaper than the conventional wet type. It is also faster in operation

with a potential of saving of over 65% of time and cost of the masonry work. It reduces wastage of materials and number of labour required for operation. Interlocking blocks can be produced with the same materials as used in the production of conventional blocks. Also, the application of interlocking blocks will facilitate specialisation on building materials at entrepreneurship scale. Small scale entrepreneurship production workshop should be set up on-site for production and easy replication of building components thus facilitating employment generation. This could generate employment opportunities for teeming unemployed youths in the society.

CONCLUSION

The study has explored the possibility of using interlocking blocks in housing delivery in Nigeria as a cheaper alternative to the conventional sandcrete blocks towards achieving sustainable cost-efficient housing for the low-income class of the society. Besides, interlocking blocks offer several advantages such as design flexibility, cost effectiveness, reduced construction time, environmental friendly and solution to space shortage. On the environmental end, the use of entirely non-hazardous waste material for such blocks to achieve the above results from locally abundant, readily available indigenous materials with low embodied energy counts. The solid Interlocking-block masonry system could become a potential alternative to mortar-bedded masonry as it accelerates the construction process and also exhibits higher productive hour with minimal wastages.

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