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The Sustainability Solution of Earth as Buildings material: Case of Gbongan Rural communities in Osun State south west Nigeria

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ABSTRACT*: The sustainability of earth as building material cannot be overemphasised with proven superior performance at the specified criteria. This research addresses the analysis of the sustainability criteria present in a sample of 120 cases of traditional earth building at Gbongan rural area in Osun state Nigeria, as locally produced and sourced material, reduced transport cost and environmental impact among others. The focus group of professional especially architect and builders were organized to coordinate the study process, ensuring adequate evaluations of issues that can facilitate sustainability of earth as a building material. Their recommendations are evaluated and classified according to physical attributes of earth as sustainable building material: twelve prevailing factors facilitating sustainability of earth as building material were identified. The sustainability solution of earth as building material were discussed which include local employment opportunity for socio economic development. The paper then concludes on some sustainability strategies known with the earth over the year as productive and effective building material.*

KEYWORDS*:* earth, sustainability, socio-economic, reduced energy, low cost

INTRODUCTION

The raw earth is a material used ages as a building material; earth architecture has many benefits not only on technical terms, but on economies and environmental factors. Earth is readily available and accessible on-site requiring no transformation; it is the simplest natural material we have at our disposal, used by man in construction, with sustainability and techniques that are living testimony to history, cultures and identity (Doat, *et al*, 1991).

According to Reeves and Sims, (2006), earthen architecture is one of the oldest forms of construction. It is composed of structures made from unfired earthen materials, including adobe (or sun dried mud brick), rammed earth and a host of other earthen components. Earthen materials serve as the primary structural element in such architecture; they are also used for rendering, decoration and conservation. The traditional earth building is evidenced all over the world, in many parts of Africa, Asia and South America, earth remains a prevalent building material. The sustainability of earth as building takes advantage of the energy embodied in the fabric of that building. The energy expended in the manufacture of materials, transportation and construction of building is estimated to equal the energy necessary to heat, light and ventilate or condition the building between five and ten years (Matthew, et al, 2012, Bernard, 2003). Akinkunmi (2012), substantiate further that, sustainability favours the retention of existing building stock. Improving and maximize use of existing buildings is the cheapest and lowest-impact sustainability solution to the provision of housing presently at rural communities in Nigeria using Origbo communities as case study.

Theoretical consideration of earth as sustainable building material

Earth construction is one of the most interesting low environmental impact materials. It encompasses a wide range of materials and techniques, stemming out of strong historical tradition. Earth construction exhibits good environment characteristics and could make a significant contribution to the improved sustainability of construction and it have high potential for making earth building of high quality and durable. However, earth in its fullest sense is presently widely used in construction, as primary construction materials such as sands and bricks.

In many forms of earth construction there are potentials for on-site or near-site sourcing of adequate earth materials. This reduces to a minimum to about 1 percent of energy required by the commonly used of cement based alternatives (Becky little and Tom Morton, 2001). In the production of earth materials there are no wastes or by-products, any defective product can be recycled and re-used. Where other materials are mixed with earth, these are generally the waste products of other industrial or agricultural processes. Earth materials create minimal pollution from the selection of material stage all through the production cycle and construction process, earth materials require very low level of processing and create very little polluting waste. It is important to note that at the end of good building life span the materials can easily be re-cycled or returned to the ground.

Background of Study Area

A Gbongan rural community in Ayedade Local Government area of Osun State is a typical traditional ancient town its geographical coordinates are 7°28’0”N, 4° 21’0"E. The morphological characteristics of the area exhibits features of typical traditional Yoruba towns which are king’s palace (*afin*) and traditional king market (Oja Oba) in the front of the palace. Surrounding the king’s palace is the high concentration of traditional residential houses for the indigenous occupants and intermediate zone of contemporary face-me-i-face-you vernacular earth dwelling, whereas the outskirt consist of sparsely distributed modern single family dwelling intercepted with few traditional and vernacular houses. Gongan rural communities have undergone considerable growth in the recent time as influxes of people were necessitate by spontaneous development such as advent of tourist centre as well as corresponding increase of commercial activities. House-form pattern commonly featured at Gongan community are typical courtyard housed and vernacular dwelling built from local earth materials. Many of those houses are still in their normal natural form while some of them have been plastered with Portland cement, either total plastering or lower part of the building; indigenous thatched system of roofing has been substituted with corrugated sheet due to technological innovation and improvement over the thatch roof used in olden day.

