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Abstract. The continuous rise of world population is putting much pressure on the housing and infrastructure stocks available to the society, thereby accentuating the need for more constructions and of course, more pressing demands on the depreciating natural resources. Today, the most used construction materials are concrete and steel, but the amount of pollutants deriving from their production has remained a source of great concern to the world. Finding solution to this environmental challenge has given rise to Sustainability Development Goals (SDGs), aimed at making the planet earth more conducive to living organisms. One of the viable approaches to reduce the high demand of construction industry on depreciating natural resources is the recourse to using more of renewable materials like timber. Timber is one of the few construction materials that have served all the ages of human lives in providing shelter. In this moment of pressing needs for more shelter and infrastructure, needed to make life more comfortable for man, the use of this renewable material must be sustained, but the strength characteristics must be known for more efficient and safe use. This research reviews recent characterization of some Nigerian timber species. This research emphasizes some good strength properties of recently reviewed Nigeria timber species, which will build the confidence of designers on safe judgment and choice of structural timber, help to reduce the cost of construction, thereby making residential houses more affordable to the lower class of the society. This will help to build a sustainable eco system for all.
Keywords: Nigeria timber species, Physical properties, Mechanical properties, Characterization, Structural applications

1. Introduction

Due to the steady rise in population in developing nations, there has been significant shortage of affordable residential housing and this has been a cause for concern to all. According to [1], the demand for structures and infrastructures is destined to escalate as the population increases, and more social challenges will emerge if the volume of new constructions does not match the demand. High volume of new constructions makes the building construction industry a steady threat to the depreciating natural resources in our environment. This explains why [2] points out that construction and our environment are inextricably linked. In Nigeria, the most populated country in Africa, the commonly used construction material is concrete [3]. It is mostly used because of the availability of cheap labour, a high number of cement manufacturing companies and the constituent materials. The high demand and the consequent high cost of construction necessitates the need to search for possible sustainable approach to affordable houses. This is one of the reasons behind some researchers [4] stating that it is important for alternative construction materials to be vastly explored as to reduce the pressure of construction industry on available natural resources. Due to the climate change challenges caused by industrialization

and high demands on natural materials, the world is greatly responding to deteriorating environmental issues through strategies that emphasize sustainability. One of the broadly adopted approach is the Sustainability Development Goals (SDGs), aimed at reducing the way we consume depreciating natural resources. This has given rise to many researches on intelligent combination of materials, including wastes, into useful construction materials [5,6,7,8]. Another approach to reduce the pressure on depreciating natural resources is to improve on the use of renewable materials like timber in the construction industry. The application of timber as a building material has evolved over the centuries and still remain very essential in this present time and in the future. According to [9], timber can be utilized in various forms: in the natural form or as processed wood such as Glue-laminated timber, Structural Composite Lumber, Laminated Veneer Lumber, etc. The use of the processed timber requires modern technology to maximize its benefits, while the nations that are less developed technologically tend to adopt the unprocessed timber in the natural form. In Nigerian construction industry, unprocessed timber is adopted principally for roof trusses, interior finishes, and in a very reduced dimension as structural loading bearing members.

One of the principal factors limiting the use of Nigerian timber for structural applications is the absence of good knowledge on the strengths and properties of the various species. Most of the timber species in the country are not characterized and this has left the usage to be based on past experience or on speculation. The need to verify the structural efficiency of Nigerian timber species has led to the characterization of some Nigeria timber species. It is only when the strength characteristics are known that the usefulness can be maximized. Lack of sufficient information on the mechanical properties of Nigerian timber species has greatly limited the structural application and has led to the adoption of unreasonably high safety factors in timber design as the strength properties are mostly estimated. This leads to poor safety judgment. Based on these prevailing situations, this research evaluates some recently characterized Nigerian timber species with the view to identifying the proven uses to which some Nigerian timber species can be safely put to. By so doing, some locally available timber species, which are renewable, can advantageously serve as a substitute to the non-environmentally friendly and expensive concrete and steel which are currently the most used materials. This will help to reduce the cost of construction, make residential houses more affordable to the to the lower class of the society and improve our eco system.

