



NBRRI

CONSTRUCTION DIGEST
No. 3

**CONSTRUCTION FOR
DURABILITY IN NIGERIA:
THE STRENGTH OF BUILDING
MATERIALS**

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NIGERIAN BUILDING AND ROAD RESEARCH INSTITUTE
(FEDERAL MINISTRY OF SCIENCE AND TECHNOLOGY)

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FOREWORD

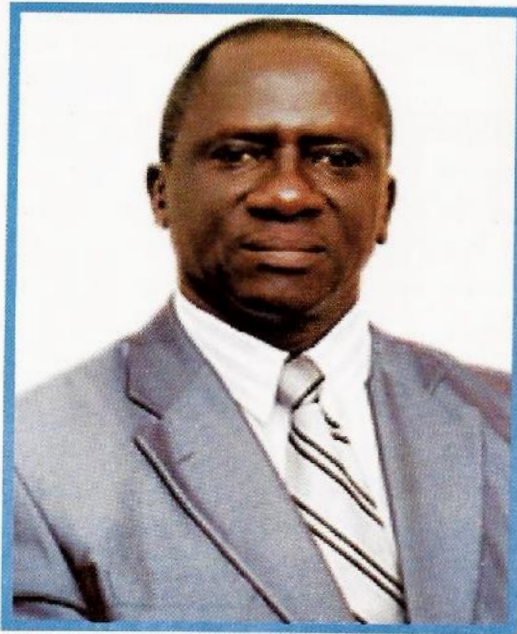
The resistance of construction materials, especially in Buildings, is an item that defines the life-span of the structure. This encompasses both proprietary and cast in-situ materials. Therefore, in defining the life-span and functionality of structures, design is made to address the limit states that include Ultimate Limit States (of collapse) and Serviceability Limit States (of deflection, vibration, fire resistance and impact). These are addressed as basic concepts in designs based on defined yield resistances of the individual materials forming the composite of structural elements or the entire structure acting as a single structural entity.

Recent challenges in the Nigerian construction industry have necessitated that specific attention be paid to the issue of strength of construction materials. Such challenges have primarily been the failure and collapse of buildings and infrastructure in the country. Investigations by the Nigerian Building and Road Research Institute, NBRRI, have identified the poor quality of materials cast in-situ as the primary cause of collapse of buildings that curtail the life-span of some old structures by drastically affecting their durability characteristics and resistances to tear and wear from cyclic loading and weather. New Buildings under construction simply explode leading to catastrophic collapse and there have been some recent incidences of catastrophic formwork collapses in Abuja and Lagos. Therefore, this article takes a look at quality of Nigerian construction materials, drawing on experimentally authenticated field and laboratory data to buttress the points. The materials treated include concrete, sandcrete blocks, cements and Timber; though the latter two may be proprietary. The data is used to highlight the need for correlation between practice and existing standards and specifications for safer construction in the country.

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1 INTRODUCTION

A lot of emphasis has been made in Nigeria in recent times about the shortage of housing and the need to provide many more homes to meet the demand by both working class and unemployed, medium and low income groups, urban and rural dwellers, and so on and so forth. The concept of durability is synonymous with the deterioration of the various constituents of building materials that are used to form the house. The increasing concern for concrete durability is justified in many ways because concrete is cheap and relatively easier to obtain; therefore the deterioration of concrete causes great loss to the economy. Hence on a wider conception, the durability of any material basically refers to its ability to serve its intended functions without loss of requisite strength and serviceability during the specified service life. The durability of concrete, as example, is studied over a long period of time with the environment of the structure having a dominant effect (Neville, 1996). The strength and durability of materials depend, to a large extent, on the physical structure of the materials.

The physical structure of materials at an advanced age is markedly different from that of the same material at an early age. Matawal et al (2010) point out that the structure of concrete at an advanced age consists of compact network of aggregates strongly held together by cement gel while early age concrete comprises of near discrete pack of aggregates, stiffened cement paste, capillary water and relatively small proportion of cement gel. It is the attendant increase in gel/space ratio (which translate into an improved physical structure) of concrete at advanced age that accounts for the relative increased strength and durability of concrete, over other materials (Matawal, 2001). As such, concrete could be regarded as an 'animate material' in terms of durability and structural ageing, which is governed by moisture content. Water is at the heart of most of the physical and chemical causes underlying the deterioration of concrete structures (Mehta, Schiessel and Raupauch, 1992).

