UNIVERSITY OF ILORIN

THE TWO HUNDRED AND TWENTIETH (220TH) INAUGURAL LECTURE

"EXPLORING LOCAL MATERIALS FOR BUILDING DEVELOPMENT"

BY

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Distinguished Invited Guests and Friends,
Students of this University,
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Members of the Print and Electronic Media,
Ladies and Gentlemen.

Preambles

Glory and praise be to the Almighty Allah the Lord of this world and the King of the day of judgement. It is with great pleasure and gratitude to Allah I stand before you to present this 220th Inaugural Lecture of this great University that has brought me up through my three degrees. I thank the Vice Chancellor for the great opportunity given to me to present the Lecture.

Childhood Training under Father's Care

Mr Vice Chancellor Sir, I received some childhood trainings under my father's care, for which I seek permission to present, because it relates to my Inaugural Lecture of today.

My good late parents have taught me in the best way of life at young age and were my best childhood teachers. May Allah forgive them their sins and grant them with Aljanna fridaoz (Aameen). My late father taught me on how to farm and carry out local building constructions; to be disciplined, prudent and endure; and to learn in both the Islamic and Western educations, respectively. He was an employee of Ministry of Agriculture Ilorin for many years, and there, he was given the responsibility of application of cows for farming activities. He retired in 1968. After his retirement, he turned into a full time farmer and preferred planting crops like maize, cassava, yam, sweet potato, guinea-corn, beans and other food crops, which were done on a large scale in conjunction with us, his children. These crops were harvested in dry season and in large quantities. However, there existed then the problems of storage of these crops and the cheap means considered that time was to build mud silos, called *Àká* in Yoruba language, for the storage. The silos were constructed in the dry season of the year and left to air-dry enough before use. It was in the construction of this mud silo that I received one of my major childhood construction trainings. Due to the relevance of this silo to the theme of this inaugural lecture and its importance in the olden days and even in this modern day raw food storage devise and for people to learn from, I therefore considered the presentation of its construction in today's inaugural lecture, may be an interested individual can take up its improvement.

My Experience in Mud Silo Construction

My training in mud silo construction started at very early age, in 1960s, in my local community, Kulende in Ilorin area. During the trainings, I played active roles on material procurement and in silo construction processes.

Preparations for silo construction

(a) Considerations: The olden day's mud silo was usually located near residence and in a clean and well drained area. These precautions were taken in order to protect the stored raw food against theft or against being soaked in water or prevented from being contaminated with filth. The construction tools were simple and light with major ones being the big cutlasses and small axes that were used to cut down usable timber pieces from trees; and the arc shaped knifes (*Dògé*) that were used for cutting grasses. Hoes were used for mixing the mud constituents.

(b) Silo materials: The silo construction materials were all natural and existed within the vicinity of the silo location. They were: pieces of a timber type (*igi-aáyán* in Yoruba language local name), fibrous grass (locally called *kóko eéran*), long grass called (*kókobẹ̣ẹrẹ*), ropes (*okùn*), big stones (*òkútańlá*-boulders), water, laterite (*taàrá*), and flexible bamboo rods (called *Aparun or Ọparun*). The *Igi-aáyán* timber was preferred then because from experience, it was found to be strong and durable. Some of these materials were further stabilized, synthesized or combined to form another usable ones, such as laterite plus grass to form composite; and the weaved grass to form thatch using ropes. The proportions of each of these constituents were chosen based on experience and large quantities of them were prepared and stockpiled before the silo construction commenced. The materials were later applied systematically to construct the silo components, that is, the foundation, the base slab, wall and roof, respectively.

(c) Silo components construction: The silo foundation was a shallow type and built using stones arranged in concentric circles; the base slab was constructed of grass-mud composite reinforced with timber rods. The silo wall was circular on plan and constructed of the same mud composite material as the base. The roof components were the thatched sheet as cover, with i*gi*-

aáyán timber as rafters and flexible bamboo rod as purlins. No nail was used.

Method of storing the raw food: The mode of storing the raw food was to first stack the food in sacks and then transferred into the silo interior. A normal size silo can take up to 10 sacks of raw food at a time, depending on the size of the sacks and that of the silo.

Maintenance of the silo: It is pertinent to mention that none of the silos constructed then collapsed after loading and any crack formed was mended with laterite. The major routine repair being carried out was the replacement of the thatch, if found tattered.
A typical mud silo, similar to those constructed then could not be found around but was downloaded and given in Plate 1.

It is also pertinent to state that as I grew older, I left my father to a Secondary School (Ilorin Grammar School), as a boarding student. This marked the end of my training. However, by this time, I had mastered the mud silo construction processes.

What can now come to the mind nowadays is that was the building of a mud silo then a civil engineering work? The answer to this question can come from the definition given to Civil Engineering, by Naseer (2014) that “civil engineering is a professional engineering discipline that deals with the design, construction, and maintenance of the physical and naturally built environment, including works like roads, bridges, canals, dams, and buildings”. Thus, the olden days building of a mud silo was a civil engineering work except that it was done by experience and no design processes were involved. Nonetheless, application of both design and experience are important for the safety of a structural system.

Some interventions for the improvement of mud silo construction

Now that I have acquired the knowledge of civil engineering, I have the opportunity to improve the mud silo construction processes. This is more important because record has shown that data on mud silo materials and its construction processes are uncommon, whereas the silo itself is an important structural system where courses in civil engineering curriculum at the university level can be applied to. Therefore, for further strength and durability improvement, students were given final year project by me for the investigation of the optimum performance of the silo mud wall. The titles are as shown inTable1.

