Journal of Environment and Earth Science
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online)
Vol.6, No.6, 2016

Technological Capabilities and Sustainable Housing Delivery: Case Studies from Nigeria

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Abstract
Sustainable housing is an interaction between the global concern of housing development within the carrying capacity of supporting ecosystems, and local socio-cultural and socio-economic concern which are specific to each society. Achieving sustainable housing should therefore be based on local translation and context. In developing countries such as Nigeria, key challenges to sustainable housing include access, cost/affordability, and quality. Addressing these challenges demands the exploitation of local technological capabilities. This paper looks at the concept of sustainable housing and examines this with reference to two case studies from Nigeria. The first involved the use of dry construction technology, while the second was based on wet construction. This is to bring to fore the place of building material technology and construction technology in sustainable housing delivery. The cases exposed the opportunities presented by non-complex dry and wet construction technologies in the delivery of sustainable housing. These technologies can be embraced with minimal training and can be easily transferred to the local population in order to speedily reduce the housing deficit, especially at the low-income level.
Keywords: Building materials, capabilities, dry construction, sustainable housing, technology, wet construction

1. Introduction

The challenge of providing sustainable housing in developing countries such as Nigeria, is enormous and multifaceted. One dimension deals with the process for speedy delivery of housing to the populace, while the other deals with the creation of products (housing) within the carrying capacity of supporting ecosystems.

Nigeria's Federal Ministry of Lands, Housing and Urban Development (FMLHUD, 2012), stated that Nigeria's housing deficit is estimated at about 17 million units. This, as Ashkin (2013) puts it, required an investment of about $600 billion, based on an average house price of five million naira. This is approximately equal to the value of all the oil Nigeria has pumped since independence. Similarly, Ayedun and Oluwatobi (2011) noted that only 10 per cent of Nigerians can afford to own a house either by purchase or personal construction, as compared to the 72 percent in the United States, 78 percent in the United Kingdom, 60 percent in China, 54 percent in Korea and 92 percent in Singapore. This is against the fact that the right to housing embedded in the universal declaration of human rights and major international human rights treaties such as the international covenant on economic, social and cultural rights. With this deficit however, Abuja, Nigeria's Federal Capital City, is spotted by many unoccupied houses. This is attributed to the fact that many of these houses are not affordable to majority of residents in the city. The most vulnerable in terms of lack of access to decent and affordable housing are the low-income group. To further compound the challenge, the population of this group has been on the increase due to rapid urbanization. Gilkinson and Sexton (2007) emphasized the importance of affordability as a key requirement of sustainable housing. Jiboye (2011) noted that to achieve sustainable development, housing policy should be in agreement with the existing national and socio-cultural realities of the country. According to Newton (1999), the real concern is the search for and the encouragement of methods and materials to achieve safe and durable houses that people can go on using with the skills and resources locally available to them. It is in this light that this paper examines the role of building materials and technology in the search for sustainable housing in Nigeria.

2. Technological and Sustainable Housing

Right through the ages, it is clear that the type of houses (shelter) present in a society was a reflection of the technological development of that society, and was evolved based on widely available materials, skills, and capabilities. This buttresses the fact that sustainable housing is context specific and cannot be borrowed, but must evolve, or be locally developed. Any technologies which are globally considered environmentally sustainable but cannot be executed locally and continually cannot not be adjudged sustainable in the context of housing delivery. For sustainable housing delivery, capabilities are required both in the processing, refining, and improvement of readily available and renewable building materials into more acceptable forms, and in the construction process. The search for sustainable housing in Nigeria and developing countries in general should aim at reducing import-dependence and strengthening of domestic technological capability and locally produced building materials for housing construction (Oruwari, Jev and Owei, 2002). It is in line with this that Olotuah and Bobadoye (2009: 59) defined sustainable housing provision as "the gradual, continual and replicable process of meeting the housing needs of the populace, the vast majority of who are poor and are incapable of providing adequately for themselves".

