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TOPIC:

ABUNDANT LOCAL STRUCTURAL ENGINEERING MATERIALS WITHOUT AFFORDABLE STRUCTURES

By
PROFESSOR MUSBAU AJIBADE SALAU

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By

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Vice-Chancellor, Deputy Vice-Chancellor (Management Services), Deputy Vice-Chancellor (Academic & Research),Registrar and Principal Officers, Dean of the Faculty of Engineering, other Deans, Members of Senate, Professional Colleagues, Dearest Students, Distinguished Ladies and Gentlemen. I want to crave your indulgence to allow me dedicate this lecture to my Late Father, Alhaji Liasu Adejumo Salau who believed in education for Poverty Alleviation, that he promised to disown any of the children that failed to go to school. He, together with the support of my mother, Mrs. Osefat Aduke Salau gave me the solid foundation on which I have built the structurally stable structure of today.

It has been a long journey in Academics and Professional practice and I give thanks to Almighty Allah for today as the journey has been very hectic, interesting and enjoyable.

INTRODUCTION

The topic for my Inaugural lecture is **"Abundant Local Structural Engineering Materials Without Affordable Structures"**. This topic has been agitating my mind for long, throughout my academic and professional career.

My Ph.D thesis was on "Mutual Deformation of Reinforced Concrete Secondary and Main Beams in Precast Construction" and I published two technical papers in the area [Salau, (1980) & (1983)]. The thesis was part of research work at the Department of Structural Mechanics, Odessa Civil Engineering Institute, Odessa, in the former Soviet Union (U.S.S.R) and the work is very relevant in developed countries and involved the long-term deformation of the system in terms of Creep and Shrinkage of the composite elements of reinforced concrete, that is, concrete and reinforcing steel bars.

However, on resuming my research work at the University of Lagos, I opined that our research work in the developing countries should be focused towards alleviating poverty of our people and development of the Nation. This is what is done in the developed states. Permanent interest is very important in this regard. We are to consider our available infrastructure facilities and avoidable research equipments. I then embarked on the search for improving and usage of locally and abundantly available structural engineering materials in Nigeria, apart from the investigation and failure analysis of distressed structures.

Vice-Chancellor Sir, my today's lecture will trace the trajectory of my academic career so far, highlight my humble contributions in the Structural Engineering Characteristics of some local materials viz Laterite, Bamboo, Yoyo Sand, Natural and Artificial fibres such as pulverized electric arc furnace slag, oil palm, coconut palm fibres in concrete as well as hollow clay pot construction.

A material is described as structural engineering material if it is durable, weather resistant and it is capable of resisting adequately tensile or compressive stresses. These properties are very important for Structural Engineers. One of such materials is Reinforced Concrete, which is the major material used for structural elements, especially in Nigeria and developing Nations.

BRIEF HISTORY OF REINFORCED CONCRETE AS COMPOSITE MATERIAL

The development of composite construction materials was dated back to the earliest Egyptians who used weeds to reinforce mud to form a composite material. In 1847, Joseph-Louis Lambot, a Frenchman, was the first person to use composite material in the form of reinforced concrete. He constructed a boat with Ferro cement. Joseph Monsier, a French gardener, patented a design for reinforced garden tubs in 1867 and later patented reinforced concrete beams and posts for railway and road guardrails. Franqcoius Hennebique in 1892, proposed the solution to the problem of monolithic joint, that is, the integration of separate members of construction such as the column and the beam, into a single monolithic element. The famous architect and engineer, Pier Luigi Nevi in 1940 reviewed the concept of Ferro cement, as formulated by Lambot. Nevi built a small warehouse, a roof for a swimming pool and a dam with Ferro cement. The advances in the area of structural engineering materials continue and today every nation is looking for locally available structural engineering materials to reduce cost of construction. The Ferro cement idea has developed to new structural materials like woven alkalis resistant glass, organic woven fabrics such as polypropylene and natural fibres like bamboo, jutes, sisals, oil palm fibres and coconut palm fibres.

REINFORCED CONCRETE IN CONSTRUCTION

Concrete is a mixture of cement, usually Portland cement, and stone aggregate. When mixed with small amount of water, the cement hydrates to form a microscopic opaque crystal lattice structure, encapsulating and locking the aggregate into its rigid structure. Typical concrete mixes can have high resistance to compressive stress of about 30 MPa. However, any appreciable tension due to bending will break the microscopic rigid lattice resulting in cracking and separation of the concrete. The tensile strength of concrete is typically 1/10th of its compressive strength. Regular concrete is therefore normally reinforced with steel bars to complement its tensile strength characteristics.

The overall cost of a construction project is essentially the summation of the cost of the construction materials and labour for erection. Studies carried out by Dirisu and Olabiran (1991) on housing revealed that the material of construction alone could account for as much as 60% of the total building cost.

Steel is one of the most widely used and probably the most expensive of all the construction materials. Its strength and ductility properties have made it an excellent choice for long span structures like bridges and tall buildings. Concrete is reinforced with steel because of its great tensile strength. Its high cost has however become a major challenge in construction.

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 programme 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. Dirisu and Olabiran (1991) opined that 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.

LOCALLY AVAILABLE CONSTRUCTION MATERIALS

There have been efforts by Governments at various levels carrying out the policy of direct intervention into the provision of shelter by building low cost housing units. Apparently, significant progress in these schemes was seemingly impossible as a result of challenges poised by continued rising cost of conventional structural materials as well as geometrical growth of population, especially in urban areas. This has led to the quest for alternative cheaper materials. In this quest, various forms of building

materials like burnt clay bricks, soil blocks, timber construction, were suggested based on the availability of raw materials for these form of construction in various part of the country. Introduction of interlocking sand blocks for walls in housing construction to reduce the use of cement was proposed by Okunsanya (1991). Therefore, the emphasis in Nigeria should be in the use of alternative to major constituents materials in reinforced concrete and blocks (load bearing and partitioning) such as steel in form of reinforcement rods and rolled sections, bricks, laterite blocks, granite, gravel, Yoyo sand, cement, Pozzolanas, palm fibre, coconut fibre, bamboo (whole and in strips) to mention a few.