Plate 1. The mud silo similar to the one I was trained with at childhood

(https://www.google.com/search?q=rhombus+earth+silo+(23/4/2021))

Table 1: Some students' undergraduate projects under my supervision to determine the optimum performance of the mud composite

S/No.	PROJECT TITLES	NAME OF STUDENTS	YEAR
1	Determination of optimum percentage fibre reinforcement in lateritic soil for silo using *Eragrostistremula (*Eeran*)*.	Oparinde, Akintunde Dare	2007
2	The study of coconut fibre reinforced lateritic soil for the construction of a mud silo.	Saka, Abiodun Ismail	2007
3	The experimental optimization of lateric soil strength for silo construction using palm kernel fibre.	Lawal, Abiodun	2007

It is important to stress that the fibre stabilized mud used for the silo is also useful for mud walls in buildings. Therefore, a local builder who may want to apply this work can approach the department for assistance. To further have stronger wall for silos and for building structures generally, it was thought that the mud wall could be replaced with strong and durable bricks. As a result of this, exploration of improved bricks was carried out through also using students' projects at undergraduate and postgraduate levels, respectively. One was the Ph.D. research work, titled "Optimization of component mixes for laterite-cement composite bricks", carried out by Alao (2017)and supervised by me. My research activities have not still stopped, as various studies are still ongoing, to strengthen mud materials.

The Inaugural Lecture Series: The first inaugural lecture in the Civil Engineering Department of this university was delivered by Prof. S.O. Adeyemi in 1988 with the title "*Nation's quest for water"* while the second was in 2003 by Prof. B.F. Sule, titled "*Water Security: Now and Future".* Both inaugural lectures were on water. Today's inaugural lecture, titled *"Exploring Local Materials for Building Development",* is on structure and material. It is the third in the series of the University Inaugural Lecture in the Department and the first in the structure and material option of the Department.

Introduction

Why choosing the title as *"Exploring Local Materials for Building Development"*: The question that can come to the mind of individuals could be why choosing this title. Some of the reasons are that building materials constitute an important component in building construction as it accounts for up to 70% of construction cost (Alade et.al, 2018). Interestingly, Africa generally and Nigeria in particular, are endowed with the abundant natural resources but they still depend on imported building materials in construction. Therefore there is no any other time than now to present this inaugural lecture because of the dare need of low cost housing, especially forthe low income earners of the society. Literatures on materials and housing indicated that many nations are being faced by housing deficits. May be, this is one of the reasons that made the United Nations to set up a Developmental Programme, tagged "Sustainable Development Goals (SDGs)"with 17 chatters, 11th of which has the title "Sustainable Cities and Communities", having the objective of creating a good and affordable public housing, assumed would be met in the year 2030.Thus, this 11th chatter indicates that housing shortages is international. Therefore, one of the answers to attaining this goal is to embrace the use of local materials in order to make the housing affordable. Use of local materials as against foreign is reported to safe up to 26% of project cost (Oluwaseun et.al. 2019) and in addition, using local material removes the dependency and slavery to foreign economy and reduces devaluation of the local currency.

Inaugural Lecture Title Explanation: The words that stand out in the title of the inaugural lecture are "exploring", "local materials", "building" and "building development". These are therefore explained as presented below.

"Exploring": The word exploring is from exploration and defined in the computer dictionary (America Edition) as examination, survey, search, investigation, assessment, evaluation. In this context therefore, exploring local materials is to carry out search, investigation and assessment of these materials, their origins, properties, processing and applications for building purposes. Exploring (searching) for local building material requires rigorous activities. Earth surface gives the material like sand, gravel, clay, iron ore, and agricultural produce like rice and other crops that can generate wastes which can be converted to building materials. Also, the savannas and forested regions of Nigeria give timber, bamboo and grass, etc. The rocks give granite, quarry dust; lime stone and shale. Some of these materials are used as found (raw) and some undergo further processing to give stronger materials like: mixing of sand and cement to give sancrete blocks; addition of lime stone and clay or shale and gypsum to give cement; heated clay to give burnt bricks; iron ore and carbon added together to form steel; timber (tree stems) converted to planks. These final products are stock-piled in the industry for sale or carried to the construction sites or to markets.

In the effort of exploring local materials for students' projects and for research activities, this took me to various places like forests, industries, markets, sawmills and wastes deposits, to obtain them. The places of exploration are as presented in Table 2.

Table 2: Exploration destinations for local materials used for research works and students projects

Type of material	Exploration destinations
Bamboo	Construction sites, forests and bamboo colonies in Ilorin
Fanpalm	Plant colonies in Alagbon village in Ilorin, Egbe and koro villages in Kwara State
Rice husk	Rice processing mills in Ilorin
Granite and stone dust	Quarry sites in Ilorin
Gravel, laterite, water and wastes such as saw-dust, waste paper, calcium carbide, grass and other agricultural wastes	Ilorin
Reinforcing bars	Iron markets and construction sites in Ilorin
Timber products	Sawmills in Ilorin and Lagos
Bone, bone ash and sandcrete blocks	Kano and Ilorin
Cement	Obtained from cement markets in Ilorin

"Local Materials":

(i) Meaning of local materials: The word **"**Local materials" refers to the materials that are available or being produced within the country. However, the word "local" is reported to generate controversies (Omole & Bako, 2013). A material can be local, based on where it is produced or where used or where sold or where found and so on. This is one of the reasons too that initiated the choice of the word "local materials" for this inaugural lecture. Using local materials, in addition to the benefits earlier stated, also supports the local businesses and feeds money into the national economy. The local materials are environmentally friendly, which can therefore make them produce save and low cost buildings (Suhamad, 2020).

(ii)Traditional and modern materials: Some of the local building materials are traditional while some are modern. The traditional materials first used by man included timber, mud, clay, wood and straw. In the olden times, people used these materials for building purposes (Laura, *et. al*, 2021 and Khitab, *et. al*, 2015). The traditional materials were more about the usage than feel or look, which also has affected the traditional mud silo just discussed as the concern on them then was on their usage without caring about making them attractive. On the other hand, a lot of the modern materials are manufactured and included concrete, bricks, steel, aluminum, and other similar ones. They are concerned with the look along with their functions. In this modern age, engineers have learnt to mix and match the right materials to come up with higher quality structures.(https://www.google.com/search?q=location+of+building+materials+in+Nigeria; downloaded on 04/10/2021).