2.1 Low-Tech vs High-Tech Solutions

Low-Tech approach to sustainable architecture implies the use of non-sophisticated materials and techniques. This is achieved by innovative use or adaptation of simple regionally available indigenous, traditional, vernacular or modern materials and methods. It interacts directly with site and climate in order to minimise energy demand by initiating a dialog between indoor and outdoor environment. Bianca-Daniela (2012) noted that this approach is based on knowledge of nature and climate which has been accumulated through the ages. In contrast to this, High-Tech solutions are based on advanced modern technologies, relying on a strategy of compensation aiming to balance out inner climate conditions with intelligent building technology (Bianca-Daniela, 2012). Cody (2014) noted that there is the recurring question of which of the two approach (High-Tech or Low-Tech) is more suited to help achieve a sustainable development. This question perhaps requires no answer since sustainable design is context specific, and design problems and programs vary in context and complexity. In developing countries such as Nigeria, the major architectural challenge still remains the provision of comfortable and affordable housing. This deficit can only be overcome by harnessing the benefits of Low-tech solutions where possible.

2.2 The Role of Building Material Technology

One of the key challenge to the provision of affordable housing in Nigeria lies in the cost of building materials. This is because building materials constitute about 70 percent of total cost of buildings (Oruwari, Jev and Owei, 2002). The alternative these high-cost modern building materials lie in the harnessing of readily available materials such as earth. However, the damages caused by building material harvesting are evident in burrow pits, rock blasting sites, and, depletion of forests among others. The rapid deforestation, resulting from unsustainable uses of forest resources is one of the major sources of land degradation (Federal Government of Nigeria, FGN, 2012). This brings to fore the need for sustainability in building material sourcing. On the other hand, these crude materials require refining and improvement in order to make them acceptable. Also, building materials, from their production through their transport, installation and use to disposal, have significant, impacts on human health and the built environment. The use of building material on a site saves production cost, time, energy, environmental pollution and transportation cost. Worthy of note when discussing materials is the Life Cycle Assessment (LCA) which is the evaluation of the impacts of materials from their resourcing and production to disposal. According to Kim and Gridnon (1998) the best way of material preservation is through the usage of resources already existing in the form of building (reuse). Ashkin (2013) recommended the exploration of refined indigenous building materials and innovative building technologies for the delivery of more affordable housing in Nigeria. One of the currently most viable refined materials is the use of Compressed Earth Bricks (CEB). There is also the innovative use of the so-called "waste-to-wealth" materials in construction. One of such is the use of Polyethylene Terephthalate (PET) bottles (plastic bottles) which hitherto littered many cities in Nigeria.

According to Pierre and Alex (2013), one of the characteristics of sustainable building materials include being locally produced and sourced. Contrary to this, it is not uncommon to see many supposedly sustainable housing projects in Nigeria constructed of materials which were largely imported. These materials were adjudged sustainable based on global context with no recourse to local context. For a country which relies largely on the sale of crude oil, and is seeking diversification of its economy, with a substantial part of its populace living in poverty, economically sustainable housing should not only be affordable, but should aim at contributing maximally to local economy. This requires that effort be made at ensuring that the benefits of the entire process is as much as possible accrued to the local economy. Nigeria is endowed with abundant readily available materials that can be used for building. This includes small-scale raw material deposit, agricultural products and residues, industrial wastes, low cost and renewal sources of energy and established technologies which can readily be applied to the local production of low cost materials (Oladapo and Oni 2012). Many of these materials have low Gross Energy Requirements (GERS). These materials however require strengthening of domestic technological capability and innovativeness to translate into acceptable houses.

2.3 The Role of Construction Technology

Technological capability connotes the availability of skilled persons who have the required technical knowledge about a process (Chambua, 1996), while skills refers to the capabilities and expertise of individuals to perform a task to a predefined level of competence in a particular occupation or activity (Frogner, 2002; Leitchester, 2006). Sustainable housing delivery demands a search for available alternative technologies towards solving existing problems.