LOCAL ALTERNATIVE TO PORTLAND CEMENT

Nigeria is a developing country with annual increasing stock of buildings and infrastructure. The main material used for these indices of development is cement.

Ordinary Portland Cement (OPC) is a basic material used for the construction of buildings and infrastructure universally. In the National Housing Policy of 1980 in Nigeria, housing problem in Nigeria was described as a "huge shortfall" with concomitant increase in backlog of housing supplies and substandard housing, suffering from overcrowding, lack of utilities and poor environmental conditions. The policy therefore has, as its objective, the provision of housing for all by the year 2000. In the 1987 report of the Nigerian Building and Road Research Institute (NBRRI), it was estimated that Nigeria would require over 20 million new housing units to achieve the objective of housing for all by the year 2000. Kolawole and Efeovobokan (1990) put the figure at about 15 million; now the needed housing units had increased tremendously based on the increase in the population within 10 years by about 30%.

In order to meet the nation's cement requirement, the Raw Materials Research and Development Council (1999) put the estimated annual cement needs at 7.8 million metric tones. It was estimated that the total quantity of cement produced by the 7 (seven) cement manufacturing companies in the country as at 1998 was 3,053,776 metric tonnes. This was about 61% of the capacity utilization of the local cement plants and as a result of the huge gap between production and demand, all the cement produced by each cement company are consumed not too far from their areas of production. To augment the shortfall, other brands of Ordinary Portland Cement are imported into the country. Substitutes or partial replacements of cement in concrete were also suggested [Salau (1997) & Okpala (1986)]. The Cement Manufacturing Association of Nigeria (CMAN) put the local production of cement and quantity of imported ones for the last three years (1996-1998) as follows:

i. Local production in 1996 was 2,530,998 metric tonnes while imported cement amounted to 1,060,300 metric tonnes.
ii. The 1997 local production was 2,519,876 metric tonnes while imported cement amounted to 1,304,582 metric tonnes.
iii. In 1998, local cement production was 2,206,355 metric tonnes while imported cement was 1,992,588 metric tonnes.

Ten years later, in 2008, our local cement production is 6.5 million metric tonnes as against the installed capacity to produce 10 million metric tonnes. The yearly demand of cement is 18 million metric tonnes and there is tendency that the local need may double this amount in the near future. Consequently, there is a continuous rise in the figure for imported cement to augment local production. The continuous decline of local production had encouraged importation of cement. Imported OPC in the years 1996, 1997 and 1998 was therefore 42%, 52% and 90% respectively while as at 2007, less than 30% of local need was really produced in Nigeria. It is envisaged that imported brands of cement would continue to increase in the future unless steps are taken to increase local production.

Early this year, 2008, the price of cement skyrocketed to about ₦2,200.00 for a 50kg bag. Thanks to the intervention of the Federal Government who has ordered lifting of the restriction on

importation of cement. Salau and Yusuf (1998) initially appraised the situation of unregulated import of various brands of Portland cement from different countries into Nigeria. We carried out investigation on the performance characteristics of the locally available (as against locally manufactured) and concluded that majority of the imported brands are more suitable in very hot environment such as arid region. The locally manufactured cement, such as Elephant Portland Cement brand was found to be of high quality and more appropriate in the southern part of the country.

Further, the construction climate in Nigeria is fraught with so many problems that lead to projects not being executed as scheduled or eventual abandonment. These lead to the storage of purchased cement for longer than necessary resulting into their getting caked. Compounding the problem is the activities of some cement traders who re-ground and re-bag cement after long period of exposure and importation of cement which may have lost their engineering properties due to long period of shipment or delay in off-loading. Salau et al (2000) conducted various tests such as mineralogical composition, consistence, finess, soundness, setting times and strength performance of mortar and concrete cubes at different ages on normal and reground caked Portland cement with a view to determine the effect of the long period of storage before regrinding. The investigation showed that a reduction in the Tricalcium Silicate (C_3S) as well as increase in Dicalcium Silicate (C_2S), the major compounds of cement, of the reground caked cement resulted in low strength capacity. The various mortar and concrete cubes strength from re-ground cement were about 10-28% that of normal cement. The re-ground cement can only be used for non-load bearing elements and sandcrete block for partitions.

It was concluded that the use of Portland cement can be restricted to load carrying structures and alternative cheap and low strength cement can be considered for minor structural elements and masory works. Then, the demand for Portland cement will reduce and considering the theory of "Demand and Supply" the cost of the cement will be affordable.

It is observed that the use of Portland cement has reduced drastically in the industrialized countries. **Then, what is the alternative to Portland cement in the other developing countries like Malaysia, Singapore, Brazil etc.? *It is Pozzolanas.*** Pozzolanic materials are siliceous or siliceous and aluminous materials, which in themselves possess little or no cementation value, but will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide liberated on hydration, at ordinary temperature to form compounds, possessing cementitious properties. The reaction is called pozzolanic reaction and its characteristic feature is that it is initially slow with the result that heat of hydration and strength development will be accordingly slow. The reaction involves the consumption of $Ca(OH)_2$ and not production of $Ca(OH)_2$ thus improving the durability of the cement paste by making the paste dense and impervious.

Natural Pozzolanas are of volcanic origin such as volcanic Ashes, Tuffs, Pumicites, Clay, Shales, Opalinic Chests and Diatomaceous Earths and they have lost their popularity in view of availability of artificial Pozzolanas. Artificial Pozzolanas can be obtained mainly from agricultural wastes or steel production residue. Rice husks, maize stalk and even some plants in the grain family are pozzolanic. Others from steel and coal production are pulverized fly ash, electric arc furnace slag, blast furnace slag, silica fume, and others. Pozzolanas can be used as a blend with the ordinary Portland cement to increase the volume of the Portland cement and thereby produce about two or three bags of pozzolans cement from a bag of Ordinary Portland Cement. Pozzolana may be blended with lime to produce lime- Pozzolana cement. The only difference between Portland and Pozzolans cement is that Pozzolans cement takes about 60 to 90 days depending on composition, to attain the 28

days strength of Ordinary Portland Cement. Table 1 shows the chemical constituents of some Pozzolanas compared with Ordinary Portland Cement.