(iii) Classification of building materials: Building materials can be classified into three major groups:(a) Cement material(cement, lime mortar, cement plus sand and water, and concrete and sandcrete blocks); (b) Solid materials(bricks, stones, timber, iron rods and aluminium); and (c)Protective materials(paints, plaster varnishes etc.), Mimi *et.al.*(2011).The first two classes contribute to the building strength, durability and stability, while the third only protects and contribute to the aesthetic appearance of the building.

(iv) Agencies and organisations responsible for building materials: In order to explore efficiently the local building materials, the Nigerian government relies on some organisations or groups for information, such are the Standard Organization of Nigeria (SON), Raw Material Research and Development Council (RMRDC), Council for the Regulation of Engineering in

Nigeria (COREN), Nigerian Building and Road Research Institutes (NBRRI) and Nigerian Society of Engineers(NSE), etc.

(v) Roles being played in the university: On my own part, one of my contributions to local materials as a teacher in the university is to teach the students on what these materials are and how they are being used for building purposes. Further ways of imparting the knowledge is through investigations carried out by the students in their final year projects, as shown in Table 3.The table covered test of timber properties, application of waste material, production and application of cement sheet, fibre concrete, aggregate size study and replacement of cement with lime. All these can as well be applied by local designers and builders in their various construction activities. The department can also carry out these on a large scale for an interested individual or for the government.

Table 3: Some students' projects on materials supervised by me

S/No.	Project Title	Name of student	Year
1	Characterization and Grading of Four Timber Species sourced from Timber Markets in Kwara State, Nigeria for Structural Applications	Rahmon, R. O.	2018
2	The study of physical and mechanical properties of wood wool cement board (WWCB)	Olanipekun, O.K.	2007
3	Effect of palm kernel fiber on strength properties of waste paper-cement sheet	Oyeleye, F.O.	2016
4	The influence of aggregate sizes and types on compressive strength of concrete	Awe, S.S.	2006
5	Investigation of (*Maratochloa flexnosa*) pankere mesh in cement mortar sheets	Aliu, O. G.	1999

"Building":

(i) Definition of building: The building being referred to in this inaugural lecture is a structural system that possesses foundation, floor, wall and roof and gives shelter to human beings and in the process gives security, serves as protection from weather, gives living space, privacy, serves to store belongings. It is supplied with electricity in order for man to comfortably live in and work (Wasiu, *et. al,2014*). Shelter is reported to be the first human need for living in this world even before food (Mansur, et. al, 2017)

(ii) Classification of buildings: Buildings, according to the International Building Code (IBC,2012), are classified into many categories as: Assembly Buildings, Business Buildings, Educational Buildings, Factory Buildings, Hazardous Buildings, Institutional Buildings, Mercantile Buildings, Residential Buildings, Storage Buildings, and Utility & Miscellaneous buildings. The mud silo that has been discussed belongs to the class of Storage Buildings. Of all the building types listed, the residential ones are the most popular all over the world, may be because it is for human habitation. However, though the buildings may belong to different classes, the building materials and the construction procedures are similar.

"Building Development":

(i) Definition of "Building Development": According to the dictionary, this compound word means building growth, building expansion or increase. A good building development is favoured when the material is durable, low cost and not scarce and there is no building collapse. However, to achieve this, there should be well planned stages of work on building, from conception, construction to maintenance. These requirements are handled by the professionals who must ensure that the qualities are met while the client provides the finance.

(ii) The role being played in the university on building development: At University of Ilorin, a good role is being played by me in the building development through my department- civil engineering. Under community development, I have got involved in building design, supervision of various building constructions, and also involved in investigation of building defects, integrity checks and building failures, as reported by Jimoh 2017, 2018 and 2019, respectively. Students are equally being trained on building development through teaching and through apportioning final year undergraduate projects of titles as shown in Table 4. These projects cover building design and building collapse analysis. On a larger scale, the department is capable of carrying out the design, construction and monitoring of building fitness with respect to stability or safety, in the town or elsewhere, for the government or individual, if approached.

Table 4: Some building related final year projects supervised by me

S/N	Project title	Author	Year
1	A survey of causes of collapse of buildings in Lagos state in the last five years	Ogunleye, G.O.	1999
2	Comparative design between BS 449 and BS 5950 on a two storey Office Building	Odunsi, W. A.	1995
3	Analysis & design of a four storey residential building subjected to vibration	Ayodele O.T.	2005
4	A comparison of manual and CSC Orion software approaches to design of reinforced concrete structures	Atume, P.	2012
6	Computerization of design procedures of some structural elements according to BS 8110	Adepoju, O.O.	1997
7	Development of software for plane frame analysis for a twenty storey building	Adewole, K.K.	1997

Allocation of Materials to Building Components

Purpose of allocating materials to building components: Building components are foundation, columns, beams, slabs, and others. The materials being applied to make a building component must make the building serve the intended purpose. There is substructure and there is superstructure components of building, each with its own exposure type. Those at the underground (substructure) are moisture or water, salt and acid attack; while above the ground (super structure) are the low and high temperatures and their fluctuations effect, acid rain, strong wind and earth quacks. Also existing on surface and underground are the insect attack and fire hazards. In all these, the building or any of its components must survive.

Suggestions on allocation of materials to building components: Some literatures have given some guides on allocation of materials to building components from which appropriate material can be chosen as shown in Table 5. Where more than one materials are available for a particular component, the choice can then be based on the material cost or its durability.

