International Journal of Sustainable Construction Engineering & Technology (ISSN: 2180-3242)
Vol 2, Issue 2, December 2011

LOCAL BAMBOO AND EARTH CONSTRUCTION POTENTIALS FOR PROVISION OF AFFORDABLE STRUCTURES IN NIGERIA

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ABSTRACT

In Nigeria and other developing countries where reinforced concrete in construction is widely used, the high and steadily increasing cost of steel has made construction very expensive. This, coupled with the political will, usually christened "Nigerian Factor" has made any conceived affordable mass housing program by successive governments a mirage. This development has triggered off the search for alternative and suitable replacement for steel reinforcement in concrete works. This search for a cheaper alternative has led to the exploration of abundant, naturally occurring materials such as bamboo, coconut fibres, sisal and oil palm fibres which can be obtained locally at low cost and low levels of energy using local manpower and technology. The use of these locally available materials as substitute for the conventional materials in reinforced concrete elements can cut construction costs by as much as between 30% and 80%. Interest in these local materials is heightened by the facts that not only are they considered cheap; they are also "eco-friendly". Also, the rising level of pollution in the construction industry has called for the adoption of "Eco-structures", which are constructions that are in harmony with the surroundings and do not violate the environment neither through the chosen building materials nor through the construction methods. Several studies have shown that contemporary earth construction has the potentials to address the urban housing crisis in the developing countries. On the other hand there is a wrong perception among the users and the professionals that, 'earth houses are only used by the poor people'. This paper investigates the information available on bamboo and earth material and their possible use as a low cost sustainable building material in Nigeria in the light of problem of affordable structure. The findings of this paper show that more research has to be done to come up with reasonable conclusion. It has however been found that this materials has been used to carry out some of the building activities. Finally the author thinks that if more information is found more can be done to put this material to use.

Keywords: *bamboo, earth, structure, construction, affordability, housing, materials*

1.0 INTRODUCTION

In most third world, tropical and Asian countries, investigation are on at finding suitable substitutes for steel reinforcement in concrete that would be cheap, strong, durable, possess good tensile characteristic and environmental friendly. Experts have evaluated natural fibre such as bamboo, oil palm fibre, palm kernel fibre and coconut palm fibre that are locally available, relatively less expensive, low energy demand during production, environmental friendly and 100% bio-gradable as possible substitutes for steel reinforcement and steel mesh. If bamboo is stripped into thin pieces and woven into a mesh it could be impregnated in the middle of a 10cm thick cement mortar to construct walls\ for low cost houses. The system being suggested will be factory made walls where door and window openings are pre-formed in the bamboo mesh and embedded in a 10cm (4inch-) thick cement mortar. The idea of a low cost house to my mind should not connote an inferior construction where inferior materials are used. Our ancestors have used strips of bamboo embedded in mud to build houses. If we can go a bit further to precast wall sections with bamboo fibres reinforced cement we shall have vindicated our modern education. Bamboo has been extensively studied as an alternative reinforcing material for concrete [1-2]. Ref [3] reported that natural fibres of the agave family have significant mechanical properties that make them suitable as potential reinforcement of cementitious matrix. Ref [4] conducted various tests to show the natural fibre reinforced concrete is stiffer, stronger and more ductile compared to plain concrete or even conventional steel reinforced concrete when subjected to abnormal cyclic loads.

Ref [5] noted that earth has been the most essential of the building materials, since the dawn of Man. Ever since mankind first congregated in villages almost 10,000 years ago. Unbaked earth has been one of they principal building materials, used in every continent. It is probably the very ubiquity of earthen buildings as expressed by [6] that has resulted in the low esteem with which it is held A cliché of television media reporting proclaims that they live in Mud huts? The phrase intended to convey poverty, squalor and misery of those in need of aid including new housing. In much of the world architects engineers and the government or authorities they served have assimilated the message and advocated building in permanent materials, especially unyielding concrete. Like other national materials such as palm bamboo or timber, earth building is associated with the disadvantage and the unprogressive, while concrete, steel frame sheet metal and plate glass are recognized as modern and prestigious even if they are often climatically inappropriate and expensive to produce and use. The rising cost and limited availability of modern construction materials such as block, cement and concrete make building an expensive proposition. Modern materials in building systems were developed because they are strong and longer lasting. The question remains for whom?