Salau (1997) studied the effect of partial replacement of Ordinary Portland Cement (OPC) with pulverized Electric Arc Furnace (EAF) slag-a Pozzolana. Electric Arc Furnace slag is the by-product of steel production using the Directly Reduced Iron (DRI). In the furnace, it is molten state, bathing the liquid steel and also absorbing the internal and external impurities.

The conclusion on EAF slag was that 30% content of Portland cement could be replaced with pulverized EAF slag without impairing the eventual strength of the OPC and recommended its use where reduced heat of hydration in the early life of concrete is essential.

The results of the investigation showed that:

i. The pulverized electric arc furnace slag has the ability to react with lime in the presence of moisture at ordinary temperature to form a pozzolana.
ii. The slag-cement mixes required less water than ordinary Portland cement alone for workability. The plasticity increases with increase in slag content, indicating more volume stability. Imperfection cracks could be minimized with its use.
iii. Slag-cement cubes generally exhibited low early compressive strength. However, the 28 day strength of up to 30% replacement compared favourably with the ordinary Portland cement mortar. At 60 days, the strength of Pozzolana is the same as for OPC at 28 days.

In Nigeria, rice is abundantly produced and the husk is a waste product and has been causing environmental problem in terms of disposal and dust pollution. The ash produced from rice husk under controlled burning and further sufficient grinding can be used as a cement replacement material in concrete. Anwar *et al* (2000) studied the main characteristics of the Rice Husk Ash

(RHA), the properties of the fresh concrete and development of the fundamental properties of hardened concrete. The research also involved the development of comprehensive engineering data-base on RHA concretes including long-term performance. Ikponga and Okpala (1992) studied the variation in strength with partial replacement of Ordinary Portland Cement with rice husk ash (RHA) and concluded that with design strength at 28days of up to 30 N/mm² could be achieved with 40% replacement of cement with RHA.

These results have shown that, in Nigeria, there are potential natural materials which are suitable for pozzolanic cements. The Governments need to support further exploration of other pozzolanas for the manufacture of alternative cements to the ordinary Portland cement to reduce the frustration from dependence on the ordinary Portland cement.

Table 1: Chemical Analysis of some Pozzolanas in Comparison with Ordinary Portland Cement

Constituents	Ordinary Portland Cement (%)	Blast Furnace Slag (%)	Flash Ash (%)	Electric Arc Furnace Slag (%)
Lime, Ca O	64.58	38.36	1.8	33.70-55.70
Silica, SiO_2	20.20	34.65	49.10	18.00-23.70
Alumina, I_2O_3	6.73	113.62	28.10	3.70-9.48
Iron, Fe_2O3	2.50	0.28	9.50	9.70-19.50
Magnesia, MgO	0.91	10.51	1.70	3.75-14.55
Manganese, MnO	-	-	-	0.30-0.87
Sulphate, SO_3	2.93	0.23	0.30	
Phosphorus, SO_3	-	-	-	
Sodium, Na_2O		0.44	1.80	
Potassium, K_2O		0.81	3.70	
Titanium, TiO_2	0.26	0.42	1.00	
Ignition Loss	1.01	-1.2	3.00	

LOCAL AGGREGATES IN CONCRETE

Aggregates are the important constituents in concrete. They are filler and reduce shrinkage and effect economy. Earlier, aggregates were considered as chemically inert materials but now it has been recognized that some of the aggregates are chemically active also that certain aggregates exhibit chemical bond at the interface of aggregate and paste (mixture of cement and water), the mere fact that the aggregates occupy 70-80% of the volume of concrete, their impact on various characteristics and properties of concrete is undoubtedly considerable.

To know more about the concrete it is very essential that one should know more about the aggregates which constitute the major volume in concrete. Cement is the only factory made standard component in concrete. Other ingredients, namely, water and aggregate are natural materials generally and they can vary to any extent in many of their properties.

Concrete can be considered as two phase materials-paste phase and aggregate phase. For aggregate phase the following should be given consideration: classification, source, size, shape, texture, strength, specific gravity, moisture content, bulk density bulking factor, cleanliness, soundness, chemical properties, thermal properties, durability, sieve analysis and grading.

For classification purpose, aggregates are divided into:

i. Normal weight aggregate,
ii. Light weight aggregates and
iii. Heavy weight aggregates.

They can also be classified according to sources i.e. either natural or artificial. Table 2 shows examples of the natural and artificial aggregates.

Table 2: Natural and Artificial Aggregates

Natural	Artificial
Sand, Gravel, Crushed Rock such as Granite, Basalt, Quartzite, Sandstone, Laterite Yoyo sand	Broken Brick Air-cooled Slag Sintered Fly Ash Bloated Clay

Aggregates can be classified as coarse and fine on the basis of their size. The size of aggregate bigger than 4.75mm is considered as coarse aggregate and aggregate whose size is 4.75mm and less is considered as fine aggregate.
It is hard to believe that aggregates that are used in plain and reinforced concrete structures throughout Nigeria have no technical characteristics and are used blindly.

The concrete aggregates should be free from impurities and deleterious substances which are likely to interfere with the process of hydration, prevention of effective bond between the aggregates and matrix. The impurities sometimes reduce the durability of the aggregate.

Generally, the fine aggregates obtained from natural sources are likely to contain organic impurities in the form of silt and clay. The manufactured fine aggregate does not normally contain organic materials but it may contain excess of fine crushed stone dust. Coarse aggregate stacked in the open and unused for long time may contain moss and mud in the lower level of the stack.

Sand is normally dredged from river beds and streams in the dry season when the river bed is dry or when there is not much flow in the river. Under such situation along with the sand, decayed vegetable matter, humus, organic matter and other impurities are likely to settle down. But if sand is dredged when there is a good flow of water from very deep bed, the organic matters are

likely to get washed away at the time of dredging. The organic matters will interfere with the setting action of cement and also interfere with the bond characteristics with the aggregates. The presence of moss or algae will also result in entrainment of air in the concrete which reduces its strength.