The overall quality assessment of most building materials is their strength which, depending on the type of material, can be tensile/flexural, compression or shear resistance. These are always obtained by subjecting the different materials to different types of tests such as tensile test, compression tests, torsion, triaxial, shear, etc. while more tests are continually being brought into the research and application arena to improve upon the precision and reliability of their expected outputs. The results of tests subjecting prepared specimens to the appropriate tests will usually reveal that the structural integrity (strength and durability) of different materials to be a function of numerous inter-related factors, such as:

- a) The individual properties of the material constituents; as in concrete, especially
- b) The slenderness ratio, especially as it relates to steel sections in compression, but equally applicable to reinforced concrete and timber in compression
- c) The direction of loading as is applicable to anisotropic materials; notably Timber and Earth-based material (Soils/Laterites)
- d) Moisture content of the materials, as in Soils and Timber; but water to cement ratio in concrete. On the whole, there is usually an optimum water condition beyond which strength of these materials deteriorates, especially in the case of soils, which will flow on their own at moisture contents exceeding their liquid limits
- e) In the case of concretes, the more the water content (water to cement ratio), the higher the workability of the fresh mix, and there are possibilities of certain deleterious effects, like bleeding and segregation that leads to porous (non-durable concrete)
- f) Condition of exposure of buildings does affect durability and strength in the long term. Either acidic or alkaline water and soil conditions will lead to corrosion of concrete and steel as with high relative humidity in the atmosphere where a lot of CO₂ will react with cement in the hydrated compound to reduce pH of the reinforcing bars and cause deterioration of the concrete (Claudio, Rubens, Fernando and Wander, 2002). Carbonization is a well known phenomenon.
- g) Intrinsic quality control processes on construction sites (mixing, vibration/compaction, thorough mixing) and extrinsic control and processes (labour skills, details, iron-bending, etc) will usually have profound effects on durability and strength of engineering and building materials.

Concrete or concrete based products are structured combinations of aggregates (fine and coarse), the binder (cement or cement substitutes), and the mixing water. At least $\frac{3}{4}$ (three quarters) of the volume of concrete is occupied by aggregates; surpassing in concrete mixes of considerable importance. Not only may the aggregate type (very specifically coarse aggregates) limit the strength of concrete, as aggregates with undesirable properties cannot produce strong concrete, but also the

properties of aggregates greatly affect the durability and structural performance of concrete (Neville and Brooks, 2003). If the aggregate used in the test leads to a lower compressive strength of concrete, and in particular if numerous individual aggregate particles appear fractured after the concrete specimen has been crushed, then the strength of the aggregate is lower than the nominal compressive strength of the concrete mix into which the aggregate was incorporated. Many substitute aggregates exist in practice for special applications and to address issues of affordability. There can be recycled concrete aggregate, periwinkle shell, palm-kernel shell, olive seed shell, even broken bottles, etc. The structural integrity of the resulting concrete from any peculiar concrete, coupled with the peculiar exposure conditions, humidity and chemical composition, will be peculiar; expected to be significantly different from concrete made from conventional materials.

2 DURABILITY AND STRENGTH ON NIGERIAN CONSTRUCTION SITES

The poor applications and use of inferior materials, especially Concrete, has been identified as a strength and durability concern on buildings in Nigeria (NBRRI, 2011a & b). As a consequence, buildings deteriorate and even collapse catastrophically long before their design life-spans are realised; some even during construction. There may be other primary reasons that precipitate the problem of failure (example, deficiencies of foundations, columns, beams or other structural elements), the failure of many structures by explosion usually tends to denote that there was poor concreting on site. Indeed, results measured on sites by NBRRI in investigations carried out in 2011 and 2012 have confirmed this assertion, as presented in Table 1. The ultrasonic Pulse velocity tests were used for the determinations, which is a non-destructive test acceptable for lump specimens from the site of a collapsed structure. Many of the failures of structures investigated by NBRRI have been by rapid disintegration of concrete elements and almost transformation of Sandcrete blocks into sand.