The whole world is in dilemma because of depletion of natural building material. Nigeria is therefore not an exception to the universal problem. This paper investigates the information available on bamboo, palm fibre and earth material and their potential use as a low cost sustainable building material in Nigeria in the light of problem of affordable structure.

1.1 HISTORICAL BACKGROUND OF EARTH AS A CONSTRUCTION MATERIAL IN AFRICA

In Africa, the Egyptian civilisation provides abundant evidence of the use of earth in building as found in the early human settlements at the Merimd and Fayum sites in the Nile delta, which dates from the fifth millennia before Christ. The dominance of the Egyptian dynasty promoted buildings of prestigious structures made of brick from the Nile clay, desert sand and straw from the grain fields. These bricks were made by hand and dried in the sun before the development of the mould. The excavation at Saggarah and Bbydos shows the use of bricks which were covered by stone. The art of brick vaulting was also developed in the lower Nubia, between Luxor and Aswan [7].

It is essential to look at historical evidence of the success of earth construction. It is currently estimated that over one third [8] to over one half [9] of the world’s population lives in some type of earthen dwelling. The history of earth building lacks documentation, because it has not been highly regarded compared to stone and wood [10]. There are cities built of raw earth, such as: Catal Hunyuk in Turkey; Harappa and Mohenjo-Daro in Pakistan; Akhlet-Aton in Egypt; Babylon in Iraq; [11].

“*30% of the world’s population, or nearly 1,500,000,000 people, live in a home built in unbaked earth. Roughly 50% of the population of developing countries, the majority of rural populations, and at least 20% of urban and suburban populations live in earth homes*” [10].

According to [12], “*earth architecture should not of course be considered a miraculous solution to neither all our housing problems, nor one which can be applied successfully anywhere, everywhere.*” Before any building is constructed with earth, it is essential to identify the soil to be used. The identification process involves various tests, which need the use of a laboratory. Apart from the laboratory identification process, local knowledge of the soil and traditional skills are necessary. In Africa, suitable soil is found in most of the countries.

Weathered soils are composed mostly of iron and aluminium oxide and when dominated with iron oxide, they are called

2.0 BAMBOO TECHNOLOGY

According to our discovery bamboo has been the construction material used in about 70% of the houses found in the rural areas of the eastern part of Nigeria. However it was evident to us that those houses were not done properly and have not followed the accepted scientific standards of construction technology – walls were not straight not reinforced and the bamboo is exposed to the effects of external elements such as sun and rain with no foundation to stand on steadily. As a result the houses looked poor and had to be repaired every year and therefore the age old bamboo technology has been looked down upon as inferior and suitable only for temporary shelter. With simple drawings and constant follow up and finally with model houses we can fill the technological gap by adding the scientific knowledge and technological expertise to enhance the traditionally accepted, user friendly, environmentally sound technology to make the locally available material- bamboo more accepted and the construction to be ***stronger***, ***durable*** *and more* ***practical*** Then to make bamboo durable, and therefore to be accepted by the community the treatment of bamboo has to be introduced. The end result will be able to build cost effective, affordable yet decent houses in Nigeria. Starting with a pilot program and expanding on the same, with families the new bamboo technology is user-friendly, community-driven, environmentally sustainable, durable and conducive in different climatic conditions. Additionally it will also provide alternative income generation activities through growing and harvesting bamboo.

2.1 IMPACT AND CHALLENGES OF USING THESE BUILDING TECHNOLOGIES

Impact

1. The immediate impact is on the number of families that will be served.
2. The program will become a 'community owned' program as the technology will be known and owned by the community being it a heritage of the communities especially the under privileged, neglected and the deprived communities.
3. Added pride and dignity to them promoting their own heritage and tradition.
4. Construction of houses will result in the increase of awareness of the need to protect the environment. The increased use of bamboo in construction will produce a 70% reduction of plantation timber used thus helping to reduce deforestation, encouraging new and existing bamboo cultivators to grow more bamboo, utilise wasteland, unused land and river banks, which will result in better soil conservation and mitigation of flood disasters.
5. This initiative will increase the options for income generation as bamboo mats can be made and marketed as more and houses are built.
6. As demand for bamboo increases more people will start cultivating bamboo.

Challenges:

1. The biggest challenge will be to change the mindset of the people to accept that bamboo construction is durable. Constant orientation and awareness program, distribution of educational materials and community group meetings will be helpful in addressing this issue.
2. Acceptance of "cement" and 'burnt bricks' as the sole durable construction material by the majority. Research findings and the model houses have been able to make a change on this though still it remains a challenge with all media and construction world being supportive of the same.