To ascertain whether a sample of fine aggregates contains permissible quantity of organic impurities or not, a simple test known as calorimetric test is made. The sample of sand is mixed with a liquid containing 3 percent solution of sodium hydroxide in water. It is kept for 24 hours and the colour developed is compared with a standard colour card. If the colour of the sample is darker than the standard colour card, it is inferred that the content of the organic impurities in the sand is more than the permissible limit. In that case, either the sand is rejected or is used after washing.

Sometimes, excessive silt and clay contained in the fine or coarse aggregate may result in increased shrinkage or increased permeability in addition to poor bond characteristics. The excessive silt and clay may also necessitate greater water requirements for given workability.

Fine aggregate from tidal river or from pits near sea shore will generally contain some percentage of salt. The contamination of aggregates by salt will affect the setting properties and ultimate strength of concrete. Salt being hygroscopic, will also cause efflorescence and unsightly appearance. Opinions are divided on the question whether the salt contained in aggregates would cause corrosion of reinforcement. But studies have indicated that the usual percentage of salt generally contained in the fine aggregate will not cause corrosion in any appreciable manner. However, it is a good practice to wash sand containing salt more than 3 percent.

Aggregates from some source may contain iron pyrites, clay nodules, soft shale particles and other impurities which are likely to swell when wetted. These particles also get worn out when concrete is subjected to abrasion and thereby cause pitting in concrete. Such unsound particles cause damage to the concrete particularly, when subjected to alternate wetting and drying or freezing and thawing. A limitation to the quantity of such impurities is already shown in Table 3.

Table 3: Limits of Deleterious Materials in Aggregates

S/No.	Deleterious Substances	Fine aggregate percentage by weight, max		Coarse aggregate percentage by weight max	
		Uncrushed	Crushed	Uncrushed	Crushed
(1)	(2)	(3)	(4)	(5)	(6)
(i)	Coal and lignite	1.00	1.00	1.00	1.00
(ii)	Clay lumps	1.00	1.00	1.00	1.00
(iii)	Materials finer than 75-micron Sieve	3.00	15.00	3.00	3.00
(iv)	Soft fragments	-	-	3.00	-
(v)	Shale	1.00	-	-	-
(vi)	Total of percentage of all deleterious materials (except mica) including Sr. No. (i) to (v) for col. 4, 6 and 7 and Sr. No. (i) and (ii) for col.5 only	5.00	2.00	5.00	5.00

IMPURITIES IN AGGREGATES

There are no records as at now of any investigation on the chemical properties of the aggregates, particularly coarse aggregates. Further, there is no record of structural failure that has been traced to the type of aggregates used in concrete mixes. This is as a result of the fact that many people are not aware that certain types of aggregates are unsuitable for plain and reinforced concrete works. Failure of dams can be caused by failure of aggregates due to easy percolation of water through the crevices at the interface of matrix and the coarse aggregate. A good design may fail during construction if the materials used are defective.

Aggregates with high sulphate content are not suitable for plain or reinforced concrete. This is because sulphates react with cement after diffusion from the pores and the reaction may cause concrete to swell and thereby initiate formation of cracks in hardened concrete. The cracks can be enlarged quite easily in wet weather, especially during a heavy rainfall.

Carbonates are also undesirable in aggregates. The effect of carbonate is to absorb water from the wet mix. The aggregate will absorb the water which the cement should have used for hydration. This will result in concrete mixes of lesser strength than the designed strength. A mix with less water may suffer from inadequate compaction. This may well be another source of structural failure especially in mass concrete construction like the dam.

Chlorides are present in the pores of coarse aggregates and at times adhere to the surfaces of coarse aggregates. Chlorides are easily found in sea sand and coarse aggregates or even in river sands and aggregates where the sea can encroach. The main effect of chlorides is the corrosion of steel reinforcement. This shows clearly that aggregates that contain chlorides should not be used in reinforced concrete. The sand that is obtained from rivers near the Lagos sea shores are therefore questionable. If salt can enter the water supply at Ishashi Water Works, what evidence have we to exclude chlorides from sand and gravels dug from the lagoon and rivers near Lagos shores.

When people talk of plain or reinforced concrete they often talk of organic impurities and sugar as the main danger. It should be noted that sulphates, carbonates, chlorides and combined water are not the only danger to plain or reinforced concrete. There are other factors of minor importance such as soluble lead and zinc compounds. Little or no research have been conducted on the chemical characteristics of the coarse and the fine aggregates that we use in plain and reinforced concrete in Nigeria.

Researchers avoid it because it is labour and money intensive. Coarse and fine aggregates are obtained from various quarries in Nigeria. The quarries should be identified with the chemical and mechanical characteristics of the aggregates. A thorough investigation of our local structural materials is of utmost importance to the structural engineers.

Different attempts have been made to replace the coarse and fine aggregate constituents of normal concrete due to economic and/or design considerations. Norsk Leca (Light expanded aggregate) has been used successfully in reinforced concrete by Shirayama (1971). Similarly, Evans and Dongre (1963) have experimented with Aglite and concluded that the resulting concrete compared favorably in strength with normal concrete. Blast furnace slag has also been used to replace gravel in concrete mixes, by Gutt *et al* (1988), Okafor (1998) suggested the use of palm kernel shell as lightweight aggregate in structural concrete. The properties tested include the physical properties of the palm kernel shell, the compressive, flexural and tensile splitting strength of the concrete produced with the palm kernel shell as coarse aggregate. These properties compared with corresponding normal concrete with crushed granite as coarse aggregate showed that palm kernel shell can always produce concrete with medium strength, not more than 30N/mm^2. This concrete will be suitable for structural elements in housing construction.

Olanipekun *et al* (2006) worked on the comparative cost analysis and strength characteristics of concrete produced using crushed, granular coconut and palm kernel shells as substitute for conventional coarse aggregate. The findings showed that concrete obtained from coconut shell exhibited a higher compressive strength than palm kernel concrete. There were also cost reduction of 30% and 42% for concrete produced from coconut shell and palm kernel shells respectively compared to normal granite. However, considering strength/economy ratio, the coconut shells are suggested when compared with palm kernel as substitute for conventional aggregate in concrete production for structural elements.