Consequently, the single most important deleterious effect on Building strength and durability is poor concreting. Concrete is generally designed in grades which, in Nigeria, correspond to classes of strength and therefore categories of concrete below those shown in Table 2 should never be used.

Table 1: Comprehensive Strengths of Concrete Elements (Adenubi Close, Ikeja)

Structural Element		Compressive Strength (N/mm ²)	REMARK
Type	No		
COLUMNS	1	12.3	Poor
	2	8.9	Poor
	3	8.7	Poor
	4	7.1	Poor
BEAMS	1	8.3	Poor
	2	7.3	Poor
	3	15.7	Poor
	4	8.1	Poor
SLABS	1	7.6	Poor
	2	8.5	Poor
	3	13.0	Poor
	4	19.7	Poor
	5	7.1	Poor

Source: NBRRI Technical Report No. 23

The concrete should be 'designed' OR 'designated' and in a 'designated concrete', the producer who is generally the constructor (not necessarily the same as a contractor) is required to produce a material to satisfy the designated strength and consistency (workability) using a particular aggregate size. Designated concretes are designated as Grade 30, for example, based on the cube strength up to Grade 50, according to the application involved. A designed concrete, on the other hand, is the one whose strength class, cement type, and limits to composition including water/cement ratio, cement content (mix ratio) are specified.

The symbol f_{ck} generally denotes characteristic strength based on cylinder strength of the concrete, which is a nomenclature in use in USA but not used in Nigeria. The concrete class therefore corresponds to the cylinder strength. The term f_{cu} denotes cube strength and corresponds to the Grade of the concrete in general use in Nigeria. If Tables 1 and 2 are compared, it will be observed that though Grades of concrete below 20 are generally unacceptable, but most of the concretes in use on majority of Sites have strengths significantly far below the minimum. Of course, lean concrete mixes are acceptable for blinding mixes and categories of mortar, but these applications are non-structural.

Table 2: Strength Classes of Concrete

Concrete Details				Normal lowest for application as specified
Class	Grade	f_{ck} , N/mm ²	f_{cu} , N/mm ²	
16	20	16	20	Plain concrete
20	25	20	25	Reinforced concrete
25	30	25	30	
28	35	28	35	Pre-stressed & Reinforced concrete subject to chlorides
30	37	30	37	Reinforced concrete in foundations
32	40	32	40	Special concretes and constructions
35	45	35	45	Special concretes and constructions
40	50	40	50	Special concretes and constructions
45	55	45	55	Special concretes and constructions
50	60	50	60	Special concretes and constructions
55	67	55	67	Special concretes and constructions
60	75	60	75	Special concretes and constructions
70	85	70	85	Special concretes and constructions
80	95	80	95	Special concretes and constructions
90	105	90	105	Special concretes and constructions

In some Sites of collapsed structures, the situation is more lamentable because the concrete does not even have sufficient strength to be subjected to measurement, like the Mpape 5-storey hospital building site. In Gwarinpa Navy estate site where a building collapsed while a demolition exercise was taking place, the NBRRI report, which is unpublished, read: *"There is clear evidence that the reinforcement for all structural elements (floors, beams and columns) had dissociated from the concrete during demolition. Expert opinion is that this is evidence of poor concreting i.e. lack of bond between steel and concrete. The inspection also revealed that coarse aggregate size as large as 40mm may have been used in the batching process. However, specimen concrete samples brought to NBRRI Laboratory and measured using non-destructive testing process gave the following rebound hammer readings: 22, 15, 11, 20, 11, 14, 16, 12, 21, 12 and 14, 10, 10, 9, 8, 7, 6, 9, 9, 10, 9 with an average of 17.5 rebound value and 9 rebound value respectively. Consequently, the compressive strengths of the 2 large-size concrete samples, converted from the rebound values were 8.75N/mm² and 4.5N/mm² respectively. The second sample was retrieved from a column concrete".* These results are disastrous and it is noteworthy, however, to mention that some of these results

were questioned by colleagues who claimed that in a destroyed structure, the use of any elements for tests was unacceptable to them because of the weakening effect of the failure. However, this is viewed as an unimportant argument because internationally, back-analysis on failure sites in order to build case histories rely heavily on visual inspections and the use of intact samples retrieved in the best way possible. These arguments are also quite understandable coming, as they were, at the heels of legal action by the families of three (3) workers who died in the Gwarinpa building collapse.