3. Less cooperation from the village skilled labourers in promoting the bamboo technology.
4. The prevailing old houses depict a poor picture of bamboo technology. Therefore, people tend to see all bamboo construction as poor technology though treated bamboo is durable for more than 30 years according to research done.

2.2 A WAY FORWARD IN MAKING HOUSING AFFORDABLE

There is a myth to accept burnt bricks, cement and reinforced concrete as the *only* material that helps constructing durable houses. In general concept, use of cement and sand in maximum quantity are the reason for durability of house. Nevertheless, they are costly and not so affordable to the poorer families. On the other hand when we look back into our history and traditions we see a difference. Clay, lime and stones have been the best used materials to build massive structures and palaces in the past and those have lasted centuries and withstood natural calamities. What do we learn from this scenario? We are challenged, especially those who are involved and shares expertise in construction, to come out with some innovative yet scientific methods, techniques and alternatives to overcome the housing problem that has direct impact on Nigerians. Some demonstration projects using bamboo technology are shown in figures 2.1 and 2.2. These are suggested ways:

1 Propagate more locally available bamboo
2 Investigate other species favourable to Nigeria climate
3 Find other ways of improving the success of bamboo to ensure ready availability
4 Find more application of bamboo as low cost building materials
5 Test the locally available bamboo strength for other application.
6 Find out how existing spaces can be used e.g leaves, seeds, and sprouts are food for both people and animals. Jointed stems in different sizes are used for pipes, furniture and household utensils.

Fig.2.1: *280 Sq.ft house, Stone foundation, Bamboo wall plastered with cement* (source:www.habitat.org/ap) [13]

Fig.2.2: 280 Sq.ft. house, stone foundation, Bamboo wall in timber frame (source:www.habitat.org/ap) [13]

Alternative construction materials

There is a myth to accept burnt bricks, cement and reinforced Concrete as the *only* material that helps constructing durable houses. In general concept, use of cement and sand in maximum quantity are the reason for durability of house. Nevertheless, they are costly and not so affordable to the poorer families. On the other hand when we look back into our history and traditions both in Nigeria and other African countries we see a difference. Clay, lime and stones have been the best used materials to build massive structures and palaces in the past and those have lasted centuries and withstood natural calamities. What do we learn from this scenario? We are challenged, especially those who are involved and shares expertise in construction, to come out with some innovative yet scientific methods, techniques and alternatives to overcome the housing problem that has direct impact on the majority of the population who live in inadequate housing in Nigeria.

Other guidelines for Selection of construction materials are (source:www.habitat.org/ap) [13]

1. Study of prevailing condition of house which is going to renovate or, new construction.
2. Keep record of materials which may be used after dismantling (if old house is going to dismantled)
3. Survey for different kind of materials which are locally available for construction.
4. Short-list of available materials and record their prevailing rates.

2.3 SOME OF THE ALTERNATIVE MATERIALS WE DO WORK WITH FOR COST EFFECTIVE HOUSING

1. Bamboo
2. Sunburn Bricks
3. Stone Boulders
4. Local wood

2.3.1 BAMBOO

Bamboo is a non timber evergreen plant that is mainly distributed in subtropical and tropical zones. Bamboo grows fast and has a high regenerating rate. Once planted, bamboo has new shoots every year. Usually bamboo can be harvested for culms purpose in the third and following years. Bamboo is both a decorative and a structural member. For shelter purposes bamboo culms between 60 to 100 mm diameters are generally adopted, which means that most of the bamboo spices available are within this range. Bamboo is widely used as a basic timber for rural housing. It is used as poles, purlins, trusses, rafters, mats for wall/ceilings/roof, frame of doors & windows and fence posts, especially in tropical countries. Though it is a natural product, the presence of large amount of hemi cellulose, starch and abundance of moisture makes it highly susceptible to biodegrading agent like white-rot, soft-rot, brown – rot, group of decay fungi and stain fungi and insects like borers and termites. In rural areas people are using bamboo without treatment. So it doesn't long last and this has created a myth in the minds of the people that bamboo is not a durable construction material. But with a simple treatment on bamboo the strength and duration of bamboo could be as long as 25 -30 years [14].