RESEARCH METHODOLOGY

The study used focus group to engaged rural dwellers in guided interview and discussion at the rural suburbs of Nigeria (Krueger,1994). The participants are experienced local house developers from rural dwellers, the focus groups were led by research fellows, who are aided by a discussion guide developed through prior interview with earth consultants, experts in building local houses with indigenous material especially earth. The focus groups are a form quantitative researches in which purposely-selected participants in the field of study are interviewed in a group setting. Such setting increases the efficiency of interviewing and interaction among the group members, it leads to more insightful response than attained through individual interviews. Such a pattern suggests the probability of a generalized view within the population being studied.

Historical context of earth as sustainable building material.

According to focus group report an understanding of earth can bring innovative and appropriate use of earth that will enable adequate conservative and sustainability measure. Earth is the most basic building materials known to man, at the study area earth has the benefit of being easily worked, using simplest of agricultural tools for construction process and capable of fulfilling the most demanding role. Analysis from focus group shows that it has been estimated that 33 percent of the population inhabit earth buildings in a varied range of construction material and architectural typology. Each architectural typology has distinct individual performance characteristics, significance and use. A significant number of those earth building can be found in rural areas, and ancient cities of Nigeria, as vernacular residential building monuments and Obas palaces which form a rich heritage of earth building (B. Walker and C. McGregor, 1996). In addition to vernacular buildings, a broader use of earth was also found in major architectural and civic projects such as communal and town halls. From the prehistoric times there was continued use of earth either as a building material, or lubricant to move heavyweight material or waterproofing agent, decorative finish or coloring agent.

Benefits of using earth in Construction as sustainable material.

Focused group assesses the environmental benefit of using earth in construction at the study area, also highlights how this could contribute towards reaching established environmental targets. The following benefits of using earth in construction have been identified:

(a) **Sustainability.**

Earth as a constructional material has inherently good environmental characteristics and can improve sustainability of construction. The surviving earth structures in Nigeria most especially the Oba's palaces, exhibits appropriate use of local material, which has resulted in diverse and distinct cultural patterns. The maintenance of this cultural diversity and local knowledge is central to the effective sustainable development (B. Walker and C. McGregor, 1996, J. Norton, 1997).

(b) **Environmental Friendliness.**

Transportation and construction process of earth materials requires about 1 percent of the energy required by the commonly used cement-based alternatives. Furthermore, in many forms of earth construction there is the ability for on-site or near-site sourcing of materials. This reduces to barest minimum the energy used in material production (M.Westermarck, 1998).

(c) **Utilization Efficiency**

The production and construction process of the earth materials comes with little or no material wastage, nor by-products. Any defective product identified is returned to the start of the production cycle and re-used.

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(d) **Pollution minimization**

Production process of earth materials creates minimal pollution, throughout the entire cycle of production construction process and use. Earth materials require a very low level of processing and create very little pollution waste. More importantly at the end of a building life span, the earth materials can be easily by re-cycled and returned to the earth. In contrast to the more commonly used building materials that cause significant pollution. Such contemporary materials require high level of processing which often result in environmental pollution, creating waste during construction and causing environmental enduring waste at the end of building life span.

Earth as a sustainable building material.

The focus group examined that earth of different typology exhibits different characteristics that may or may not be suitable for construction. The constructional processes that will enable high quality outcome depend apparently on the properties of earth material used. Minke (2000) identified the following properties:

(a) **Strength**

Earth employed in building has an appreciable strength in compression, but it is weak in tensile strength especially when damp. When earth is used as a load bearing material, forces must be transmit within the thickness of the earth structure to the ground. Therefore the recommended thickness for monolithic load bearing earth wall is between (450mm and 900 mm). However, it is possible to construct slender wall, such as arches and vaults if the slender structure is being supported while drying out.
Furthermore the compressive strength can be increased by compaction, which of course raises the density of the structure.

(b) **Durability**

The durable nature of the earth materials for building construction is obvious from ever durable traditional earth buildings that have survived centuries of continual use.
Compaction, additives and surface coating improve the durability of earthen material reducing the effect of tendencies of abrasion. Earth building in a local damp environment need to be protected from prolonged water contact. This can be achieved by placing the walls out of reach of ground water and splashing by protecting the wall from rain splashing with an adequate roof overhang and by protecting the exposed surfaces with breathable surface coating. Impermeable surface coating to earth wall should be avoided, because it traps water within the earth wall therefore encouraging rising dampness and it shrinks as drying out this can be improved by addition of straw.