Table 5: Building components and the corresponding materials required for its construction

Building Components	Building Materials required
Foundation	Burnt brick, plain or reinforced concrete, wood
Floor	Stabilized earth, burnt clay and concrete , precast concrete, bamboo floor, timber floor
Wall	Stone, earth-(e.g. laterite), burnt clay, concrete blocks, reinforced concrete, ferrocement, fibre concrete, natural fibre, grass, leaves, bamboo, timber,
Roof	Grass thatching, timber , burnt clay, fibre concrete, tiles, corrugated galvanized iron sheet, Earth, reinforced concrete, bamboo

In table 5, some materials are weak while some are strong and durable like steel and concrete, but they are costly. On the other hand, the low cost materials like thatch, timber and bamboo, are weak and have low durability but abundant locally. Therefore, it is required to carry out research activities on them, to improve their properties, to achieve both low-cost and durable and sustainable materials.

Actions Towards Patronising Local Materials

Reasons for need to patronise local materials: Reasons why local materials should be partronised and not manufactured or imported materials, have been expressed in various literatures. Spence & Cook, (1983), published the comment made by the late President Julius Nyerere of Tanzania, where he challenged the prevalent attitude of users of building materials, to prefer the manufactured ones or imported ones, that "there are indeed alternatives to cement, to concrete blocks, to corrugated–iron roofs, to steel doors and window frames; alternatives which can make good use of locally available raw materials, and of abundant local labour rather than scarce capital and foreign exchange". Although this expression was made about 40 years ago, the problem of preference of foreign engineers and imported and manufactured materials to local building materials still persists. Similarly expressions were made Emmanuel Appiah-Korang of Ghana, in a keynote address during an international conference in Ghana.

Actions by the Nigerian Government on provision of building materials: In order to ameliorate the problems facing the achievement of low cost building materials, and also to reduce the effect on national economy, Nigeria has set up the Raw Materials Research and Development Council with the objective to support and expedite industrial development and self-reliance through the maximum utilization of local raw materials as inputs for our industries (Adegoke, 1989).

Efforts made by individual researchers: On individual basis, many researchers, especially in the developing countries, are working to combat the problems that can affect owing a cheap house through study of cheap local materials. For example, Agbede and Manasseh(2008), investigated the use of cement-sand admixtures in laterite brick production for low cost housing; likewise, Abraham and Albert(2013) reported on sustainable housing supply in Nigeria through the use of indigenous and composite building materials. There are also many other researchers that have studied using other types of local materials for building development.

Effect of Material Misapplication on Building Development

Misapplication of materials in construction: While some people are using the building materials according to the specifications, some have embarked on wrong use. The wrong use major effect is to cause the building to collapse, as reported by Oyenuga, 2014, Hilary, *et. al*,2018; Oyebode,2021; and Bamigboye, *et. al* ,2018. One of the misapplications, according to these literatures, was on cement that appears to be a major material that is being abused in construction. According to the authors, there are two major types of cement grades in the markets for designers to recommend: $32.5N/mm^2$ and $42.5\ N/mm^2$. Each grade is suitable for some specific uses. In addition, the designers or manufacturers of materials need to also specify other things to achieve the appropriate concrete strengths, like the appropriate water/cement ratio, maximum time of placing concrete after mixing, storing method for cement and maximum number of days of storing cement before use. Apart from misapplication of cement, similar wrong uses are also facing other building materials like steel and timber.

Results of misapplication of building materials on building stability: The misapplication of materials lead to preliminary faults like cracks, weaknesses, deflections and finally collapse. Information regarding preventions are given in BS 8110 (1997), Oyenuga (2014) and John (2014). Evidences of effect of misapplication of materials on building have been reported in Nigeria. Oyenuga (2010) reported that in Abuja, block wall turned into dust on collapse in 2010. Also in 2010, a two-storey building collapsed in Auch, Edo State and caused by poor concrete strength in the order of $10N/mm^2$ as against 25 N/mm^2, the required strength. Also, the JABI building collapse in Abuja was caused by using packs of blocks as foundation. In Ilorin in 2012, a report of building collapse along Cocacola road was reported by Jimoh *et al.*, 2012. In order to solve these problems, in addition to giving advice on the need to follow the specifications, there is also a need to flush out the quacks in the building industry. Thus, preventive measures against all negative activities against building development must be incorporated in the research activities.

Level of Compliance to Standards on Local Building Materials

Some materials are produced locally such as sandcrete blocks, timber, bricks and tiles. However some are good and some are not. Innocent builders buy these materials believing that they are made to standard. Therefore as part of my community development activities in this respect in the university, students were given projects on materials to pick from markets, such as the cements to test for their properties like water of consistency, initial and final setting times, to check results against the standards. Table 6 shows the titles of related projects on occasional investigations of material in the markets, as students’ final year projects and supervised by me.

Table 6: Compliance investigations on market sourced local building materials

S/No.	Project Titles	Name of Students	Year
1	Survey of sandcrete blocks strength cast in Ilorin	Adebayo Muftau Olawale	2008
2	Characteristic properties of portland cement in Ilorin metropolis	Yusuf, Oziohu Kudirat	2009
3	Determination of characteristic strength properties of mild steel reinforcement in Ilorin metropolis	Oyekan, Yetunde Oyebolaji	2009
4	Determination of the characteristic strength properties of high yield steel reinforcement in Ilorin metropolis	Akanni, Muritala	2009
5	Investigation into the strength and dimensional compliance of Ilorin market reinforcement with codes of practice	Oyelowo, Oladotun David	2018

The materials investigated by these students' cover the following areas: compliance to standard of cements, sandcrete blocks, reinforcing bars, and other concrete materials. The students gave details of whether the materials being used for construction were good ones or bad ones. The details are available in the students' projects. This investigation is an activity that the government can employ the services of the department for, to monitor and control the presence of fake building materials in the markets.

