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# An Assessment of the Sustainability of Locally Sourced Timber Specimens for use as Building Material

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**Abstract**

*This study aims to determine the sustainability of locally sourced timber as a building material in Benin City, Nigeria, by carrying out some physical and mechanical properties tests on locally sourced timber specimens (Oku, Ekki and Walnut) readily available at local sawmills in the region. These tests were done based on the British Standard code 373:1957. Proper preparation and testing of each specimen was based on standard procedures. The timber specimens were weighed, and oven dried to determine its moisture content and specific gravity/density. Compression, Tensile and Bending test were done on all specimens using the necessary machines and equipment. The data from the various test were properly recorded and analyzed. Results from the various laboratory tests were collated and comparison of the various specimens were done to determine their viability as probable building materials. From the results Ekki has the highest tensile strength (150.83N/mm$^2$) and compressive strength (54.6N/mm$^2$), while Oku which has a higher bending strength (406.25N/mm$^2$) of the three timber specimens. Ekki being a hardwood would be the most desirable for heavy duty construction while Walnut would be better suited for lightweight construction and furniture making*

## 1. Introduction

According to the Nigerian National Population Commission (NPC, 2023), Nigeria is one of the most populated countries in the world having population around 223.8 million as on 2023. Nigeria is a developing country where huge number of infrastructural projects is going on. This includes Benin City, the capital and largest city of Edo state in southern Nigeria, also the fourth most populous city in Nigeria [1]. An enormous number of environmental problems are emerging because of urbanization. Modern, advanced infrastructure and technologies use more energy and have an influence on the environment, either directly or indirectly [2,3].

Urbanization also increases the amount of energy and materials consumed as well as the amount of carbon dioxide released into the atmosphere, all of which contribute to atmospheric pollution and negatively impact human health [2]. These actions cause climate change, which in turn causes a variety of man-made and natural disasters [4]. The only way to lessen the impact of pollution is to transition to sustainable building practices. The current state of ecological difficulties will be improved, and contamination will reduce with the use of sustainable building materials [5].

Building materials are in constant demand since the global construction sector is expanding quickly in practically every nation. There is a growing need for construction activities in addition to new building projects, infrastructure, and utilities, but there is a rising demand for improving existing buildings known as “Building adaptation” [6]. As a building is being constructed, various materials must be assembled. Among these materials are steel, glass, concrete, and wood, among others. These raw materials must be extracted, processed, transported from the manufacturer to the construction site, and finally placed all require energy. The majority of developing nations, including Nigeria, rely heavily on fossil fuels to generate energy for these kinds of operations. As a result, greenhouse gases including carbon dioxide, Sulphur dioxide, methane, and others are released into the atmosphere, depleting the ozone layer and resulting in global warming and, consequently, climate change. The need for more environmentally friendly building materials is necessary to combat the adverse effect of infrastructural development in the country.

Timber is typically employed as a structural element in portions of a construction where load bearing is minimal or nonexistent, this was basically to maximize workability and decrease expense. Despite this, in many nations where wood serves as the primary building material for most structures, the design of these structures takes wood into consideration and the wood may receive specific treatment either before or after construction. Also, species are used in construction, depending on the property required. Some species possess high resistance to bending and compression stresses, chemical or insect attack, or resistance to fire than others, which makes them desirable when these properties are needed [7].

According to [8],[9],[10] among the benefits of using timber as a building material are its availability, physical and aesthetic qualities, workability and versatility, environmental sustainability, flexibility in space arrangement, industrial production, and comparative cost effectiveness. The primary goal of engineered construction is to produce a structure that optimally combines safety, economy, functionality and aesthetics.  Timber, like other building materials, has inherent advantages that make it especially attractive in specific applications [11]; It is a durable option for primary structural members highway bridges and when properly pressure-treated can last up to 75 years[12], In comparison to traditional reinforced concrete or steel-concrete composite floors, composite systems that utilize large timber beams/joists and slab in conjunction with reinforced concrete slab and or steel beams offer a number of advantages including lighter structures with a lower energy and carbon footprint[13]. Local building materials will make development more accessible, sustainable, and able to support a diverse and vibrant community. These benefits will also have a ripple impact on the local economy [14].