Refractory materials such as chamotte, limestone, chlorides, shale aggregate, slags burnt bricks and synthetics are used as coarse aggregate for structural purposes where high temperature is expected such as in the foundries, ceramics, iron and steel metallurgical industries for lining the path of the furnaces and for thermal shielding of nuclear thermal power plants as well as in the chemical industries. Where refractory materials are not readily available or available in limited quantities or/ and for economic reasons the use of normal concrete is invariably sought. The results of the experiments carried out on normal concrete as refractory material showed that, there was no appreciable loss in compressive strength of normal concrete when exposed for only 2-4 hours, to temperature up to 300°C while there is about 40% loss in strength at about 450° C-500°C.

In areas where there are no granite rocks available or available in small quantity, there may be a substitute materials such as basalt, which belongs to the same family of igneous rocks as granite but of basic rather than acidic origin. Geological findings show that basalts are widely spread throughout a number of continents including Europe, South America, Australia and Asia, though not as widely spread as granite in Africa. In Nigeria, basalt formations are found in the South and West of Biu Plateau, Namu, Gindiri, Pankshin and Runka areas and also in Jos Plateau in Plateau State. They also occur in Rabah, Gwaini, Wuino and Sokoto Plateau of Sokoto State. Traces of basalt can also be found in the Yoruba Plateau.

Basalt is fine grained (less than 5mm) surficial igneous rock with porphyritic crystals. It is characterized by approximately equal proportion of calcium-rich plagioclase and pyroxene as well as feldspar with less than 20% by volume of other minerals such as olivine, quartz, calcium-poor pyroxene and iron-titanium oxide.

Salau (1989) conducted experimental investigation on the possibility of replacing aggregates (coarse and fine) in normal concrete mixes with locally occurring basalt for use in high heat resistant environments or where the concrete can be subjected to sustained cyclic thermal exposure. The compressive cube strength values obtained for basalt and granite concrete specimens and their percentage to the initial strengths (at room temperature of 25ºC), as the temperature of the kiln rises are shown in Table 4. These values were determined after cooling to room temperature.

The results in Table 5 point out that with increase in the number of heating-cooling cycles, the granite concrete cubes lost their entire strength and started chipping and spalling at the end of the third cycle. The basalt concrete strength stabilized after the third cycle with 17% of residual strength and this was retained even at the end of six cycles of heating and cooling. These results showed that granite concrete may not be able to sustain cyclic heating and cooling as obtained in refractory materials but could satisfactorily resist heat up to 400ºC.

The following general conclusions were drawn from the test results on normal concrete (which contains granite and sand as its aggregates) and basalt concrete (containing basalt stones and dust as aggregates) under repeatedly heating-cooling temperature up to 900ºC:

1. The water absorption and porosity of normal and basalt concrete specimens fell within acceptable range of normal refractory materials.

2 There was instability in the volume expansion of normal concrete while basalt concrete displayed some coherent stability in volume expansion. The average volume expansion in normal concrete is about nine times that of basalt concrete cubes.

3 At the end of the first cycle of heating and cooling, subsequent heating and cooling cycle had no significant effect on weight loss of both normal and basalt concretes.

4 There was a sharp reduction in strength with increasing surrounding temperature in the normal concrete compared to basalt concrete where there was a gradual loss. At the end of the first cycle, the normal concrete retained only 18% of its initial strength, while the residual strength of basalt concrete was about 50%.

5 Normal concrete may not withstand sustained or cyclic thermal exposure. It lost its entire strength after the third heating and cooling cycle while the basalt concrete has a stabilized strength of about 20% of its initial strength at the end of the fourth cycle.

Basalt concrete, from locally obtained basalt, could be considered for used as slab and foundation material around the oven in indigenous nail and roofing sheet furnaces as well as in rolling mills instead of low heat resistant normal (granite) concrete or scarce and expensive imported refractory materials.

LOCAL LATERITE TO REPLACE SAND AND GRANITE

Weathered soils are composed mostly of iron and aluminum oxide and when dominated with iron oxide, they are called LATERITE. When aluminum oxide dominates, they are usually yellow or grey and are known as bauxile, Gidigasu (1976).
In an effort to find a suitable and cheap alternative building material to the existing ones for low cost houses, laterite was introduced into the aggregates of concrete. Laterite has featured in building construction works for a very long time in Nigeria. The majority of the houses in rural areas in use today were built from lateritic soils.

Table 4: Effect of Heating on Residual Compressive Strength of Basalt and Normal Concrete

Temperature (degrees)	Basalt Concrete Compressive Strength (N/mm^2)	% Residual Strength *	Normal Concrete Compressive Strength (N/mm^2)	% Residual Strength
25	28.8	100	30.1	100.0
100	28.3	98.1	28.7	95.2
200	27.7	96.2	27.1	90.1
300	26.6	92.4	25.4	84.3
400	25.2	87.4	23.5	78.2
500	23.8	82.5	19.4	64.4
600	22.6	78.4	16.4	54.5
700	19.1	66.2	12.8	42.4
800	16.8	58.4	10.20	30.5
900	15.1	51.0	5.5	18.0

* $\% \text{ Residual Strength} = \dfrac{\text{Strength at temp. } (T^{o}C)}{\text{Strength at temp. } 25^{o}c} \times 100$

Table 5: Effect of Heating Cycles on the Residual Strength of Basalt and Normal Concretes

No. of Cycles	Basalt Concrete Compressive Strength (N/mm^2)	% Residual Strength	Normal Concrete Compressive Strength (N/mm^2)	% Residual Strength
0	28.8	100	30.1	100
1	15.1	52	5.5	18
2	19.0	31	2.0	7
3	6.0	21	0.0	0
4	5.1	18	0.0	0
5	5.1	18	0.0	0
6	5.0	17	0.0	0

The practice varies depending on the location and related local problems and physical properties of the lateritic soils. Ola (1985) found stabilization of laterite with cement, lime, bitumen, etc, to be effective means of improving engineering properties of lateritic soils for road construction, rural infrastructures and low cost housing.

Laterite deposits occur extremely in Australia, Asia, South America and in Africa. They are generally used to produce bricks for dwelling houses in these areas because of their relative cheapness. Location of clay deposits in Nigeria is shown in Figure 1. Laterite usually contains a good quantity of clay particles.