Practical Application of Materials and Theoretical Exercise to Constructions:

(i) Application into the construction of two Lecture Theatres:

Preamble: A lecture theatre is a cherished structure classified as an educational building and considered as a physical facility in the university. It is usually recommended by the National

University Commission for accreditation of programmes in the universities. One of the lecture theatres constructed then was for the faculty of science, of 500-capacity, and the other was the engineering lecture theatre, of 300-capacity. The pictorial appearances of the two lecture theatres are as shown in Plate 2. In a normal building construction in the university, the construction team is usually made up of an architect, a civil engineer, a quantity surveyor, an electrical and a mechanical engineer and the client representative, works department and physical planning unit. For these buildings, the Civil Engineering Department was the Structural Consultant headed then by Prof. O.A. Adetifa, in 1996 to 1997. The involvement of the department was an advantage, as the stages of construction became teaching aids for lecturers, thus, enhancing students understanding of the class work in both design and construction processes. After the design, I took up the supervision of the construction.

Structural peculiarities: Some structures could have a part that may involve racking brain on for possible solutions. In these lecture theatres, the structural peculiarities, from the inspection of the architectural drawings, were the tall external walls that were more than 10 m high as against 3.4 m for normal floor to floor height in normal building, and the high floor levels, especially at the back of the lecture theatre. The high floor could cause bulge during floor construction as the compacted fill must be properly rammed in the process. The height of the wall and its stretch could cause overturning and excess tensile or compressive stresses leading to cracks of the wall after its completion. In order to prevent these, the consideration then was to introduce a peripheral structural frame consisting of retaining walls that were well connected to the columns and beams, while the sandcrete blocks occupy the voids as panels. This is more stable and reliable than having ordinary block wall. Analysis of the retaining walls, the columns and the beams was carried out using appropriate equations and design procedures as contained in BS8110, 1997.

Construction: The construction of the lecture theatres included that of the foundation, the floor, retaining walls, beams and columns, block wall and the construction of the roof. The process followed the normal routine work. The concrete mix ratio was 1:4:8 for the blinding and 1:2:4 for the structural elements, with application of adequate concrete mixing and compaction methods.

Materials used: The materials used were the cement, aggregates, water, iron reinforcing bars, timber, structural steel sections for the roof trusses and corrugated steel roofing sheets, all sourced for locally. The construction was done by contract and my own role then was to check that the contractor followed the specifications.

Commissioning and maintenance: The building was completed in 1997 and commissioned in the same year. On maintenance processes, it involves only the repainting of the wall and replacement of the rusted roofing sheet that were carried out. It is important to state that after the 26 years of their constructions, there has not been any crack seen on the walls of these buildings. This shows that the framing type used and the checking of the contractor were done appropriately.

Plate 2a: The Lecture Theatre Science-Construction Supervised by me in 1997

Plate 2b: The Lecture Theatre Engineering (Construction Supervised by me in 1997)

(ii) Construction of a recreation structure- the suspended walkway

Preamble: This suspended walkway is located at the Zoological garden University of Ilorin. Unlike the lecture theatre, this one is not a building but classified as a utility and miscellaneous structure. It is the first and the only one in Kwara State and in the North Central part of Nigeria, aimed at providing comfort and satisfaction to the prospective visitors to the Unilorin Garden and boost the tourism potential and the image of the University. It is also found in other nations of the world like in Ghana and similar to a suspension bridge and therefore could be a teaching aid for engineering lecturers. It was constructed on a direct labour basis, designed by me, and the construction supervision team was also headed by me, as directed by the Vice-Chancellor then Professor I.O. Oloyede.

Material, Design and Construction Considerations: The components were towers, suspension cables, side-net, walkway (consisting of aluminum ladders and flat timber platform). The materials used were light, and of low size in order to reduce the imposed loads on the towers. Materials were obtained locally except the side nets that were imported from Ghana.

Reconnaissance survey of the location was first carried out which enabled us to choose the span (length) of the walkway to be 152m. The tower height was based on the one at the republic of Ghana, and was made to be between 12m and 15 m high. Based on the span of 152 m, four towers were used (two exterior and two interior).The two exterior towers were made of standing trees in order to reduce the cost and the internal towers were of reinforced concrete. Load retained were made full on the walkway, taken as $2.5kN/m^2$. This was used to determine the forces in the cables and their diameters obtained accordingly. The exterior towers were subjected to overturning moments which were neutralized by inserting stay wires. Side sway was also possible which could cause sideways overturning of the towers, This was also determined and catered for in the tower design.

Structural peculiarities: The major structural peculiarity of this walkway was the heights of the towers that were up to five building floors (15m) which made the slenderness ratio to reach 30. The height could make the towers liable to buckling and overturning. To avoid these, the approach adopted was to derive appropriate weight of the tower from equation (1) , given by

$$RT=FW+FC \qquad (1)$$

where RT =lateral resistance of the tower based on its self weight; FW= lateral wind force and FC is the lateral force from the cables hanging on the tower, where moment is taken about the base of the tower. From the weight result, the appropriate size of the tower was obtained.

Construction: Also the tall tower construction was a problem because of its height and the process of construction was carried out with caution, especially in making sure that it was perfectly vertical. Verticality was ensured by dropping weights at the midpoints of the rectangular sectional faces of the tower. Concrete mix ratio used was 1:1:2, and water cement ratio of 0.5, because of the exposure that was severe. After the construction of the towers, the cables and the side nets were linked to the towers by knotting method at the joints, while all aluminium ladders, serving as walkway frame, were joined together by bolting and the timber walkway platform bolted to the ladders. The timber staircases were constructed using the normal carpentry works. The completed walkway is presented in Plate 3.

Commissioning and maintenance

The construction was completed in 2012 and commissioned in the same year. The construction team members with me were staff of works department university of Ilorin, while Prof. A.B. Olayemi, the then Vice Chancellor, Management Services was the overall Chairman of the Committee. I thank them all for their cooperations in the completion of the project.