## 2. Materials and Methods

### 2.1 Study Area

Benin City is a humid, tropical, urban settlement, which comprises three major local government areas (LGAs), namely: Oredo, Egor, and Ikpoba Okha. Benin City is a narrowed, key-shaped, north-to-south strip of land in West Africa. The area is about 1125 km2 and situated on fairly flat land, about 8.5 km above sea level. It is located between latitude 6°44′ N and 6°21′ N and longitude 5°35′ E and 5°44′ E as shown in figure 1.

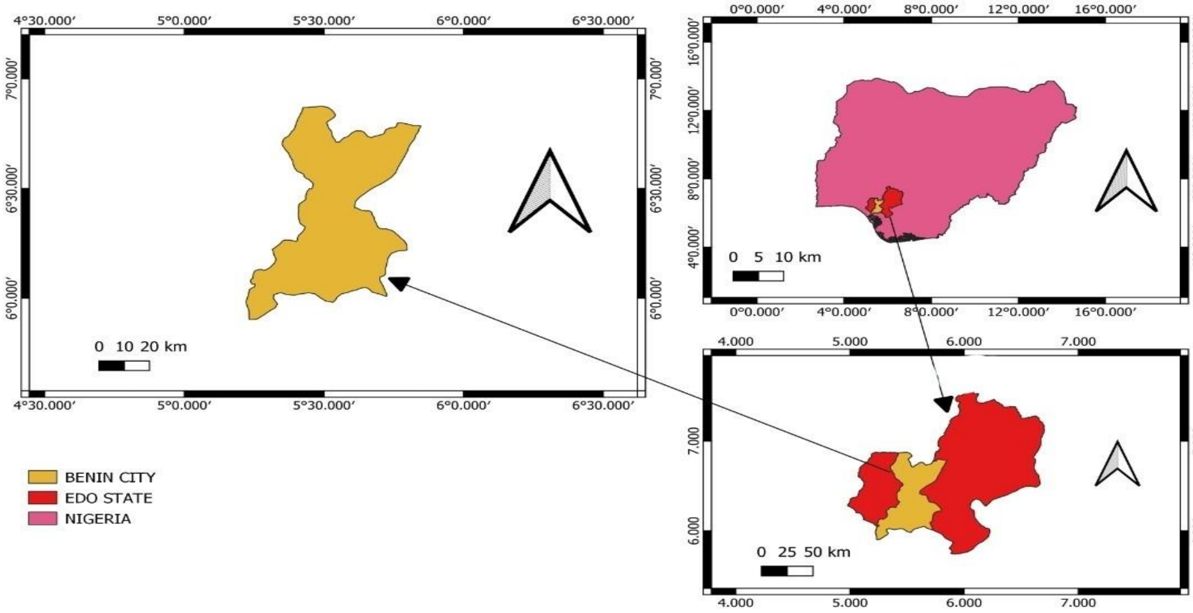


**Figure 1: Map of study area**

## 2.2 Specimens and Fabrication

A total of three specimens were used to carry out this experiment of which are: Oku, Ekki and Walnut. These specimens were acquired at a local sawmill in Benin City along First East Circular Road, then were sawn according to the British standard code (BS 373:1957) as shown in figure 2,3 and 4.