Harvesting considerations

1. Choose only those bamboo which are more than 3 years of old and it can simply determine by observing the colour of the culms has changed from clear and shiny green to greyish green and white bands at each node that have almost disappeared with replacement of gray bands.
2. As chances of attack by fungi will be more while moisture content is large so it is better to harvest bamboo in dry season.
3. Always cut the bamboo 20 to 30 cm above the ground or just above the first node.
4. Always use sharp tool or saw to avoid damaging of bamboo.
5. Keep the bamboo aright with support of other trees or on such arrangement for two to three weeks which helps to reduce the starch content of culms and as a whole it helps to reduce the chances of attack by insects or Bostrichidae and Lyetidae beetle.

Treatment of Bamboo

Bamboo can be treated mainly two ways)

1. Non chemical Treatment
2. Chemical Treatment

1. Non-Chemical Treatment

Traditionally the following treatment methods are adopted.

a) Water immersion treatment
b) Smoking
c) Using diesel *(Source: National Building Code-1994)*

a) Water immersion treatment

Normal practice followed in many bamboo producing areas is to immerse freshly cut bamboos in running water for about three to six weeks and keep it them for at least one week. By this treatment starch from bamboo is leached out making the culms immune to insect attack.

b) Smoking

This method is simple and effective .In this, bamboo are kept in a temporary smoking chamber to destroy starch by allowing smoking until they have a slightly dark color on its surface.

c) Using Diesel

Dry bamboos, both whole and split could be treated with light diesel oil by dipping in to.

2. Chemical treatment

Several permanent treatment method are available to protect bamboos and from insect attack and fungal attack. These methods are both preventive and remedial. For such kind of treatment many kind of chemicals are in use like creosote oil, Borax and Boric Acid.

a) Internodes Injection

Internodes injection for whole bamboo (poles and columns) 20-25ml. Creosote oil poured through 6mm hole in each inter node, the hole is closed with wax or putty. It is rolled once in two days for a week before it is put to use. The oil gets absorbed through the inner walls through the cross structural area, this treatment is used for dry bamboo.

b) Diffusion process

In diffusion process freshly felled culms or bamboos having moisture content of above 50% are kept submerged in preservative solutions for 1-2 days followed by stacking under shade for 10 – 15 days. To treat dry bamboo culms, they are be wetted before content will be about 50%. Split bamboos are also could be treated in this way and this way this treatment is more effective in split bamboos and slivers. By puncturing or drilling holes near the internodes before submerging them in preservative solution, treatments could be carried out for whole bamboos. The hole thus made can plugged with putty after taking the bamboos from the treating solution before they are stacked. This method will enhance penetration of treatment solution in whole bamboos. Preservatives which could be included – Boron, compounds, Copper Chrome – Arsenic (CCA), Copper Chrome – Boric (CCB), Acid copper chrome (ACC) [14].

<u>Possible building structures and points to be remembered</u>

Mainly bamboo are used as various construction material in housing as from foundation to the top. It may either be used as reinforcement on sub soil foundation, as horizontal tie member for plinth, lintel, and top of wall as well as rafter and purlins of roofing work. From ancient time different architectural buildings are made up of bamboo. Generally from technical point of view, bamboo is stronger in tensile member but it may also be used as column with some of engineering techniques. It is recommended that it is not wise to use bamboo as horizontal member on more than 10-12 feet without middle support and only to be used after treatment as mentioned above. By special care and treatment, it prolongs the age of structural bamboo up to 30 to 40 years.

<u>Fabrication: - cutting, joints and finishing</u>

The dimension and size of the bamboo are mainly depends on structural component and loading. While designing any shelter or house, the built up area as well as the spacing between two partitions is more important. 11 feet to 15 feet between two partitions generally are suitable without having a support in between. In bamboo houses generally, the slant of the roof of GI or corrugated bamboo roofing sheet are used so the height will have to be maintained not more than 8 feet on lower side and 11 feet on top side. For the different purposes on housing bamboo can be fabricated as follows figure 2.3.

Only basic carpentry, Masonry tools and skills are necessary for the construction of bamboo houses. Figure 2.4 below shows end profiles of bamboo poles for use in construction. For the joints and other clamping points these kind of cutting or fabricating is preferred. With clear instruction and proper workmanship we may get such a kind of joint arrangement with using steel clamps and nut arrangement.