NBRI Technical Report No.22 clearly identified poor concreting, low design mix ratio, lack of adequate OR improper curing, large impurities and organic matter in fine aggregates (sand) used for concrete batching, etc. in the inspected specimens of the collapsed building at Mararaba on the outskirts of Abuja.

Generally, the emphasis on concrete quality and strength is to underscore its significance in the event of a failure caused from whatever factors. Table 3, as example, is an elementary illustration of the widely differing properties of steel and concrete when they act in composite state in reinforced concrete.

Table 3: Properties of Concrete and Steel

Property	Assessment of Composite or Individual Material Response	
	Concrete	Steel
Strength in Tension	Poor	Good
Strength in Compression	Good	Good but slender members will buckle
Strength in Shear	Fair	Good
Durability	Good	Corrodes if unprotected
Fire Resistance	Good	Poor; suffers rapid strength loss at high temps

Philosophy of design dictates that in design of reinforced concrete sections, a proper analysis must be undertaken in which resulting stresses from varied practical loading conditions are considered and provisions made for the worst, not optimal, conditions. The mathematical assessment is made so that in the composite action of the Reinforced Concrete elements, steel is made to take the stresses in sections where tensile stresses result from either bending, shear OR torsion (twisting) forces. However for this composite action to be effective, there are many conditions that must be satisfied. These include the need for the steel reinforcement to be as close to the surface of the element as possible so that an undue cracked section does not have to be permitted in the large concrete area, the cross-sectional area of the steel must be adequate in relation to the imposed forces, etc. However from the view-point of collapsed structures, a very important property is that there should be proper bonding between the concrete and the steel and these entail a proper concrete grade/strength as well as adequate surround of the steel with concrete so that there is good grip. Thus, a structure may fail but will not collapse catastrophically if there is proper bonding. This discussion has much significance to the Nigerian situation of poor concreting and can be expatiated to throw a lot of additional light on the preponderance of collapsed structures in the Nigeria.

3. QUALITY MANAGEMENT OF SANDCRETE BLOCKS IN THE COUNTRY

Outside framed structures where the loads (dead and superimposed) are carried primarily on the structural framework (roof trusses, structural plates/floors, beams, columns and foundations), the majority of housing types are not framed. The responsibility for transmitting loads to the ground

below is now vested in the blockwork which needs to be strong and durable to withstand the superimposed loads for sustainable periods as long as the design life span of buildings. As a matter of fact, what has been confirmed from NBRRI investigations between 2011 and 2013 is that even many framed buildings are surviving by the conversion of partition blockworks into load bearing walls, which should not be so but for the poor state of the elements comprising the framework. The quality of blockwork therefore becomes a critical item in durability and strength considerations of our buildings.

Fortunately, so much work has been done on the quality of sandcrete blocks that, if religiously followed, Nigerians would have even made public protest against blockmakers in this country numerous times in order to get Government institute stern policies to safeguard users against being ripped off or cheated by businessmen in this arena. This author has tested sandcrete blocks since 1981 for construction purposes and yet their standards have continued to degenerate in spite of clear evidence that block industries have been producing poor quality products all through the years. In Table 4 are the results of tests from typical specimens of sandcrete blocks from different Sites in which an average of 3 tests were conducted to produce each result from a random choice of samples from a Site in South – South geopolitical zone of Nigeria. The authors of these tests, Ewa and Ukpata (2013), note that the 28-day compressive strengths of these blocks vary from 0.23 to 0.58 N/mm², with an average compressive strength of 0.35 N/mm². All values fall below the national standard, NIS 87:2000, specifications which is also contained in the Building Code (2006).

In earlier tests conducted on specimens by Anosika and Oyebade (2012) from three different towns with results presented in Table 4, where control samples using the same mix but following careful preparation and curing procedures, show that blocks in the FCT to comply with specifications for non-load bearing walls, but fall short of requirements for load bearing walls. Blocks in other locations are all non-compliant except in a single location which satisfied specifications for non-load bearing walls, but not for load bearing walls. Afolayan, Arum and Daramola (2008) also tested a large number of blocks in Ondo State and got the results of 150-mm thick blocks to average 0.55 N/mm² and those of 225mm blocks to average 0.45 N/mm².