2. Overview of timber as a construction material

Timber is one of the oldest construction materials in the world and has served all the ages till date. When timber is obtained from managed and controlled forests, it tends to be a sustainable construction material as it has the capacity to renew itself and at the same time, giving negligible or no negative effect to the environment. The volume of timber usage worldwide competes favorably with concrete and steel, but the level of pollutants emitted from steel and cement production has remained a source of concern to the world [10]. The extensive use of timber in construction is linked to its good properties such as lightweight, good tensile and compressive strength, relatively low cost and its renewable nature [11]. There are more residential buildings constructed with timber than any other structural material in the advanced world [4]. Nigeria is very rich in the supply of timber and previous research confirms that some of the timber species found in Nigeria are suitable for construction. Timber possesses the ability to transfer tension, compression and shear because of its strength in relation to its weight, which is one of the reasons it's an attractive structural material. Timber grains have natural patterns, aesthetically pleasing finishes and distinguished features of various species which make clients and architect's love for the material. Carpenters of the ancient era manipulated timber and connection details to enhance beauty and aesthetics in the construction of the buildings [12]. Timber has been most popularly used for roof structures in Nigeria. A survey by [13] on materials mostly adopted for making roofs in South West of Nigeria showed that timber accounted for 66%, while the usage of raffia palm, concrete and steel stood at 19 %, 11% and 4 %, respectively. Omo (C. millenii), and Afara (T. ivorensis) were the most popular species of timber used in Southwestern Nigeria due to their availability and ability to span cross functional, structural, and decorative use cases. Suitability of Nigerian timber as a structural component

in modern construction is proven by the many tests of various wood species in Nigeria. The work of [13] provided an illustration of how various types of timber species are used and where their different applications overlap in the following as shown in Figure 1:

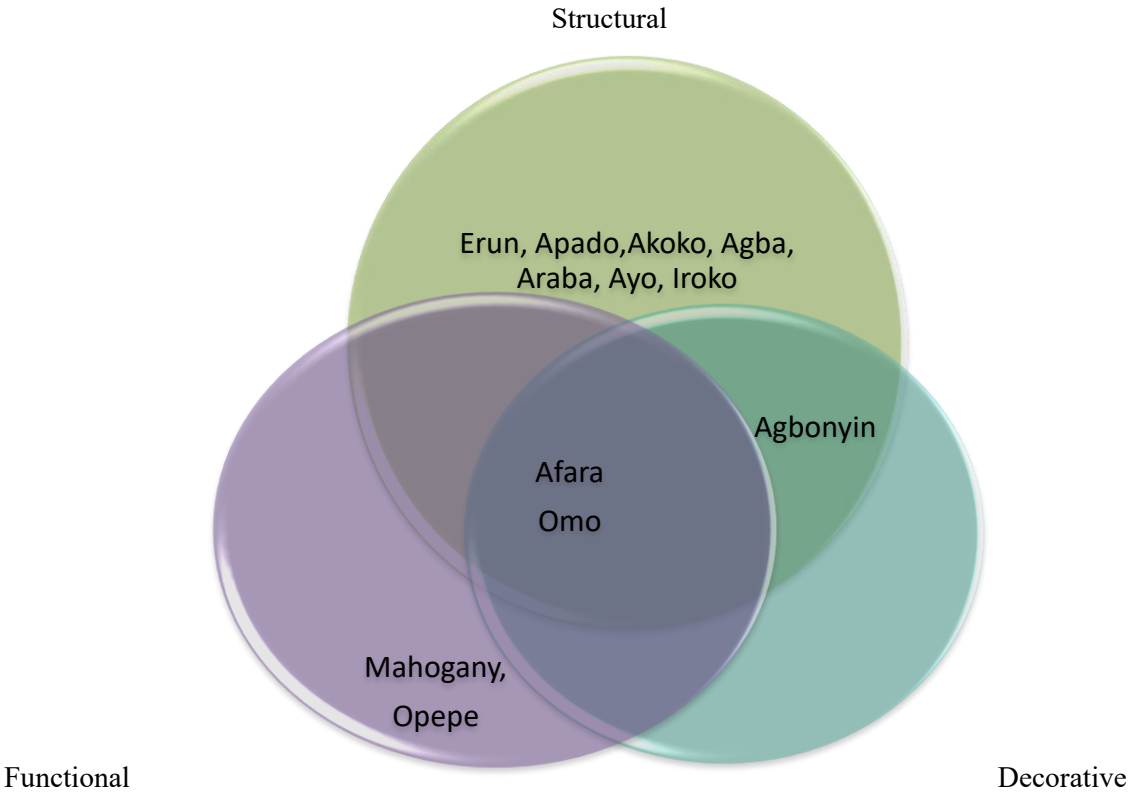

Figure 1. Various use of some Nigerian timber species in South West Nigeria (Adesogan, 2013)