Fig 2.3: Bamboo Column
(source:www.habitat.org/ap) [13]

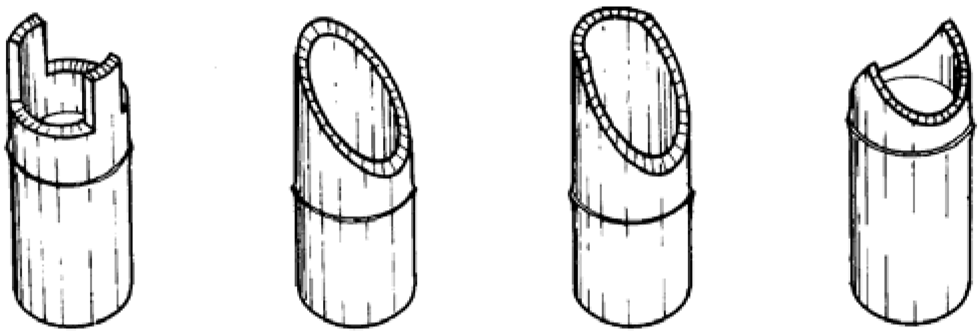

Fig.2.4: End profiles of bamboo poles for use in construction
(source:www.habitat.org/ap) [13]

In the proposed bamboo house the columns are constructed from whole bamboo poles. The poles are fixed at the level of foundations/plinth. For this purpose the end 500 mm of the pole is injected with cement based mortar and reinforced with a steel bar- see Figure 2.5 .The bamboo should be reinforced in this way before mounting them in the foundations.

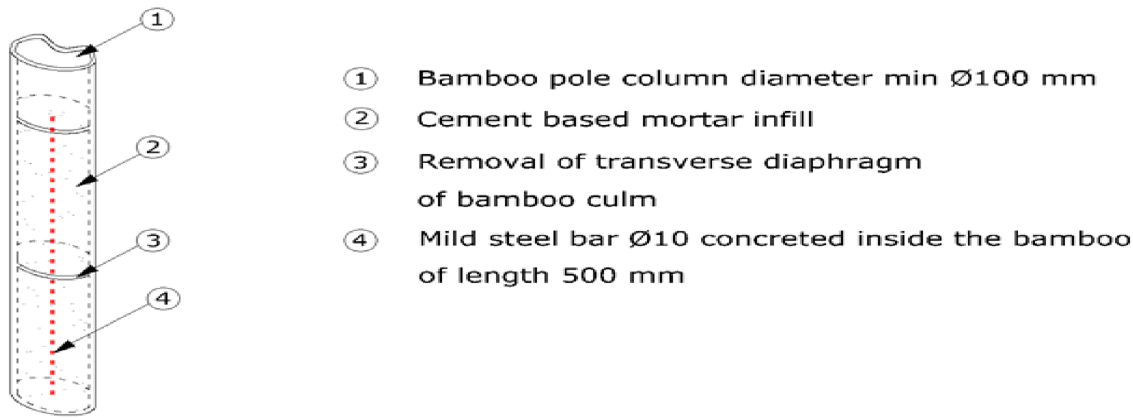

Fig.2.5: End 500 mm of the pole is injected with cement based mortar and reinforced with a steel bar (source:www.habitat.org/ap) [13]

All bamboo columns are connected at the top to a timber or bamboo with some steel plate. This beam has a rectangular cross section for timber and hooking arrangement of reinforcement from bamboo. The bamboo pole column is connected to this beam through an anchor bolt. The anchor bolt is embedded in the pole where cement based mortar is injected- see Figure 2.6.

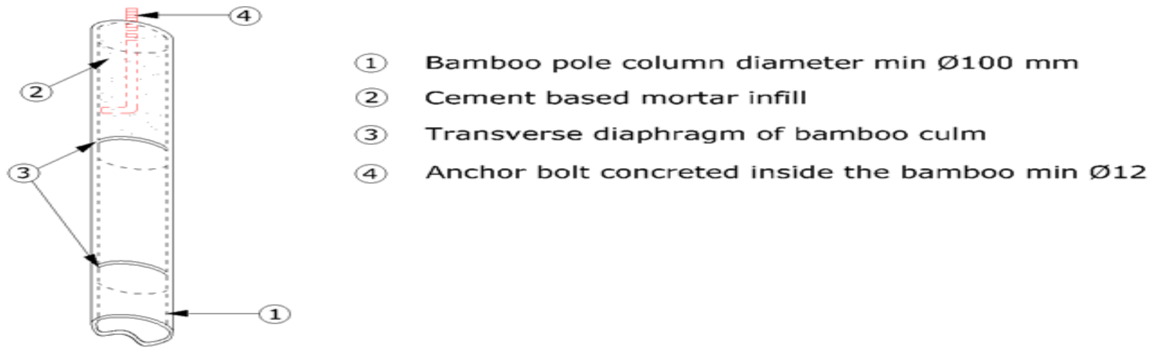

Fig.2.6: Bamboo pole column is connected to beam through an anchor bolt (source:www.habitat.org/ap) [13]

3.0 EARTHEN CONSTRUCTION

Earth as building materials is available everywhere, existing in many different compositions that can be processed in a myriads of ways.