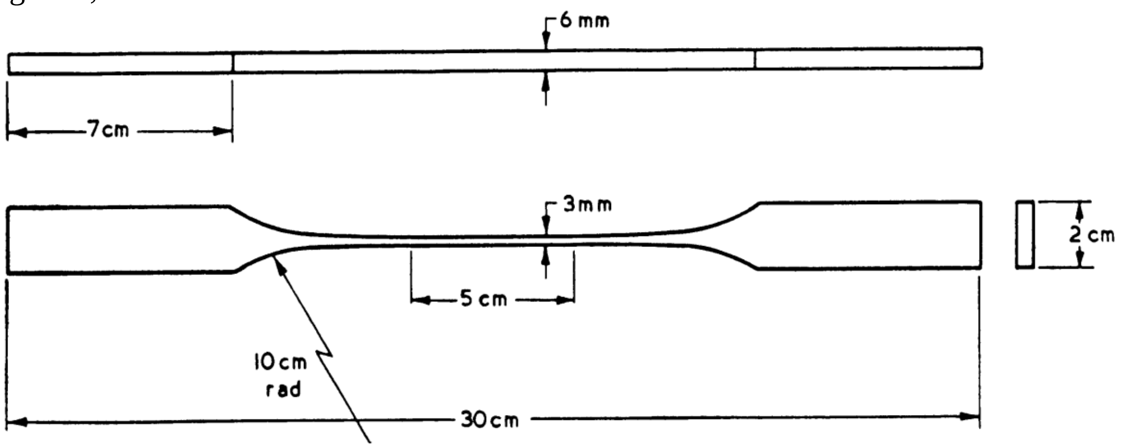


**Figure 2: Test Piece for Tension Parallel to Grain (BS 373-1957)**

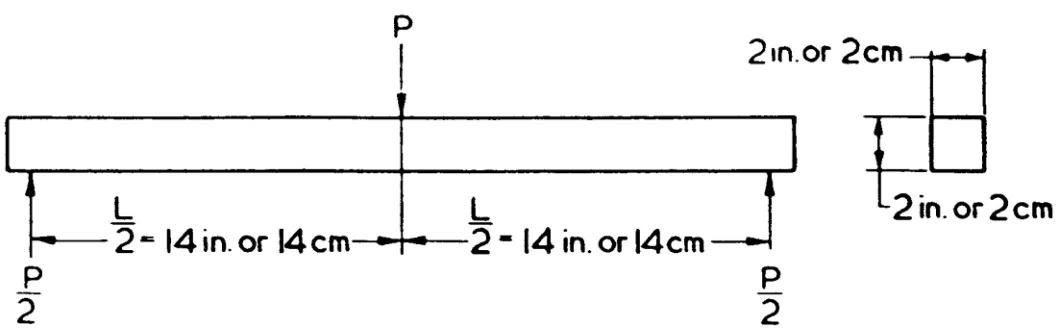


**Figure 3: Beam Test. Central Loading for 20mm or 2cm Standard Test Piece (BS 373-1957)**


**Figure 4: Form of Test Pieces for Compression Parallel to Grain 6cm Standard**

## 2.3 Test Performed

1. **Moisture Content Test**

The oven-dry method was used in carrying out this test. Each wood specimen to be tested on was weighed on a scale balance and its weight recorded, then they were placed into an oven of temperature between 215° F and 220° F (102° C and 105° C) for 24 hours.
After 24 hours the wood samples were removed from the oven and weighed again to obtain the dry weight of the specimen. The moisture content of each sample was calculated using equation (1)

$$moisture\ content\ \% = \frac{(wet\ weight - dry\ weight)}{dry\ weight} \times 100 \quad (1)$$

Where, wet and dry weight of the specimen are in grams (g)

2. **Specific Gravity and Density**

The specific gravity of each of the specimens were calculated by, dividing the recorded dry weight of the specimens obtained from the moisture content test with the measured volume as shown in equation 2. The volume of each specimen was calculated by multiplying the respective dimensions of that specimen.

$$\text{Specific gravity} = \frac{mass}{Volume} \quad (2)$$

Where, mass of specimen is in grams (g)
Volume of specimen is in cubic centimeter ($cm^3$) i.e $50 \times 2\ \times 0.6 = 60\ cm^3$
While the density of each specimen was calculated using equation 3

$$\text{Density} = \frac{Specific\ gravity \times (dry\ weight + 100)}{100} \quad (3)$$

Where, specific gravity is in gram per cubic centimetre (g/$cm^3$)

3. **Tensile Strength Test**

The universal material testing machine was used for the experiment. The test piece was positioned so that the larger cross-sectional dimension and the yearly ring direction are perpendicular to each other. The toothed plate grips, which are intended to provide an axial load, would apply the load at the ends of the sample. The maximum load would be measured when the sample split in two. The following formula is used to find the material's tensile strength is given in equation 4

$$Tensile\ strength\ \left(\frac{N}{mm^2}\right) = \frac{Force\ at\ failure\ (N)}{Minimum\ cross-sectional\ area\ (mm^2)} \quad (4)$$

4. **Compressive Strength Test**

The samples already prepared and fabricated to standard were positioned between the parallel plates of the compression machine, grain parallel to the plate. Load was applied at both ends of the test sample at increasing magnitude. The test was completed when a visible deformation is seen on the timber sample. After the samples were crushed, the crushing loads of each sample were recorded. Equation 5 is used to calculate the compressive strength of each sample.