Timber types such as Iroko (M. exelsa), Ayo (H. grandis), Agba (G. balsamiferum), Erun (E. suavecolens), and Apado (C. gradiflora) are useful for structural use. It can be seen that Afara (Terminalia superba) and Omo (C. millenii) lie in the area where all used cases overlap while Agbonyin wood species is useful as decorative and structural. Despite this widespread use of timber for various applications in construction industry, [14] noted that there is a big gap in usage and quality of timber in some areas of Nigeria. The authors noted that in Minna, Niger State, the building contractors had little knowledge about quality of timber they use while customers rarely enquire about the quality of timber. It was also observed that in Minna, no standard rule existed to govern the quality of timber used. Consequently, the trend is that there is a drift of demand towards cheaper and low-quality timber, with increased use of lesser-known wood or uncharacterized species. This shows that the demand and price for timber does not follow quality since the construction industry in Minna does not consider quality of timber as a guiding factor. This lays credence to the fact that the use of timber as a construction material in Nigeria is not standardized as the choice of timber material varies from region to region and have respond more to price than to quality. Since structural use of timber is the most important application of timber in construction industry, it very essential that the timber species be characterized, as to make the best use of their properties during design and to obtain safe structures at the end of its usage.

3. Review of Recently Characterized Nigeria Timber Species for Structural Applications

Procedures for designing Ayin (Anogeissus leiocarpus) wood column under axial load were developed by [15]. Specimens were subjected to direct axial compression test while stress and strain data were harvested. Critical stress and slenderness ratio were obtained via Euler-Engesser stress formula, which

help in deriving an equation that established agreement between the theoretical and experimental stress data. This equation simplifies the design of Ayin (Anogeissus leiocarpus) wood column. The suitability of three Nigerian timber species of Melina (Gmelina arborea), African locust beans (Parkia biglobosa) and African mesquite (Prosopis Africana) obtained from the forest in Idah town in North-Central part of Nigeria as structural members was studied by [16]. These three species were tested for tensile, compression, bending and shear strengths in conjunction with moisture content and density. Results of the tests showed that the compression, bending strength and shear strengths, together with the Young modulus and density are similar for the three species, while the moisture contents were significantly different. These timber species were classified as hardwood of higher strength classes (D30 – D70) in accordance to BS 5268. Therefore, they are suitable for structural use. Ogbono (Irvingia gabonensis) specie grown in South Eastern Nigeria was characterized and graded by [17]. This tree bears local names in different localities of Nigeria (Bini -Ogwe, Efik –Oyo, Ijaw - Ogboin, South East - Ogbono and South West - Oro). Two logs of this timber specie obtained from Akpugo forest in Enugu State were sliced into planks and seasoned naturally for six months in accordance to BS 373 prescriptions. Laboratory test results were adjusted to the values at moisture content of 12% in toeing the line BS5268. The bending stress, mean Young modulus and density results obtained showed that Ogbono tree species can be assigned to strength class D70, which is appropriate for heavy load bearing structural elements like bridge beams and railway sleepers. The works of [18] on White Afara (Terminalia Superba) timber specie obtained from Kaduna and Zaria timber markets. Characterized the strength properties according to Euro codes. Bending strength, modulus of elasticity, moisture content and density were determined in accordance with Euro codes. The White Afara samples were not affected by different environments from which they were obtained and were classified to fall within the strength class D24 according to EN 338 Part 8 and strength class N6 according to NCP 2 Part 14. This goes on to indicate that the specie is a hardwood with a high medium bending strength. [19] studied the structural behaviour of the Nigerian grown Abura (Mitragyna ciliata) timber subjected to compression and shearing forces. The purpose of this research was to assessed the suitability of this timber specie for bridge beams. Reliability studies and deterministic investigations were performed on the beam samples under the ultimate limit state considerations. The reliability indices recorded were satisfactory at depth of 400 mm, breadth of 150 mm and span of 5000 mm, while the samples showed low level of safety under only shearing forces. So, this can be comfortably adopted for structural beams.