3.1 TYPES

The following are among the more popular types of earthen construction [15]

1. Adobe
2. Rammed earth
3. Compressed earth blocks

3.1.1 ADOBE (LATERITE BLOCK)

Adobe is air/sum dried brick from and composed of inorganic soil and sand. The soil must have minimum clay content of 10%. Fibers such as straw may also be added to increasing the stability of the block as work well as binders. An adobe brick is typically 250 to 300mm and weighs between 13 -22kg [16]. Some of the steps that can be taken to protect adobe structures are [15]:

- Placing walls on concrete or stone foundations.
- Using water inhibiting additives
- Plastering adobe walls with stucco
- Providing substantial overhangs.

3.1.1 RAMMED EARTH

Rammed earth involves the compacting of moist soil between rigid forms to create monolithic earth walls with similar properties as that of adobe walls. The soil for rammed earth construction must have about 30% clay and 70% sand and small gravel. It is critical to ensure that the moisture content of the wall is just right as if the mixture is too dry. Then it will lead to a weak and crumbly wall [16].

3.1.2 COMPRESSED EARTH, BLOCKS

Compressed earth blocks (CEBs) are a relatively recent technology and combine the nest characteristics of traditional earthen technology and modern brick making process. Earth is poured into moulds and compressed either manually or mechanically.

3.2 BENEFITS

The most obvious advantage of earth construction is the abundance of the raw material earth. Other advantages of earthen construction include [17-24]:

- High thermal insulating properties
- High sound insulation
- Not susceptible to insects or rodents
- No waste generated during construction
- Inert- contains no toxic substances
- Construction is inexpensive and simple
- High workability and flexibility
- High fire resistant.
- Earth construction is economically beneficial.
- It requires simple tools and less skilled labour.
- It encourages self-help construction.
- Suitable for very strong and secured structure.
- It saves energy (low embodied energy).
- It balances and improves indoor air humidity and temperature.
- Earth is very good in fire resistance.
- Earth construction is regarded as a job creation opportunity.
- Earth construction is environmentally sustainable.
- Loam preserves timber and other organic materials.
- Earth walls (loam) absorb pollutants.
- Easy to design with and high aesthetical value.
- Earth buildings provide better noise control.
- Earth construction promotes local culture, heritage, and material.
- Earth is available in large quantities in most regions.

3.3 CONSTRAINTS OR DRAWBACKS

The in spite of the well established technology and also of the application areas [25], laterite blocks has not really found favour in housing programmes taken up in the country either in the public or in the private sector level. The constraints are mainly due to [19-24, 26]:

- Acceptability of the material in view of bias and stigma attached to the material. Otherwise considered to be the material which is and also for use of only the poor man
- The lack of institutional arrangement for market availability of the blocks as normally available for sandcrete blocks through block industries and suppliers.
- The lack of support through code provisions either in the national codes or through the Public Works Department (PWD) codes.
- The lack of references of materials in most of the schedule of rats in the country as an alternative to sandcrete blocks.
- The over-emphasizing use of materials like sandcrete blocks as of higher strength in comparison to stabilized laterite blocks.
- Tendency to adopt a safer pattern of using established materials.

- Lack of demonstration project that will infuse confidence among the people for using the laterite blocks technology for housing and building.
- Lack of sufficient machinery to be distributed all over the country of proven capabilities and training for entrepreneur and workers for manufacture of stabilized laterite blocks of required quality.
- Less durable as a construction material compared to conventional materials.
- Earth construction is labour intensive.
- Mud houses behave poorly in the event of earthquakes.
- Structural limitations.
- Need high maintenance.
- Professionals make less money from earth building projects.
- Special skills needed for plastering.
- Loam is not a standardised building material.
- Need higher wall thickness.
- Suitable only for in situ construction.