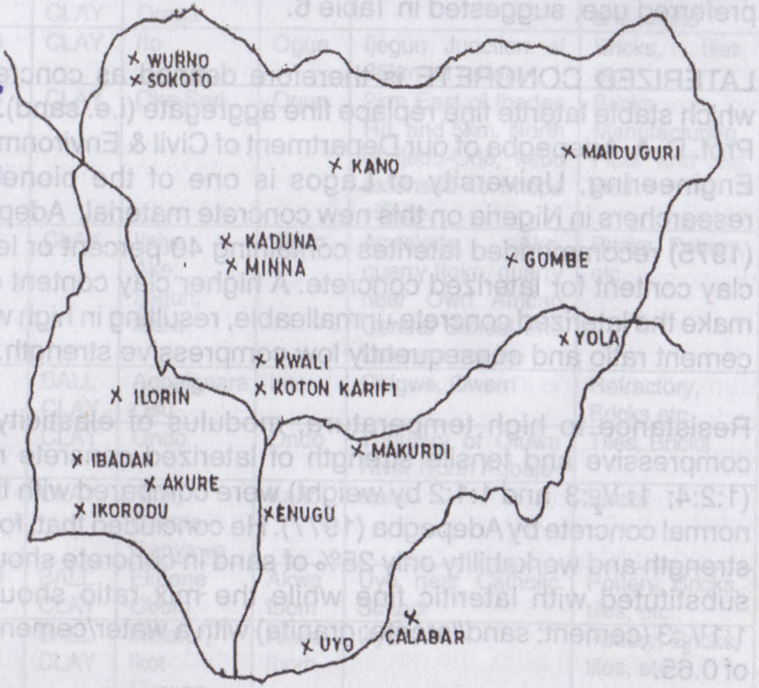

FIGURE 1: LOCATION OF CLAY DEPOSITS IN NIGERIA

Laterite is highly weathered material, rich in secondary oxides of iron, aluminum or both and is found mainly in tropical and subtropical regions. There are two types: fine laterite and rock or quarry laterite. For engineering purpose, Gidigasu (1974) has identified two types of fine laterites: "sensitive" and "stable" laterites.

The sensitive laterite, which are unsuitable for engineering purposes, are generally found in regions of recent volcanic activity, and evaluation of their properties is unreliable. The stable laterites suitable for structural works, are amenable to standard laboratory tests. A systematic survey of clay deposits by the Nigeria Geological Survey Department is given in Figure 1 and their preferred use, suggested in Table 6.

LATERIZED CONCRETE is therefore defined as concrete in which stable laterite fine replace fine aggregate (i.e. sand). Late Prof. D. A. Adepegba of our Department of Civil & Environmental Engineering, University of Lagos is one of the pioneering researchers in Nigeria on this new concrete material. Adepegba (1975) recommended laterites containing 40 percent or less of clay content for laterized concrete. A higher clay content could make the laterized concrete unmalleable, resulting in high water-cement ratio and consequently low compressive strength.

Resistance to high temperature, modulus of elasticity and compressive and tensile strength of laterized concrete mixes (1:2:4; 1:$^1/_2$:3 and 1:1:2 by weight) were compared with that of normal concrete by Adepegba (1977). He concluded that, for high strength and workability only 25% of sand in concrete should be substituted with lateritic fine while the mix ratio should be 1:1$^1/_2$:3 (cement: sand/laterite: granite) with a water/cement ratio of 0.65.

Table 6: Clay Deposit Suitable for Bricks in Nigeria

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 extensive 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

Lasisi and Osunade (1984) studied the effect of grain size and optimum moisture content on the cement-stabilized and unstabilized lateritic soil and concluded that compressive strength obtained for cement-stabilized lateritic soils depended on the mix proportion and that there exists a linear relationship between the optimum water/cement ratio and the laterite/cement ratio. The results on the effect of chemical admixtures on the compressive strength of lateritic soil material for masonry units showed that the compressive strength of stabilized specimens containing sugar admixtures are higher than those with no admixtures or with calcium chloride while the strength also increases with curing time and the levels of admixture.

In Brazil, just as in Sierra Leone, there are no suitable sand and gravel for concrete but there is abundance of coarse and fine laterite. Thus, in Brazil, laterized concrete has been accepted and used for construction of houses and bridges.

Soil deposits vary in composition from one site to the other, hence you will expect the composition of the Brazilian or Sierra Leonian laterites to be different from those of Nigerian. The properties of lateritic soils that will influence its rate and ease the mixing include: the degree of finess, particle shape, stickness, chemical stability and chemical composition. The delay in the general use of laterized concrete in housing construction is due to the poor and inadequate knowledge of its durability and long-term resistance. Salau and Olatunji (2000), in an International Conference on housing "Shelter Africa 2000", reported the results of their investigation on the physical and strength characteristics of varying grades of laterized concrete with fine. The results showed that:

i. For the same mix proportion, percentage laterite content and water/cement ratio, the density of laterized concrete reduces gently with age from 28 days but stabilizes at about 70 days.
ii. Due to the higher fine aggregate/cement ratio in the 1:2:4 mix compared to 2:3:6, more water would be expected in 1:2:4 mix for the same laterite/sand content. For the same mix

ratio, the rate of strength gain with increase in laterite content increases as the water/cement ratio increases.
iii. The maximum cube strength of laterized concrete was attained around 50-56 days for different mixes and water/cement ratios depending on the % laterite content. The reduced strength at 70 days was still higher than 25N/mm^2 strength on which most designs are based.
iv. For 0 and 25% laterized concrete, rate of gain in strength with age is inversely proportional to the w/c ratio whereas for 50%, 75% and 100% laterite substitute the rate of strength gain is directly proportional. This may be due to the necessity of additional water for workable mix for higher % laterite substitution in view of the higher absorbent nature of clay (about 44%) in laterite.
v. The strength in normal concrete (0% laterized concrete) is only about 10% higher than the corresponding 25% laterized concrete.

The results showed that, a mix proportion of 1:2:4 with up to 50% substitution of fine aggregate with laterite and water-cement ratio of between 0,50 and 0,60 is recommended for structural elements in housing development. The resultant cube strength is not less than 30N/mm^2 at 70days. This shows about the same strength as the corresponding normal concrete (0% laterite) at the same age.