Table 4: The Strength of Sandcrete Blocks from South- South

Site No.	Strength in N/mm ² at specified Curing Period			
	3days	7days	14days	28days
1	0.04	0.18	0.20	0.32
2	0.04	0.23	0.35	0.47
3	0.05	0.08	0.15	0.34
4	0.05	0.13	0.29	0.52
5	0.03	0.11	0.11	0.23
6	0.04	0.19	0.33	0.47
7	0.05	0.17	0.29	0.45
8	0.05	0.08	0.34	0.54
9	0.04	0.13	0.33	0.47
10	0.04	0.07	0.35	0.58

It is important to assert that in this Author's personal tests, which covered a large period from 1979 to date, the results have varied. In the early years, it appeared that there were lots of clear efforts to meet with standards with some specific production centres clearly producing excellent blocks. However, these companies (like Stone Products Limited in Jos, Plateau State of Nigeria) clearly fizzled

away with time and left only the managers of poor batching plants. Testing blocks is frequently a waste of precious time and energy as visual inspection can clearly reveal which blocks are good for further quantitative analysis. There have hardly been any blocks that register above 1.00 N/mm² whenever tested but Abuja has frequently provided the exception of some quality blocks. The producers also make blocks using stone dust and their prices are usually from 1.67 – 2.00 times the prices of those produced using unwashed river sand. For the purposes of education, the Nigerian standard accepted for sandcrete blocks specifies 1.75N/mm² for non-load bearing walls compared to 2.0N/mm² for British specifications, also extracted for demonstration purposes. The value for load bearing walls is 2.5 N/mm². It is also noteworthy to know that 3-categories of sandcrete blocks exist in the country: 100mm (solid), 150mm and 225mm (both hollow) thick that are 225mm high and 450mm long. The solid blocks are seldom used but are quite ubiquitous in West-African countries, especially Ghana. Because of lack of washing of sand, Nigerian blocks tend to have a high water absorption rate (7-20%) making them heavy for the standard 1:8 mix specified.

Overall, the situation can be blamed on quality control, poor selection of the fines used for batching the mix, inadequate curing periods and poor curing techniques. The ineptness of Government and Regulatory authorities is clearly at the peak of the reasons for poor sandcrete blocks.

Table 5: The Strength of Sandcrete Blocks from 4 Locations (in N/mm²)

TOWN	Site/Sample	A	B	C	D	E	Mean
Ota	1	1.10	0.66	0.66	1.20	0.88	0.90
	2	1.32	0.88	0.88	1.32	0.99	1.08
	3	1.10	0.44	0.66	1.43	0.99	0.92
	4	1.32	1.10	0.88	1.32	1.10	1.14
	5	1.10	0.66	0.77	1.10	0.88	0.90
Umuahia	1	1.25	0.98	1.14	1.25	1.21	1.17
	2	1.48	1.15	0.90	0.82	1.90	1.25
	3	1.90	1.10	0.96	1.32	1.08	1.27
	4	1.95	1.20	1.38	1.28	1.10	1.38
	5	1.88	1.31	1.66	0.96	0.94	1.35
FCT	1	2.15	0.98	1.95	2.18	0.97	1.65
	2	2.28	1.78	1.98	2.10	2.46	2.12
	3	2.05	2.01	2.20	2.08	1.84	2.04
	4	1.56	2.45	2.24	1.96	2.19	2.08
	5	1.88	1.98	2.60	1.98	1.96	2.08
Laboratory Specimens		3.52	3.63	3.74	3.41	3.52	3.56

4 STRENGTH OF NIGERIAN CEMENTS

Nigerian Cement production rose steadily from 1.9mt in 2003 to 16.5mt in 2012, an increase of over 768 percent, dictated by demand, locally and within the West African sub-region with an installed capacity that rose from 3mt in 2002 to 28.5mt in December 2012. Current existing expansion projects and new Cement plants are designed to add 14.5mt installed capacity to the cement industry to give a total capacity of 43mt by 2015. The Cement has to conform to Nigerian Industrial Standards (NIS) for cement products. The Standards Organization of Nigeria (SON) specifies the minimum criteria for manufacture and importation of cement for sale and distribution in the Nigerian market while R&D is conducted by the Nigerian Building and Road Research Institute, NBRRI.