3.4 AREAS OF SUPPORT ASSISTANCE NEEDED

Based on experience [25], the following are major areas of support assistance needed to make laterite blocks making technology popular in housing project both at the public sector and private sector.

- They should be increased access to block making machines.
- Training of people in this field
- Codes support
- Schedule rate
- Public building using earth materials (demonstration projects)
- Exposure on the subject to students of architecture and engineering.
- Public awareness

Location of clay deposits in Nigeria is shown in Figure 3 1. Laterite usually contains a good quantity of clay particles. A systematic survey of clay deposits by the Nigeria

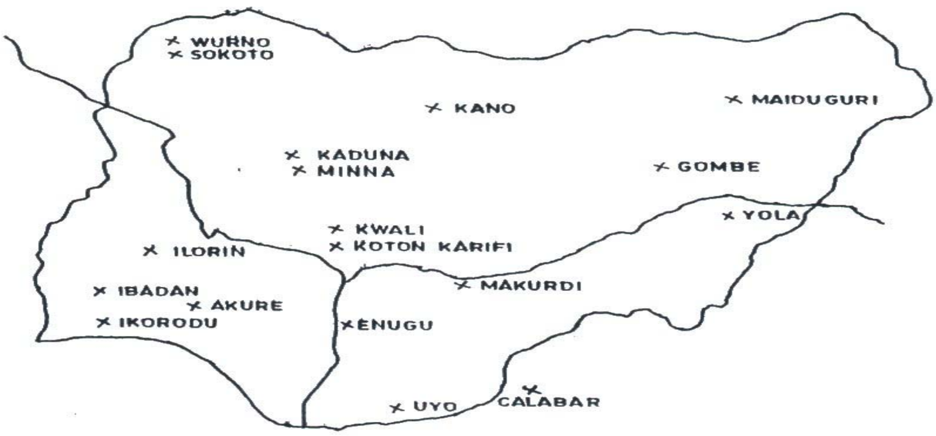

Fig 3.1: Location of Clay Deposits in Nigeria
(Source: Salau 2008) [27]

Geological Survey Department is given in Figure 3.1 and their preferred use, suggested in Table 3 1.

Table 3.1: Clay Deposit Suitable for Bricks in Nigeria (Source: Salau 2008) [27]

S/No	CLAY	LOCATION	STATE	ROUTE/AREA	SUGGESTED INDUSTRIAL USE
1	CLAY	Agbassah, Kingbo, Uyode	Delta	12m, E.W.E., Ughelli, 16km from Ughelli-Warri Road 4 and a half km N. W., Ughelli & 7km W.S.W, Ughelli	Bricks, Pipes (Floor) Foilet Bricks, pipes etc.
2	CLAY	Kiagbodo	Delta	Delta, Ughelli, 16km East of Ughelli, 30km N.W.W. Sapele on Ossiomo River	Bricks, pipes, etc
3	BALL CLAY	Ebutte Orega	Lagos	Ikorodu	Pottery, tiles and bricks
4	CLAY	Ifo	Ogun	Ijegun Junction at 36km on railway	Bricks, tiles, etc
5	CLAY	Oke-Seri	Ogun	2km East of Ibadan Rd. and 5km. North of Ijebu-Ode, Ijebu bextensive to Imope village.	Bricks Manufacturing Floor and roof tiles
6	CLAY	Ijaiye, Ake, Ijegun, Ibara	Ogun	Abeokuta, Ake, quarry Itoko, quarry near Own African Central School and Lafenwa quarry	Bricks, Pottery, etc.
7	BALL CLAY	Agbaignara Osu	Imo	Okigwe, Owerri	Refractory, Bricks etc
8	CLAY	Ondo	Ondo	Tributary of Oluwa River North Agbaje	Tiles, Bricks
9	CLAY	Rimi, Dakata Ganyawa	Kano	Kano	Bricks
10	BALL CLAY	Ekpene Obom	Akwa Ibom	Uyo near Catholic School	Pottery, Bricks, tiles, etc
11	BALL CLAY	Mbiafor, Ikot-Ekpene	Akwa Ibom	Uyo	Pottery, Bricks, tiles, etc
12	FIRE CLAY	Obuga	Enugu	Enugu, Escarpment to West of Enugu from Obuga to Nyaba River.	Refractory Bricks