In order to compliment the findings on the short-term (not more than 28 days) strength characteristics of laterized concrete, Salau and Balogun (1998) and Salau (2002) studied respectively the shrinkage and creep deformation of laterized concrete short columns. Note that creep is a property of concrete members by which they continue to deform over considerable length of time at constant stress or load, while shrinkage is a deformation and volume change of concrete members under the influences of a different nature, even without external loading. The general findings, on the long-term durability, being that instantaneous modulus of elasticity and compressive strength of laterized concrete with 25% laterite content of fine aggregate compared favourably with those of normal concrete of similar mix proportion by weight and water/cement ratio. The mix ratio of $1:1^{1}/_{2}:3$ (cement: sand/laterite: granite) by weight was also suggested.

Much works have been done on laterized concrete including the long-term resistance for it to have been used in building, however, no code of practice on laterized concrete to encourage the users. Laterized concrete was pioneered in Nigeria more than 30years ago. However, its introduction into the construction industry has been delayed also because we still have sharp sand and granite/ gravel to use but these are not cost effective. The adage still comes true that "Necessity is the mother of invention". The researchers are getting tired of working and development of substitute of imported structural engineering materials without the practical application, that is, support from organized private sector, the government and the public at large.

LOCAL BAMBOO AND PALM FIBRES ALTERNATIVES TO STEEL MESH OR STEEL REINFORCEMENT

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. We 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% biogradable as possible substitutes for steel reinforcement and steel mesh.

In the area of concrete there are two important offshoots (i) the ferrocement and (ii) glass fibre reinforced cement. The word "ferrocement" indicates that the material is a composite of ferrous material and cement. It is not a reinforced concrete but it is in the same family of composite materials like concrete. Ferrocement is cement mortar reinforced with welded or chicken mesh. The mesh or fine wires which are closely spaced is

completely impregnated in cement mortar to form thin sections of about 25mm thickness. The glass fibre reinforced cement was the result of a research by Dr. A. J. Majunder at the Building Research Establishment in 1967. It has since gained fame. It is being used to make roofing sheets, claddings, furniture, baths and most household furniture.

The reason for highlighting ferrocement and the glass fibre reinforced cement is not to introduce them to you for use rather they are meant to suggest to you that bamboo can be used to replace the chicken mesh or the glass fibre. 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 connotate 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 [Youssef (1976) and Kankam *et al* (1980)]. Castro and Naaman (1981) reported that natural fibres of the agave family have significant mechanical properties that make them suitable as potential reinforcement of cementitious matrix. Lakshmipathy and Santhakumar (1980) 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. However, the behaviour of fibre reinforced concrete under normal loading was not investigated by them.

Air-dried palm timber has been the traditional structural material for constructing roof trusses and shutter frames in some part of

West Africa and can still be found in antiquated buildings, this proving to be resistant to attack by insects and fungus.

For artificial and natural fibre reinforcement, the major process of reinforcement is the transfer of stress to the fibres by means of shear traction at the fibre-matrix interface once the matrix is deformed under load. In natural composite material, like palm timber, the fibres are continuous elongated chains of cellulose which do not run entirely straight and parallel, but meander through the matrix along the axial direction. Thus, the transfer of load from the matrix to the fibres is expected to be very effective and the reinforcement effect would be considerable.

A Ghananian, Kankam (1993), investigating the use of Raffia palm in structural concrete, recommended it for use in minor concrete members such as lintels, pavements slabs, cover slabs and drains. Adetifa (1990) reported that the ultimate load carrying capacity of fan-palm reinforced concrete beams increased with increase in percentage of reinforcement. Jimoh and Adetifa (1993) further studied fan-palm reinforced concrete one-way slabs to determine the effects of variation of reinforcement, pre-load, repeated cyclic load and alternate wet and dry cycles on their flexural strength and crack formation. It was observed that the first crack load was not appreciably affected by the reinforcement as there was little variation in the plain unreinforced slab and fan-palm reinforced slabs. It was also noticed that the ultimate failure of fan-palm reinforced slab was accompanied with large deflection and wide cracks due to low modulus of elasticity of the fan-palm fibre.

Salau and Sadiq (2001) reported results of investigation to assess the possibility of replacing steel reinforcement with oil palm fibre strips, obtained locally from oil-palm trunks and concluded that the use of oil palm fibre strips as reinforcement in concrete improves the Flexural strength and post cracking ability as well as serviceability performance of plain concrete. Also, the mode and pattern of failure of reinforced beams under flexure are

independent of the materials used for reinforcement. We recommended that the oil palm fibre reinforced concrete with a maximum of two 25mm width and 10mm thick splints can be considered for minor structural elements in rural and urban low-cost housing as the esthetic problem from the slight increase in deflection can be tolerated in many houses in rural and even urban areas in developing countries. The palm fibre strip reinforced concrete can also be used in minor structural concrete elements such as lintels, cover slabs and drains.

Salau and Ikponmwosa (2008) studied the structural characteristics of bamboo strips, reinforced concrete slab with a view to determining their adequacy their adequacy in building construction. The results indicated that bamboo has a fairly tensile strength and could be a reasonable substitute for steel reinforcement in reinforced concrete slabs for flexural applications in affordable housing component development. We also discovered that the use of fibre rope in conjunction with sand and bitumen yield a fairly good bond between the concrete and the reinforcing bamboo.

Salau and Sharu (2004) further assessed the contribution of bamboo strips in the strength of laterized concrete columns and the results showed that the bamboo reinforcement did not contribute to the load-carrying capacity of the laterized concrete columns due to its low modulus of elasticity and shear capacity. Bamboo strips are thus not recommended as reinforcement in laterized concrete columns.

For the past one hour or so, I have been explaining the research work conducted to ascertain the availability of local materials in substitution for imported ones in structural engineering practice. But why are there no structures using the research findings and why is the cost of construction not affordable by the teeming population? Why is the cost of housing rising daily and continuous inflation in the cost of materials which can be easily substituted at the back of our compound? This is as a result of psychological indoctrination of our leaders and people that our traditional or local technology needs further development as imported materials are always better.