The quality of Nigerian cements has improved over the years as initially poor laboratory results improved in tests by Matawal and ZeGyang (2012) in which fourteen (14) brands of Portland cement in the country were tested. An extract of some of the numerous results already presented in numerous academic and professional fora in Nigeria and abroad is presented in Figure 1. Some of them were CEM Is while others CEM IIs and all the cement brands assessed met the SON requirements with regards to initial setting time; ≥ 75 minutes for cements of strength class 32.5N/mm²; and ≥ 60 minutes for cements of strength class 42.5N/mm². One sample only of the 14 brands failed to meet the required standard strength of ≥ 10 N/mm² at 2 days and ≥ 32.5 N/mm² at 28 days; using standards cement mortar cubes. All other cement brands met the required minimum. As for standard designed concrete samples using cubes, only one sample (the same as for the cement mortars) out of 14 did not meet the minimum specification.

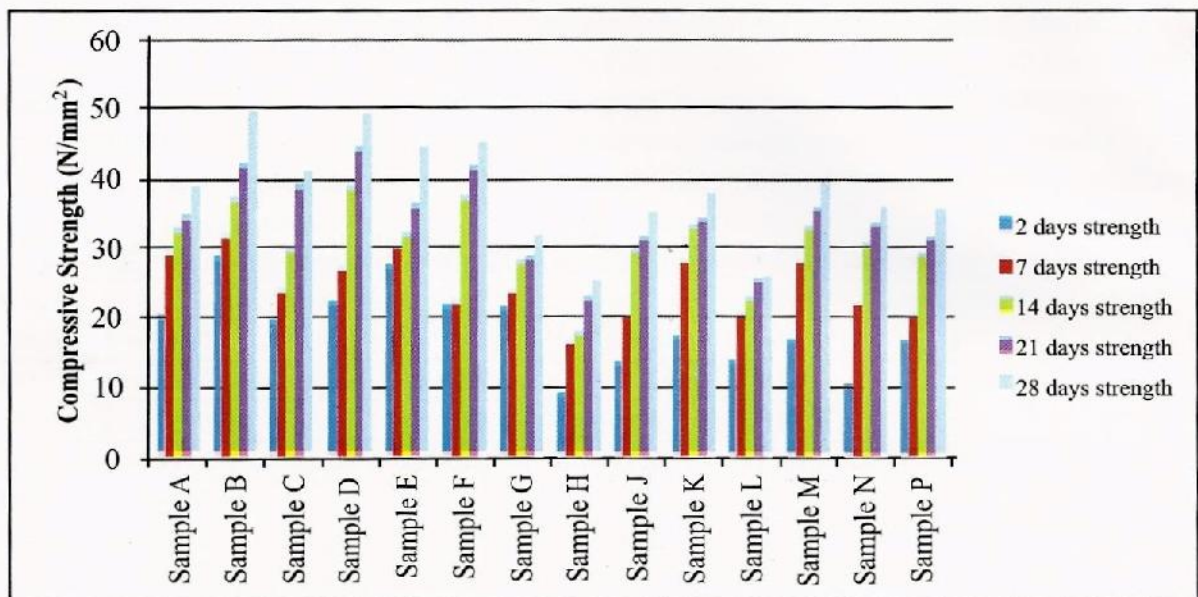


Figure 1: Concrete Compressive Strength

5 STRUCTURAL PROPERTIES OF NIGERIAN TIMBER SPECIES

Table 6 below compares the tensile and compressive strengths and specific gravity of Timber woods with those of other traditional materials. Nigeria has a large reserve of these Timber resources though these being depleted at exhilarating rates. These include Mahogany, Obeche, Maligna, Iroko, etc, which are the major ones; and Eucalyptus Siever Pedondora, Bombax Costatum, Pakia Clappertoniana and Kaya Selignosis amongst the minor species.