On maintenance, the sidenets deteriorated and routinely being replaced ones in two years, while one exterior tree tower has been replaced with a reinforced concrete tower, due to some defects in the tree. As at today, that is 12 years after its construction, the two reinforced concrete towers are intact, rigid, upright and they show no cracks. A publication on the maintenance of the walkway was published by the construction team, where more details can be obtained (Jimoh *et. al.*, 2012).

Plate 3a: The two-leg reinforced concrete tower of the Suspended Walkway, designed and construction supervised by me in 2012

Plate 3b: The completed suspended walkway supervised by me in 2012

Material Research Activities towards Building Development

Of all the local materials being used in Nigeria for construction, that I have investigated, timber is prominent. This is because timber is widely available locally and has many species to choose from and to work with, relatively cheap, abundant and possesses good workability in construction. However, its application in majority of the constructions is by experience (no design applied), which is attributed to lack of design data.

(b) Specific Research: The specific research activities I have undertaken areas follows:

(i) Investigation on improvement of lateritic soil properties for brick making: Sand and laterite are low cost natural building materials that are in abundant on earth surface. Their research and exploration are essential for building development. It is for this reason that Alao and Jimoh (2017) investigated the mixture of cement, sand and laterite, with cement not more than 1/10 of the mixture, to cast bricks. Brick strengths ranging between 8 $N/mm^2$and 19 N/mm^2 were obtained. The bricks met the specification of 2.5N/mm^2 specified in Nigerian Industrial Standards. More on this is available in the publication.

(ii) Production of cement sheets using wastes: There are abundant palm trees in the tropics. They possess fibres and shells, as reported by Findlay (1978) and there could be wastes of these materials. Also wastes from industry are abundant as reported by Li (2011) while asbestos ceiling sheets are poisonous as they could cause lung cancer. It is in effort to replace the asbestos material, that prompted Jimoh, Adedeji and Raji,(2009); Sanusi, Jimoh and Raji, (2011), Ekwebe and Jimoh, (2011); and Olawuyi and Jimoh (2012), to investigate various waste materials as fibres in cement sheets. Olawuyi and Jimoh (2012), worked on mixure of cement, waste paper and coconut fibre, in ratio 1:1:0.1 by weight to produce 300x300x5 mm cement sheet specimens. The test results gave an average flexural strength of 1.6 N/mm^2. The sheets were not as brittle as the common asbestos ceiling sheets.

(iii) Investigation of timber sizes: From the experience of steel rod uses and timber applications, there is need to investigate the presence of undersize solid materials as this could affect the safety of the building and the marketability of the material. In order to find the actual deviations from the standard, Jimoh and Adefemi, (2012), investigated timber sizes in the markets with focus on 50x50; 50x75;75x150; and 150x225 mm , and found that the error in size deviations from the standard size ranged from -10 mm to -15 mm which are more than -1+3, (recommended for tolerance class 1),and-1+1,(recommended for tolerance class 2), according to BS EN 336 (2003). This has shown that substandard timber sizes are in the market and the government should take steps to prevent further production.

(iv) Determination of rational design equations for timber beams: In timber beams, the conventional flexural formular being used to design wood beam is based on the use of modulus of rupture, given as S= M/Z, where S is the tensile stress (called modulus of rupture) at the bottom face of the beam, M is the applied moment and Z is the section modulus. This equation is reported not reliable, long abolished for materials like steel beam, concrete beam and pre-stressed concrete beam, respectively, and it survives only in timber. In view of this, investigation was carried out on timber species to generate the equations.

The general equation (2)was obtained as

$$M_r=af_tbd^2. \qquad (2)$$

where M_r is the moment of resistance, a is a constant depending on a timber specie, f_t is tensile strength of timber, b is the width and d the depth of the timber section.

The accuracy of the equation was at 70 %. Details of the derivation procedures and the equation obtained for each timber species are reported by Jimoh, (2000); Jimoh, (2008); Jimoh, (2012); and Jimoh, (2019).

(v) Derivation of simplified design equations for timber columns: The conventional design equations for timber columns, the popular equation by Euler, was reported to reproduce experimental data accurately for slender columns but an over-estimated ultimate stress is obtained when applied on short and intermediate columns. It has also been reported that division of the slenderness ratio into short, intermediate, and slender categories with subsequent analysis is quite involved and may not be necessary. Instead of categorization into these ranges, a continuous column formula is therefore a simpler design method. This therefore prompted me, Jimoh, (2000), to derive equations to cover the three slenderness ratios (short, intermediate and slender) for some timber species. The general polynomial equation (3) proposed is of the form

$$f_c=a(L/R)^3+b(L/R)^2+c(L/R)+d \qquad (3)$$

where f_c is the design compressive strength, L is the length, R is the radius of gyration, L/R is the slenderness ratio and a,b,c, and d are constants depending on the timber specie.

The theoretical over experimental varied from 45 % to 85 % with an average of 65%. Details of the equations for various species are reported by Jimoh, (2002); Jimoh, (2005); Jimoh, (2007); Jimoh (2008); Jimoh, (2009); Jimoh, Rahmon and Joseph (2017); and Jimoh, Rahmon and Ibrahim, (2018).

(vi) Characterization, classification and grading of timber: Classification and reclassification of new and old timbers in market is important. This is because in NCP2, 1973, there are only 55 Nigerian timbers presented as shown in Table 7, whereas there are many more that are still unclassified but are available in the market. Classification assists the designer to choose a timber from many in a class and also makes a timber marketable. With the new timber that have arrived the market after the publication of this code of practice, it means that many are still not classified which therefore makes continuous research necessary.