The suitability of Ekki (Lophira alata), Apa (Afzelia bipindensis), Iroko (Chlorophora exceisa) and Abura (Mitragyna ciliate), which represent N1, N2, N3, and N4 classes of Nigerian timber species for bridge decks were conducted by [20]. A timber bridge deck was modelled on timber stringers on the basis of AASHTO LRFD. It was established that, strength classes, stringer spacing, timber thicknesses and width were verified as the most influential factors of the structural performance of these Nigerian timber species adopted for bridge decks. These results will be helpful in future prediction of stringer spacing for bridge deck design and analysis of Nigerian timber species for bridge decks. Regression analysis was applied to determine the relationship between the properties of Nigerian Teak (Tectona grandis) and Ebony ((Kanyan) Diospyros mespiliformi) timber species by [21]. To ascertain the potential of these Nigerian timber species, specimen for tests were prepared on the basis of EN 13183-1 and EN 408, while oven dry density, bulk density, moisture content, bending strength and Young modulus were determined. The results showed that wood density has a strong correlation with the bending strength of these Nigerian timber species and therefore very useful for forecasting strength properties and for advantageous utilization of these timber species.

The suitability of samples of Dogonyaro (Azadirachta indica) and African guinea pepper (Xylopia aethiopica), obtained from different areas of Kwara State, Nigeria for structural applications was conducted by [22]. The physical properties determined were moisture content, specific gravity and density, while the mechanical tests were for compression, shear, tensile strengths, modulus of rupture, modulus of elasticity and hardness. These tests were conducted on the basis British Standards, Nigerian Standards and Euro codes (BS 5268, 2002; NCP2, 1973 and EC5, 1995). The authors concluded that these timber species were hardwood of strength classes D30 - D70 according to BS 5268 and are

therefore suitable for structural applications. The compressive strength characteristics of Apa (Afzelia bipindensis) and Opon (Lannea schimperi) timber species obtained from sawmills in Ilorin, Kwara State, Nigeria were performed by [23]. The samples were naturally seasoned for seven (7) months and tested in accordance with the British Standard BS EN 408 (2003) Test for physical and mechanical properties of structural timbers involved moisture content, density and compressive strength. Results obtained showed good combination of both buckling and compression resistance of these timber species. Therefore, the suitability of these timber species as axial load carrying members were established.
The characterization of Iya (Daniellia ogea) obtained from forests around Ilorin Local Government, Kwara-State, Nigeria was done by [24]. The samples were prepared in accordance to BS EN 408: 2003. The moisture content, density, compressive strengths perpendicular and parallel to grain, tensile strength parallel to grain, modulus of rupture, local modulus of elasticity and the apparent modulus of elasticity were determined. The results obtained compared very favourably with known characterized species in the market. The mean density achieved was far higher than the range of coniferous softwoods, therefore, Iya timber specie can be classified as deciduous hardwood and good for structural applications. The use of Apa (Afzelia bipindensis) wood species in construction was verified by [25]. Tests were conducted on three timber logs obtained from Kwara State, North Central Zone of Nigeria. Samples were air-dried and tested parallel to grain in compression, tension and bending, following the BS codes, Euro codes and Nigerian standards. This timber specie was classified to belong to the strength group D30. The characteristic strength obtained is satisfactory for structural purposes. The reliability of Afara (Terminalia sperba) and Babo (Isoberlinia doka) obtained from sawmills in Ilorin, Kwara State, Nigeria for structural use as compression members was conducted by [26]. Moisture content, density and compressive strengths of various samples were determined. This research derived equations for the design of Afara and Babo columns and therefore recommended the equations as the more appropriate approach for the design of timber compression members in Nigeria.

4. Conclusion

This particular investigation on recently characterized Nigerian timber species establishes that Nigeria as a nation is endowed with good structural timber species, but perhaps lagging behind in terms of widespread application of timber as a major load bearing material in building and infrastructural construction. Again, (Aguwa et al., 2015) expanded the meaning of construction not only to mean housing application, but also to include building of substantial public infrastructure. Tests of various timber species provided a picture of the availability of a wide range of structural timber species that are not advantageously utilized to help reduce the burden of construction materials on nonrenewable sources. The results of all the studies indicate that Nigeria has a number of wood species that are suitable for structural and functional applications, by far the most important uses of timber in construction. These findings will further improve the acceptability and trust of Nigerian timber species as structural construction materials. More researches in characterizing Nigerian timber species are recommended as to make the best use of the renewable materials of which the nature has endowed the nation.

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