(c) **Thermal Properties**

Dense form of earth construction have high thermal mass and are able to store heat and thereby releases it slowly to balance indoor climate. Furthermore the light non-load bearing form of earth construction are resistant to heat flow and provide good insulation. It has been proven to alter the thickness and weight of earth material to achieve different thermal effect to satisfy particular needs in different context.

(d) **Humidity Regulation**

Earth is able to absorb and release humidity which thereby balance indoor climate. The humidity is absorbed by the walls and slowly released to the atmosphere thus reducing condensation, which prevents fungal growth.

(e) **Fire Resistance**

Earth building materials are fire resistant unless they contain significant amount of fibre. It has also been proven according to German building standards, that earth with a high straw content is not combustible if the density is higher than 1700kg/m^3. Light earth fibre mixes are fire resistant and can be enhanced with the use of earth (G. Minke, 2000).

Identified constructional sequence of earth as sustainable building material.

The focus group examined that earth of different typology exhibits different characteristics that may or may not be suitable for construction. The constructional processes that will enable high quality outcome depend apparently on the properties of earth material used. Focused group identified the following construction sequence:

a) Local sourcing for suitable Earth for Building Construction

Minke (2000) performed a series of test to establish a performance specification for building soil. Soil whose characteristics fall outside these guidelines can be modified by adding appropriate amount of gravel, sand or clay to obtain better mix as it applies to local traditional practices. They usually source earth for construction on the site, using the subsoil excavated from foundations, basements and septic tank location. According to focus group report the local builder will examine the earth *insitu* to determine the nature of material available, if the properties are not suited for construction; relevant modification can be done to influence the property suitable for construction, (Table I). Where earth is not available in sufficient quantities is sourced from local clay pits nearer to construction site or road construction operation site where earth is often a waste product. This is preferable in order to reduce transportation and energy cost.

It has been observed during the study that earth building construction is prevalent in areas where clay soil and sands are abundant.

TABLE I : PERFORMANCE SPECIFICATION:

Performance Indicator	Mud wall	Rammed earth
Clay content	10-25%	7-15%
Moisture content	18-25%	10-16%
Strength	400 - 1000KN/M^3	800 - 2000KN/M^3
Linear Shrinkage	Less than 6%	Less than 3%

(Centre for Earth Architecture, Plymouth University (2000))

b) Suitable mix

According to focus group earth building practice is extremely varied in terms of quality of earth material available, the way they can be used, the functions to which they are applied, and how they perform in different context. According to local builders, suitable earth for construction is found in the sub-soil layer. Topsoil is unsuitable because of organic matter content which will decompose, however it is possible to modify earth mix to suit particular use, (Table 2).

TABLE 2 : DECIMAL GRADING:

Performance Indicator	Mud wall
Clay content	Less than 0.002 mm
Silt Content	0.002 mm to 0.06 mm
Sand Content	0.06 mm to 2.00 mm
Gravel	2.00 mm to 60.00 mm

(British Standard Grading)

Identified Techniques

In accordance with focused group specification the type of soil available usually determines the appropriate building technique to be used. Balancing of clay and other aggregates has been found to be essential for most earth building. Moisture content has also been identified to influence the nature and workability of the earth building. The following techniques have been identified.

(a) **Mud Wall**

This technique is most suited to heavy clay soil and is the most common form of earth construction found in Nigeria. The sub-soil is mixed with water until it reaches sticky but firm consistency. On some occasions straw may be introduced to avoid shrinkage or crack. The mix is then laid on strip layer of stone foundation, trodden down and shaped with hand by experienced builders to form a freestanding mass wall. In Nigeria this type of construction is best carried out in dry season, so that each layer of mud can become firm before the next layer is laid. Openings are formed as the walls are raised and load-bearing elements such as wood or already made wood opening frame may be inserted into the opening, such wood and frame act as supporting device for lintel and the last mud layer. It was observed that majority of mud walls are unprotected without any breathable rendering except for the deep overhanging eaves. Also, the lower part of the external wall is identified with little lower erosion. This type of building has stand out, most ancient palaces, town hall, communal hall, residential and the likes has been constructed with mud wall technique, such building has been stable and structurally sound, even till now, some have lasted for centuries, without any deformation, except routine maintenance, most of Nigerians cultural housing where cultural heritage are kept have been rendered mud wall typology. Critical analysis of those mud wall revealed that they are always bulky, the depth of such wall are between (450mm – 900mm), which makes them structurally sound. Mud wall is a simple, labour intensive form of construction well suited to self-build and community participation.