Gallopin (2003) noted that achieving sustainable design does not lie in extraordinary solutions, but the application of simple but rational solutions. This submission is very important in sustainable housing development, since housing is a basic need that is still elusive to the majority of people in developing countries. Housing projects are some of the simplest design and construction projects, and should provide opportunities for the development and empowering of local personnel. Many buildings which were constructed by foreign personnel are today experiencing challenges in their maintenance. These challenges emanate for two reasons. The first is the absence

of personnel with such skills, with the only option being to engage personnel from outside the country. The second is the fact that the foreign firms that constructed such projects made use of imported materials and components which were not locally available for the purpose of replacement. Also, while many Nigerians are unemployed, it will be ironical to appropriate a basic necessity such as housing delivery to foreign design professionals, contractors, and technicians, at the detriment of the local economy. Housing delivery programs and strategies should be developed around local capacity. Technologies which are not locally available may be considered sustainable only through a process of technology transfer and diffusion (Oruwari, Jev and Owei, 2002). It is important to be mindful that self-help and community participation is an integral part of indigenous African architecture, culture and value system (Adebayo and Adebayo, 2000), therefore, tackling the enormous housing challenge, especially in rural areas, may require the application of skills which can be transferred to the local populace to increase the speed of delivery.

2.3.1 Dry versus Wet Construction

Concrete blocks has long been by far the dominant building material in Nigeria. Construction with concrete block tends to be labour intensive and construction cycles are long, since block structures must settle before finishing work can be done. Dry construction - building constructed without conventional mortar, with industrially manufactured alternative to blocks and mortar, can address both quality and cost issues for low-cost housing. One of the recently popular dry construction technologies gaining ground in sustainable housing construction in Nigeria is the use of Compressed Earth Bricks (CEB). Pierre and Alex (2013) gave the following as the advantages of Compressed stabilized earth blocks:

- It is much cheaper than bricks.
- Use of local soil and on-site manufacturing saves on transport costs and fuel consumption, especially in remote areas with poor road infrastructure.
- Low embodied energy value of around 0.42 MJ/kg and a negligible carbon foot print.
- Earth structures have good thermal properties which save on heating and cooling costs.
- Earth blocks are fire, noise and bug resistant.
- The brick-making process can be easily taught, and the stabilizer can be used in remote areas to create earth building material.

3. Case Studies

Two cases were studied. These are Unity Housing Estate, Kuje (UHEK), Abuja, and Sabon Yelwa Housing Estate (SYHE), Kaduna State, both in Nigeria. The first case was based on largely dry construction process, while the second was of wet construction.

UHEK is situated on a 9.8-hectare land in Kuje, Abuja, Nigeria. The estate was planned for the construction of 200 housing units of two prototypes, one of two bedroom flats, and the other of three bedroom flats (Figure 1). SYHE is situated on a 17-hectare land in Sabon Yelwa village, Kaduna, State, Nigeria. The project is the product of effort of a number of collaborating non-governmental organisation (NGOs) (Figure 2).

Figure 1. Housing units at UHEK

Figure 2. Housing units at SYHE

3.1 Local Sourcing of Building Materials

The major building material used at UHEK is CEB. The others are concrete for foundation and column, steel for lintels, and clay tiles with timber structure for roofing. The material used for production of CEB, which is laterite, was available on the site, and the CEB was produced on site (Figure 3). The only negative impact here is the aftermath of the excavation which left a pit beside the site.

For SYHE, the key materials used is Polyethylene Terephthalate (PET) bottles (plastic bottles). Other materials include earth as 'infill' for the PET bottles, mud as binder, concrete for foundation, window sill, lintel, and head coarse (Figure 4). The use of concrete was minimised and constituted only about 12per cent of the plaster.

Figure 3. Stacks of CEBs at UHEK

Figure 4. Collected PET bottles at SYHE

3.2 Reduced Impact of Building Material Transportation

At UHEK, the fact that the major material (CEB) was produced on site reduced the environmental impact attributable to building material transportation. The only transportation of the bricks was from the point of manufacture to the plots, and the impact of this is minimal.

At SYHE, the transportation was a bit more. This is due to the fact that the PET bottles were collected

from hotels and bars in neighbouring communities, and needed to be transported. However, this is still minimal. Also, the other major material is earth, which was readily available on site.