We should not forget that without the practical application, the research findings will stop in the laboratories and will be of no value. Today, Japan has become a world giant in Electronics because of the funds provided and support for the researchers as well as the practical application of their results and findings.

There should be the government and private sector determination to have confidence in the academics and research Institutions about the results of their findings and as such intensify support for the practical implementation of such findings.

It will be recalled that in the middle of eighties, Gen. Kontagora (Rtd), the then Hon.Minister of Works and Housing, supported Prof. Olusanya (then Okusanya and a Senior Lecturer in the Architectural Department of the University of Lagos) and his research team on Low-cost housing and provided the sum of ₦100,000.00 for each wing duplex at the Onike Entrance Gate of the University of Lagos. The building was made up of interlocking blocks for walls; the first floor concrete slab was constructed using whole bamboo as reinforcement. Even the roof was made of paper-cement composite tiles as against asbestos or long-span aluminium. The building is still standing till today, apart from the fact that the roof has been changed to long-span aluminium due to leakage.

I have no doubt that if further funding had been provided, the researcher(s) would have perfected more cost effective buildings and structures using the local substitutes for the imported materials.

Another example of support to research findings is the Clay Industry at Oregun, Lagos State. This company started producing mainly fancy blocks (ornament blocks), about 20 years ago,

before it changed to load-bearing bricks as well as hollow clay pot ribbed floor construction as at that time.

The most widely used flooring system for suspended floors locally is the solid *in situ* reinforced concrete slab. At the scale of residual construction, this system is structurally inefficient as most of the strength and materials go into supporting its own weight (the dead load). Elaborate preparations go into casting it in form of temporary access, formwork, props, iron bending etc. And then the casting of whole floor has to be done in one process, sometimes requiring working late into the night with make-shift lighting on precarious terrain. The system seems quite wasteful in terms of labour, time and materials making it quite expensive. Salau and Olatunji (2000) reported results obtained in an attempt to establish the quality of the locally manufactured structural clay products in relation to local and international standard specifications as well as ascertained the structural performance, safety and economy of the clay brick structural use of elements in housing construction. The elements include columns, beams and slabs.

Today, the usage of the hollow clay pot ribbed slab construction has been popularized, especially in areas where reduction of loads on foundation is very essential due to the weak soil strata.

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:

- 8-Storey Hotel building on Akinwunmi Street, Okupe Estate, Mende Maryland, Lagos State in 1989. (Collapsed on the Eve of Official Opening)
- Saque Comprehensive Primary and Secondary School, Port-Harcourt, River-State on the 15th June, 1990.
- Two-storey building at Maryland, Lagos State on the 1st Jan. 1999
- Uncompleted church building at Mafoluku, Lagos State
- 3-storey building at Abuja, 1996
- 3-storey building at No.3 Cheme Avenue, New Haven Enugu, Enugu State, on the 12th June, 1997
- Main entrance canopy of the main approach to the Eleganza Ball Pen Industry Estate, Ajah, Lagos State, 2000
- Collapse of completed and earlier certified fit, three-storey building at Ebute-Metta West, Lagos Mainland in 2006
- 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
- 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.
- Partial Collapse of Bank of Industries Building at Custom Street, Lagos in 2006
- Two-storey Residential House at Ibadan Street, Ebute-Metta East in Lagos Mainland in 2007
- Residential Building at Okepopo, Lagos Island in 2008

Salau (1996) presented paper on Causes and Prevention of Collapsed Building at a seminar organized by the Lagos State Ministry of Environment and Physical Planning. I investigated structurally distressed buildings (Salau 1998) at Ojo Giwa and Okoya Streets, Lagos Island with a view to avoiding total collapse of such buildings. I have also been participating actively in the Investigation and Failure Analysis Committee of the Nigerian

Society of Engineers, where reports of the above stated incidences were written and recommendations presented to the State Governments. 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).

From the experience of the investigation of the failed structures, the lesson to be drawn therefrom can be expressed with this statement:

The one thing which these failures conclusively point to is that all good concrete construction should be subjected to rigid inspection. It should be insisted upon that the inspector shall force the contractor to follow out the specifications to the most minute details. He must see that the materials used are proper and are properly mixed and deposited, also that the forms are sufficiently strong and that they are not removed until after the concrete has set. It is believed that only by this kind of inspection it is possible to guard against the failure of concrete structures.

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."

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.

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 pozzolanas 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 Professional Bodies especially 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.

ACKNOWLEDGEMENTS

Mr. Vice-Chancellor, Sir, I give utmost gratitude to the Almighty Allah, the Great Shepherd, who had guided me up till today and I still hope for his further guidance on the right path, the path of those upon who He had favoured.

I am greatly indebted to the University of Lagos, for giving me the opportunity to be who I am today. The University has created a conducive and enabling academic environment for my career development and academic excellence. I am always proud of UNILAG.

I am grateful to all my teachers at different levels and students for their confidence in me and support. I will like to single out Prof. T.A.I Akeju who was the Acting Head of the then Civil Engineering Department and Prof. Fajemirokun who was the Dean of the Faculty of Engineering for the opportunity given to me to serve in the faculty, when I just came from the Soviet Union to participate in the compulsory one year Youth Service Corp. This was the time when people felt the degrees from Eastern Europe were inferior to those from U.S.A or Western Europe. I had to disabuse many minds during the service period. Today, there is no Department in Engineering without a Soviet trained Lecturer.

For those who have contributed to the development of my career and made this lecture a reality and success, especially my immediate family, I say very Big Thanks. I will like to appreciate my wife, the very beautiful ebony black, Hajia Zainab Olufunmilayo Salau, for her support, love and care. She abandoned her career and well paid job to take care of the home front and provided me the enabling environment to succeed.

I will not forget to join with my family, brothers, sisters, my professional colleagues especially from the Nigerian Society of Engineers and C.O.R.E.N and people of goodwill who had supported and believed in me all along.

Mr. Vice-Chancellor, Sir, distinguished colleagues, esteemed guests, ladies and gentlemen, I am immensely grateful to you all for your patience and kind attention while the lecture lasts. I wish you all journey mercies.

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