Table 7: Timber number per strength group in NCP 2, 1973

Strength group	N1	N2	N3	N4	N5	N6	N7	Total
No of timber in the group	6	7	22	6	4	7	3	55

An investigation on Apa (*Afzeliabipindensis*) reported by Jimoh and Adefemi (2017), gave tensile strength as 69N/mm^2 modulus of rupture of 87N/mm^2, using these result and others therefore classified *Apa* timber into $N_6$of NCP (1973) table. Information on other timbers is reported by Jimoh, Rahmon and Babatunde, (2017); Jimoh and Aina, (2017); Ibitolu and Jimoh, (2017, 2018); Jimoh, Rahmon and Babatunde, (2017); Jimoh and Rahmon (2018); Ibitolu, Jimoh and Babatunde (2019);and Rahmon and Jimoh (2020).

(vii) Use of plastic and polymer wastes to cast tiles: In Nigeria, there are wastes of dumped plastic bottles, polythene and water bags at various places. In a study by Jimoh, et al (2017), report were produced on these wastes by melting to produce tiles of size 300x300x10. The tile flexural strengths ranged from 4.7 to 6.3 N/mm^2. The tiles have properties that can make them usable in buildings. The procedures and tile products are presented in publications by: Jimoh, Tazou, Kimeng and Rahmon (2017); and Olivier, Jimoh and Adedeji (2017).

(viii) Production of pozzolanic materials from wastes: Pozolans are materials which are on their own alone are not cementitious, but when combined with calcium hydroxide materials become cementitious. This simple beneficial mixture was explored using various industrial and agricultural wastes. Jimoh, Ameen and Atolagbe, (2017); investigated production of pozzolanic materials as alternative cement material using ash produced from wastes such as the rice husk and guinea corn. Ash was produced at an optimum burning time of 6 hours of the waste. Ash and lime at various proportions were mixed with water and cast into cubes and tested. Mortar strength of $3N/mm^2$ was obtained. The result indicated that the productis a good material for plastering and block laying. Details for various ash productions are reported by Ma'aruf, Musa and Jimoh, (2014); Jimoh, Ameen and Atolagbe, (2017); Tuleun, Jimoh, Ozigi and Rahmon, (2018); Abiodun and Jimoh, (2018); Tuleun, Jimoh and Wasiu, (2019a); and Tuleun, Jimoh and Wasiu, (2019b).

(ix) Study of timber as alternative reinforcement in concrete: Application of timber as alternative reinforcement in concrete to replace the costly steel in some concrete elements was carried out by Jimoh (1993). Tests showed that to develop the same strength (with steel slab) of the same dimension, the cost of fanpalm reinforcement was 1/5 that of steel while amount of fanpalm reinforcement required was about 4 times that of steel. In this respect, fanpalm is usable as alternative reinforcement, especially in light structures. Detail results for various timber as reinforcement were reported by Jimoh and Adetifa, (1993); Jimoh, (2009); Philip, Tuleun, and Jimoh, (2020).

(x) Determination of effect of varying aggregate sizes on concrete strengths: For effective application of aggregates in concrete, a uniform grading is preferred. The uniformly graded aggregates improve the strength, reduce the porosity and make the concrete durable. Li (2011), therefore, advised that a well-defined grading with an ideal size distribution of aggregate will decrease the voids in the concrete and hence the cement content. As the price of the aggregate is usually only one-tenth ($^1/_{10}$) that of cement, a well-defined grading not only will lead to a better compressive strength and low permeability, but also is more economical at lower cost.

In order to exploit this opportunity, **Jimoh et, al** (2012), determined the effect of varying aggregate sizes in concrete by mixing varying aggregate sizes and fixed other ingredients and cast into concrete cubes. Concrete was prepared from aggregate sizes passing through 20 mm and retained on 14 mm sieve size. This gave the compressive strength of 24 N/mm^2 and corresponding water absorption of 3.2 % while another concrete prepared from aggregate size passing through 14 mm and retained on 10 mm sieve size gave a higher strength of 25N/mm^2but lower water absorption of 2.7 %.This showed that low aggregate sizes increase the strength and durability of concrete. More reports are available in publications by Jimoh, (2007); Oyewole, Arilewola, Jimoh and Oyejobi, (2011); Omopariola and Jimoh, (2018); Omopariola and Jimoh, (2020a); and Omopariola and Jimoh,(2020b).

(xi) Determination of effect of concrete constituents on water leakage: Also by reasons given by L(2011), effects of varying concrete constituent in concrete on water leakage from model water tanks was carried out by Jimoh and Jimoh (2010). Mix ratios were 1:2:4; 1.5:2:4; 2:2:4 of cement, fine aggregate and coarse aggregate and water cement ratio of 0.5, were used to cast model tanks of internal dimensions 200x190x190 and 40 mm thick. After it dried, water was poured into each of them simultaneously and the water headfall measured. These gave respectively, decreasing rates of 1.05mm/hr; 0.67 mm/hr and 0.42 mm/hr. It showed that increasing cement in concrete decreases porosity. This is useful in controlling and determining theoretical water leakage and least porosity in the concrete. More on other similar cases are reported by Jimoh and Joseph,(2010) and Jimoh and Rapu, (2010).

(xii) Study into Fanpalm (*Borassusaethiopum*) stem for structural application: Also by exploitation of the abundance and properties of palm trees in the tropics as reported by Findlay (1978), Fanpalm was investigated. Fanpalm is a local material that is useful for local structural applications, but little known. Jimoh (2010) investigated fanpalm whole stem as a structural hollow section. The dimensions of the stem diameter were

380mm at the bottom to 530 mm at the middle third, and 40-110 mm thick with compressive strengths ranging from 61 to 81 N/mm^2. Analysis showed that the stem could support a load of 11700 kN (equivalent to 1.8 $x10^6$ litres of water). More reports are presented by Jimoh, (1990); Jimoh and Adetifa, (1993); Jimoh, (1997); Jimoh, (2000a); Jimoh, (2000b); Jimoh, (2006); and Jimoh, (2010).