3.3 Reduced Embodied Energy

The production of earth-based materials consumes much less energy and pollutes much less than other alternatives such as concrete blocks and fired bricks. The CEBs used at UHEK were not burnt or fired. This reduces the embodied energy of the major building material for the housing estate. CEBs are compressed to achieve the required strength after the process of curing was effectively carried out. Similarly, SYHE made use of waste materials (PET bottles) and earth. This also has low embodied energy since none of these were manufactured and no energy was expended.

3.4 Favourable Thermal Properties

Thermal performance of building materials is critical to achieving thermal comfort in buildings. As a building material, CEBs has high thermal capacity, thereby making it a good material for building in hot dry climates. This is of great benefit in Abuja, where UHEK is located. For SYHE, though PET bottles were used, mud remained the major mass of the building thus the thermal properties are similar to that of UHEK.

3.5 Financial Viability

The fact that the CEBs and mud-filled PET bottles were produced locally, with readily available resource and semi-skilled labour, and little transportation, makes them cost effective. This is in comparison to the cost of energy needed for production of other building materials such as fired brick and concrete blocks. These materials are cheaper than fired bricks due to the fact that a lot of energy is needed to power a furnace for fired bricks. Compared to concrete block, they are also cheaper when considering the cost of cement and sharp sand used. Financially it can be concluded that the material more sustainable than most other local alternatives.

3.6 Recyclability of Building Materials

CEBs are not fired and do not undergo any change of state during their production. This makes them easily biodegradable. Also, CEBs can be reused after demolition. For mud-filled PET bottles as used in SYHE on the other hand, the mud infill returns to the earth when the building life-span expires, while the PET bottles can be recycled.

3.7 Minimal Waste and Pollution in Manufacturing Process

Little or no waste was generated in the manufacturing process of the CEBs at UHEK. This is because the production was done at the same spot where the laterite was sourced, and any surplus or spilled laterite was returned to the earth. Also, the CEB making is a non-toxic process, as compared to materials such as concrete. For the PET bottles used at SYHE, there is also no waste, since the mud was filled on site and the PET bottles were already regarded as waste but was reclaimed.

3.8 Low-Tech Construction Technology

The use of CEBs at UHEK meant that the construction process required less-skilled or semi-skilled, and the skill required can be easily transferred within shorter periods as compared with concrete block laying. This process also requires less time and energy as the CEBs only required interlocking and no placement of mortar for binding (Figure 5). This is one of the benefits of dry construction methods to sustainable housing delivery.

Fittings and fixtures were also easily incorporated in the buildings, as cutters and drills were used where necessary to create access for piping and conduit wiring. Aesthetics was a factor that was not neglected, as many would have imagined the possible outcome of brown brick walls which might be difficult or not pleasing to render. Surprisingly, proper and efficient renderings were made on already finished structures to ensure a calm and aesthetically pleasing environment.

At SYHE, the construction involved the excavation of a 400 by 400mm foundation trench. The excavated earth is used as binder and for filling the PET bottles. The houses were constructed with capped, earth-filled PET bottles, each weighing about three kilograms. The earth is mixed with little amount of water and then compacted in the plastic bottles in layers with a metal rod after which the bottles are then capped. The bottles are stacked in layers and bonded together by mud, with a complex network of strings holding each bottle by its neck, providing extra support to the structure (Figure 6). The sand filled plastic bottles are laid on either the cap facing the outside and the base facing the interior or the cap facing the interior and the base facing outside. This provided aesthetic options.

Figure 5. Dry construction using CEB

Figure 6. Wet construction using PET bottles

4. Conclusion

The adoption of foreign sustainable housing design concepts without reference to local context negates the core values of sustainability. Sustainable housing delivery in developing countries such as Nigeria should not only address the global environmental challenges, but also local priorities such as access and affordability. This can only be achieved through the improvement and refining of locally and readily available building materials, and the development of solutions based on local capabilities and skills. This will address core issues such as renewability, reduced pollution, energy issues and affordability. Both non-complex dry and wet construction technologies can be explored. This should however be based on skills which are locally available or those can be easily transferred in order to speedily reduce the housing deficit, especially at the low-income level.

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