3.5 CONSEQUENCES OF UNAFFORDABLE STRUCTURES

The after-effect of the unaffordable cost of construction is intentional and unprofessional economy in construction materials which normally lead to collapsed buildings and structures. Recently, there have been cases of collapsed buildings and structures but only few are reported. The Nigerian building professionals, especially the Structural Engineers have also been indicted. The incidences have led to questioning their competence and capability. Majority of the collapse of concrete structures are during the construction period due to the use of materials. Among the well publicized structural collapse of buildings are [27]:

i) 8-Storey Hotel building on Akinwunmi Street, Okupe Estate, Mende Maryland, Lagos State in 1989. (Collapsed on the Eve of Official Opening)

ii) Saque Comprehensive Primary and Secondary School, Port-Harcourt, River-State on the 15th June, 1990.
iii) Two-storey building at Maryland, Lagos State on the 1st Jan. 1999
iv) Uncompleted church building at Mafoluku, Lagos State
v) 3-storey building at Abuja, 1996
vi) 3-storey building at No.3 Cheme Avenue, New Haven Enugu, Enugu State, on the 12th June, 1997
vii) Main entrance canopy of the main approach to the Eleganza Ball Pen Industry Estate, Ajah, Lagos State, 2000
viii) Collapse of completed and earlier certified fit, three-storey building at Ebute-Metta West, Lagos Mainland in 2006
ix) Collapse of uncompleted Bank building at No 1, Murtala Muhammed International Airport Road, Mafoluku, Oshodi, opposite Glass House office of “Construction New Digest” in 2006
x) 4 collapses in Port Harcourt between Aug. and Sept 2005 (Abacha Road, Rombia Str, Old GRA and Tourist Beach) at different stages of construction in a reclaimed mangrove swamp.
xi) Partial Collapse of Bank of Industries Building at Custom Street, Lagos in 2006
xii) Two-storey Residential House at Ibadan Street, Ebute-Metta East in Lagos Mainland in 2007
xiii) Residential Building at Okepopo, Lagos Island in 2008

It should be noted that materials, either locally or imported, do not fail but the wrong selection of materials at the conceptual, design and construction stages are often the cause(s) [27]. From the experience of the investigation of the failed structures, the lesson to be drawn there from can be expressed with this statement.

Finally, the responsibility of an Engineer is given in the delight book of Henry Pertoki, *To Engineer is Human.“Structural design is more akin to coaching. However, the design engineer must do better than any coach, for he is expected to win every game he plays. That is a tough assignment when one mistake can often mean a loss. And when defeat occurs, all one can hope is to analyze the game film and learn from the mistakes so that they are less likely to be repeated the next time out.”*

4.0 CONCLUSIONS

The conclusion is that the dream of housing for all by Year 2020 and United Nations’ Millennium Development Goals (Year 2015) can only be achieved if the abundant local structural engineering materials in Nigeria, on which a lot of research works have been done, can be used to get affordable houses and structures.

The failure of the government in the provision of adequate houses for the population has made laterite blocks inevitable for the masses. However the low esteem with which the material is regarded can be overcome if some of these recommendations given above can be implemented. In this way government will not burden herself with the provision of housing as this will now shift to private developers and the government can concentrate on essential building services

The findings of this paper show that more research has to be done to come up with reasonable conclusion. It has however been found that this materials has been used to carryout some of the building activities. Finally the author thinks that if more information is found more can be done to put this material to use

5.0 RECOMMENDATIONS

1. Standard Organization of Nigeria, agency responsible for Quality Control of Construction Material should ensure that all brands of imported cement satisfy the relevant Nigerian codes and suitable for the environment.
2. For sustainable economic and industrial development, governments at all levels and organized private sectors should invest on the development and application of abundant local materials in Structural Engineering.
3. There should be continued focus on the development and usage of earthen construction as this will significantly reduce the usage, overdependence on Ordinary Portland Cement and stabilize its cost. This will contribute to the achievement of the Millennium Development Goals.
4. The usage of bamboo and other natural fibres such as oil palm fibre, palm kernel fibre and coconut palm fibre should be encouraged as possible substitutes for steel reinforcement and steel mesh.
5. Governments and Organized Private Sectors should have confidence in results of research findings in Nigeria and adequately support their practical applications.
6. Various recommendations on the possible preventive measures on collapse of structures, presented to the Government by the Nigerian Society of Engineers should be considered while the appropriate Government Regulatory Bodies should ensure their enforcement in the construction industry in Nigeria.

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