(xiii) Investigation of commercial sandcrete blocks: As earlier reported by Oyenuga (2010) that in Abuja, block wall turned into dust on a building collapse in 2010, is a pointer that sandcrete blocks need frequent investigation. Therefore, Ma'aruf and Jimoh (2013) investigated properties of sandcrete blocks produced in Wudil and Warawa local government areas of Kano State. Strength as low as 0.29 $N//m^2$was obtained, as against 2.5 N/mm^2 recommended in the Nigerian Industrial Standard. This is a case of substandard material.

The above research activities on timber were carried out using some materials sourced from the locality as shown in the plates below while the major testing equipment were the universal testing machines also available within the locality.

(xiv) Places of publications of the research activities: The research works on the local materials were published in reputable conference proceedings and journal outlets within and outside Nigeria, in Ghana, Iran, Ethiopia, Romania, Malaysia, Indonesia, India, Switzerland and South Africa.

(xv) Pictures of some of the tree plants that grow within the locality of Ilorin yielding the majority of materials being used for research activities.

Plate 4: Fan-palm trees (B*orassus aethiopum*).The stem produces fibres and strcutural sections. They (the stems)were converted to lengths usable for building constructions and collected in sawmills for research purposes, for property investigation, chacterisation and grading. The lengths were investigated as alternative reinforcing bars in concrete and as columns or structs and as beams, for which simplified design equations were derived.

Plate 5: A colony of Oil-palm (*Elaies guineesis*). The stems and fruits produce fibres and the fruits also produce shells. The fruit fibres and shells were collected at local red oil industries for study, for property investigation and application as fibres in cement sheets and as alternative aggregates in concrete, respectively.

Plate 6: Coconut palm (*Cocos nuciveri*): The stem and fruit poduce fibres usable in cement sheets and also fruits yield shells that are usable as alternative aggregates in concrete. The fibres, shells and cement sheets were investigated for applications in building constructions.

Plate 7: A Bamboo Colony (*Bambusavulgaris*).The culms produce fibres and structural sections usable as alternative reinforcing bars in concrete and in cement sheets. The culms are also used as poles in buildings and as scaffold.

Plate 8: African Balsam tree (*Daniellia oliveri*):

Plate 9: African Mahogany(*Khaya senegalensis*):

Both tree stems yield various timber lengths and sections usable in building constructions. The lengths were collected in sawmills for investigation for property investigation, characterization and grading. Their applications as columns and beams were investigated with derivation of simplified design equations. Many other timbers were also investigated.

Discussion

The list of materials explored so farare: laterite, cement, sand, water, bricks, timber from various species, waste ash, aggregate , fanpalm material, grass material, fibres from palm trees, timber-reinforcement, bamboo-reinforcement, saw-dust, waste paper, jatropha waste seed coat and waste carbide. All these local materials are non-metallic and obtained with low technology methods and low energy requirement in their productions except cement. These will make the materials of low cost.

Some of the above materials were further combined, synthesized or stabilized to produce building materials such as pozzolana, concrete, cement sheet, sancrete blocks, bricks, tiles, and stabilized mud composites, bamboo reinforced concrete elements, timber reinforced concrete elements, earth–timber reinforced slabs and thatched sheet. The processes also require low technology and low energy consumption in their production. These will also make the cost involvement low.

The products can be home made by individuals because they require low technology in production. Such products are bricks, tiles, ceiling sheets and sandcrete blocks. When carefully prepared, they could be useful cheap and low cost materials that can be transformed into local industries which may become an employer of labour.

Generally, throughout my research endeavours, the materials encountered can be categorised into three:those found within the country or manufactured withing the country with their raw materials found locally; (ii) those manufactured within the country but with imported raw materials and (iii) those manufactured outside and imported for building purposes. All these need to becarefully chosen not to affect the individual or national economy.

Conclusion

The following conclusions can be drawn.

As part of my contributions, students have acquired the knowledge on some local building materials, their locations, testing and applications which will assist in building development.

The students' project reports presented in this inaugural lecture are good source of information for achieving a cheap and durable local building materials.

Timber that can produce alternative reinforcing bars have been identified which can be applied successfully in some concrete elements.

Alternative materials to make ceiling and wall sheets have been identified and the sheets can be home made.

Alternative cement material can be produced using the local waste materials but with its own separate values of properties like the water of consistency, initial and final setting times and days required to achieve the design strengths.

The addition of some percentage of pozzolana to replace cement in concrete is an enonomical way of utilising cement in concrete for low cost construction.

Using uniformly graded aggregates is an economical way of application of aggregates in concrete. Porosity is reduced and cement content needed is equally reduced thereby improving the strength and lowering the cost.

New data and design equations have been generated for timber beams and columns, that can enhance their design, and their characterisation and classificationsfor applications in building constructions.

Recommendation

Use of mud silo should be promoted as it is a cheap structureand recommended for local farmers to apply on their farms or houses for storing their raw food.

Government should prevent deforestation like irrational tree felling and bush burning and encourage tree planting, as majority of the local materials usable for construction purposes areforest derivatives.

There should be a synergy between the university, especially the civil engineering departments, the construction industry and the related government agencies such as the raw material research and development council and standard organisation of Nigeria, to enhance material production and to control the circulation of fake building materials in the markets.

The structure and the material engineering option of civil engineering department should be well funded for effective material researches to accelerate material and building development to meet the national needs.

Interested civil engineeringgraduates who may wishto specialise onlocal material productionfor building purposes should be encouraged.

The Government should promote and encourage the use of local materials for building purposes.

Future areas of focus on material research:

Further studies will focus on more improvement methods on strengths and durability properties of the local materials for building purposes. Also specifications would be drawn for the local materials based on the results obtained from research activities. Full size specimen tests will also explored.

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