Table 6: Maximum Strength of wood to other building materials (Dinwoodie 1994)

Material	Tensile strength, N/mm ²	Compressive Strength N/mm ²	Specific gravity, G _s
Wood	104	37	0.46
Concrete	4	69	2.5
Steel(Mild)	459	800	7.9
PVC(rigid)	59	55	1.5
Glass	50	50	2.5
Aluminium	247	-	2.8

It is important to know that unlike the other Building materials, with the possible exception of naturally stratified soils, Timber is basically anisotropic in nature. This property primarily stems from the seasonal growth pattern of trees in the forest which is in concentric rings approximating to seasons of the year, especially as it relates to rainy and dry periods of growth. It therefore follows that the compressive, direct tensile, flexural, hardness and shear strengths of any timber specie will depend on the direction of test because the transverse direction will give different results from the longitudinal and lateral directions. The tensile strength of white wood is in the middle of the range but when strength is quoted in terms of specific gravity so that the strength of an equal mass of material is compared, timber is far superior to the traditional materials.

The seven minors of indigenous timber species already in use in the Nigerian Market were taken from three different locations with the aim of examining their structural adequacy for the purposes of construction by Matawal and Abubakar (2009). Field and laboratory experiments were conducted on the samples in accordance with NCP2 and BS5286 regulations. The results obtained indicated that they fall within the minimum requirements of the two codes and the study identified Eucalyptus, Kaya Selignosis, Asobalina and Pakia Clappertoniana to be structurally adequate for building construction and sufficiently available in commercial quantities. Additionally, engineering data hitherto unavailable for these species were generated for practicing engineers.

The species were obtained from Lame/Bura, Kanawa Forest Reserves and Bokkos Town for which, based on the tests and other analyses, can be said to naturally have pleasing and attractive appearance with densities falling within the range of 360 to 860kg/m³; which is adequate by NCP2 for any construction purposes. These fall within the strength group of N2, N3 & N6 with strength properties varying with loading direction relative to the grain. Compressive strengths range from 23 to 110N/mm² for parallel to grain, 7 to 68N/mm² for perpendicular to grain and 5 to 50N/mm² for tangential to grain; while the species are easy to cut, shape and join, using simple tools.

Table 7: Properties of seven Timber species (Minors)

S/N	Specie	Strength (N/mm ²)					w,%@ 100°C	g/cc	G _s
		Flexural		Compressive					
		Par	Per	Tan	Per	Tan			
1	Eucalyptus	58.6	24.0	40.5	23.5	18.5	12.1	0.51	0.615
2	Siever Pedondora	13.5	7.8	12.3	7.1	5.1	12.8	0.39	0.854
3	Kaya Selignosis	77.8	43.2	110.2	67.7	49.8	12.6	0.86	0.893
4	Asobalina	37.2	21.4	86.8	50.2	38.1	12.8	0.51	0.835
5	Boswelli Delzelli	24.1	13.4	23.2	15.4	11.0	15.8	0.45	0.600
6	Bombax Costatum	17.1	10.7	34.4	22.2	16.7	12.9	0.36	0.663
7	Pakia Clappertoniana	32.1	19.0	78.0	48.6	35.6	12.8	0.72	0.769

*Parallel (Par), Perpendicular (Per) and Tangential (Tan) to the grain;
w – moisture content, p – density and G_s – Specific gravity*

6 CONCLUSION

The discussion in this paper has merely looked at conventional building materials for superstructural works in buildings. Even on convention, soils are primary building materials that are used and applied as fills, as construction materials for parking lots and access roads. Soils are also used for non-conventional materials like compressed bricks (which are conventional in other countries),

interlocking blocks, and they comprise the foundations of all structures. So much can be written about durability and strength of buildings as it relates to soils particularly when it has to do with compressibility, settlement, shear strength and bearing capacity. A discussion of durability must take into consideration the foundation and its interaction with the soil. Nonetheless, however elaborate the steps taken to address strength of materials, it is important that the buildings should be made to be serviceable through their life-spans by investigating the soils properly and designing appropriate foundations to address any special conditions.

However, there can be many innovative building materials used specially in many respects and these vary from one part of the country to another. A discussion on these has not been presented in this write-up. Furthermore, serviceability limit states like vibration, deflection, fire resistance, lightening effects, impact loading, accidental and incidental events are also important issues of durability.

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