(b) **Earth Brick**

This method of construction varies according to different contexts. Clayed sub-soils are mixed with water and/or fibre to a mud-like consistency before they are moulded with locally made formwork, which could be of different shape such as oval, rectangular, or square according to different contexts of use. The bricks are air dried before use, the density of the earth bricks can be varied according to different context of usage. Denser bricks can carry loads; it eliminates a large proportion of shrinkage and settlement which occurs in mass earth techniques. The courses of earth bricks are laid on stripped stone foundation, earth mortar are usually used traditionally to act as binder between the bricks. Openings are formed similar to mud wall typology, opening frame usually act as lintel supporting devices. Hand-made earth bricks have the advantage of being simple to make and is therefore appropriate for manufacture by unskilled labour, it can be produced in batches. The equipments necessary include simple wooden mould for low technology applications.

(c) **Compressed earth bricks**

This type of earth bricks are produced in a manually operated press, which exerts a large amount of pressure on the earth in the mould. These are produced in standard sizes with soils that have lower proportion of clay usually less than 10% and higher proportion of sand. The drying time are speeded up in comparison to wet mounded bricks, the bricks can be stacked immediately, which eliminates the need for large drying and storage spaces.

(d) **Earth infill in timber frame construction**

This type of construction is found in eastern part of Nigeria it is common among the *Igbos*. In this type, the timber frame provides the structural support for the roof and the earth is need as a non structural infill for wall. Traditional daubs (earth infill) are prepared as mud wall mixes and applied manually to skeletal structural support called wattle, which ranges from stakes to bamboo (G. Minke, 2000).

Comparism of salient physical attributes that facilitates earth as sustainable building material.

Physical attributes	Building material	
	Contemporary material	Indigenous
Inflation	High	---
Capital Involvement	High	Low
Self help construction	Low	High
Close proximity of material	----	High
Cost benefit	Low	High
Special training skill	High	Low
Special equipment	High	----
Environmental friendly	___	High
Maintenance cost	High	Low

Source: Field work

Prevailing factors facilitating sustainability of earth as building material were identified.

1) Locally produced and sourced materials
2) Low Transport costs and environmental impact
3) Thermal efficiency
4) Financial viability
5) Recyclability of earth as building material
6) No Waste and pollution generation in manufacturing process
7) Low Energy required in the manufacturing process
8) Use of renewable resources
9) No Toxic emissions generated
10) Low Maintenance cost

Sustainable solution of Earth as building material.

a) Local and unprocessed
b) Recyclable material
c) Minimised transport and manufacturing energy and air pollution
d) Local employment

Victoria university of wellington, New Zealand. 2007

Supporting strategies for Earth as sustainable building material.

It would be useful to translate issue and finding obtained by focus group into strategies for earth as sustainable building material in the developing economics, simply because provision of infrastructure facilities is towards urban centres. These have led to substandard and dilapidated housing stock, poor living condition, economic breakdown and overall environmental degradation in the rural areas. To put the record straight according to Mabogunje (1980), improving the performances of indigenous earth is concerned with the improvement of standard of living of the low income rural population through transforming the social-economic structures of their productivity activities. The ways to measure the practicality of focus group participants is in term of effectiveness of proposed supportive actions include efficient, equity and acceptability.

FINDINGS AND DISCUSSIONS

Comments from the discussion are categorized into the following sustainable indicators.

(i) Suitability of building site for earth structure.

(ii) Selection of preferred earth building technique and suitability of workmanship that matched with standard, as showed in the field test.

(iii) Consideration of suitability of soil for construction work.

(iv) Designing an-earth building that will enhance structural strength and durability.

(v) Detailing precautions.

(vi) Effective external Fabric protection.

(vii) Frequent repairs and maintenance measures.

CONCLUSION

Improved indigenous rural housing play an important role in quality of living and socio-economic activities of rural dwellers. Focus group finding support that substandard housing situated at the rural area encourages rural urban drift and discourages local industrial developments, this generated unemployment problem. Interaction with rural dweller reveal that the quality of life developments is affected because of appreciable rural development need, such as quality housing system that will enhance quality of living education system, health system and industrial development. This research focuses on how indigenous earth building can be adopted and improved to provide adequate and appropriate building performance for a variety of purpose that will enhance rural development. Furthermore to achieve improved rural housing performances a practical improved rural implementation of the above listed recommendations is required for the opportunity of spreading rural development. This becomes tools to enhance socio-economic characteristic of rural dwellers which contribute to overall national economy.

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