$$Compressive\ strength\ \left({N}/{mm^2}\right) = \frac{Crushing\ load\ (N)}{Cross{-}sectional\ area\ (mm^2)} \quad (5)$$

**5. Bending Test**

The bending test was carried out using dead weights due to the unavailability of the universal testing machine, hence the samples were modified using a specification of 20 x 6 x 500mm as shown in plate. A hanger was connected to the mid-span of the beam and dead weights were added at the base of the hanger while both ends of the beam were clamped with a bench vice. The dead weights were increased sequentially till the timber sample failed. The load was applied, readings were taken from the dial gauge (supported by a retort stand and attached with a metal clap to the sample) at different load from the universal testing machine until failure occurred. The bending stress was computed using equation 6

$$Bending\ stress\ \left({N}/{mm^2}\right) = \frac{3PL}{2bh^2} \quad (6)$$

Where:
P = Maximum load in Newton
L = Distance between supports in millimeter = 500mm
b = Breath in millimeter = 20mm
h = Depth in millimeter = 6mm

## 3. Results and Discussion

### 3.1 Tensile strength test

This test was performed on three different samples each of three timber specimens, the data acquired during this test is recorded in table 1.

**Table 1: Tensile Test Result of Each Samples and Respective Specimens**

| Timber specimen | Test 1 | | | Test 2 | | | Test 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Load (KN)** | $W_1$ **(g)** | $W_0$ **(g)** | **Load (KN)** | $W_1$ **(g)** | $W_0$ **(g)** | **Load (KN)** | $W_1$ **(g)** | $W_0$ **(g)** |
| Oku | 0.7 | 14.32 | 14.20 | 0.69 | 15.71 | 15.10 | 0.7 | 16.02 | 15.40 |
| Ekki | 5.9 | 23.76 | 23.00 | 5.4 | 23.30 | 22.50 | 5.0 | 23.20 | 22.40 |
| Walnut | 0.15 | 16.65 | 16.10 | 0.33 | 18.34 | 17.80 | 0.16 | 17.06 | 16.40 |

Where; $W_1$ and $W_0$ are the respective wet weights and dry weights of each sample

Table 1 shows the range of the wet weight and dry weight of each timber specimen having conducted a total of three trial test. Ekki being the highest weighing specimen ranging from 23.2g to 23.76g when wet and 22.4g to 23g when oven dried, the Walnut specimen with wet weight ranging from 16.65g to 18.34g and dry weight ranging from 16.1g to 17.8g and lastly Oku specimen ranging from 14.32g to 16.02g when wet and 14.2g to 15.4g when dried. These results show Ekki as the timber with the highest weight and Oku being the lowest weighing timber of the three specimens.

Despite Walnut weighing higher than Oku timber from table 1 it has a lower load bearing capacity than Oku when tested for its tensile strength. Its load ranges from 0. l5KN to o.33KN while that of

Oku ranges from 0.69KN to 0.7KN. Ekki being the highest of both specimen can withstand a load of 5KN to 5.9KN.

**Table 2: Average Values of Data for the Tensile Strength Test**

| Timber Specimen | Load (KN) | $W_1$(g) | $W_0$ (g) |
|---|---|---|---|
| Oku | 0.7 | 15.35 | 14.9 |
| Ekki | 5.43 | 23.42 | 22.63 |
| Walnut | 0.25 | 17.35 | 16.77 |

Table 2 shows the average values of results gotten from table 1. Oku having a wet weight of 15.35g and dry weight of 14.9g, Ekki having a wet weight of 23.42g and dry weight of 22.63g and Walnut having a weight of 17.35g and dry weight of 16.77g. Ekki bearing the highest load, Oku with a load of 0.7KN and walnut with the lowest value of 0.25KN

**Table 3: Moisture Content, Specific Gravity and Density Result of Tensile Test Samples**

| Timber | Load (KN) | Moisture content in % | Tensile strength (N/$mm^2$) |
|---|---|---|---|
| Oku | 0.7 | 3.02 | 19.44 |
| Ekki | 5.43 | 3.49 | 150.83 |
| Walnut | 0.25 | 3.46 | 6.94 |

The values for moisture content, specific gravity, density and tensile strength are calculated using equations previously stated above.
The minimum cross-sectional area = 6mm × 6mm = 36 $mm^2$

From table 3 it is visible that all the specimens tested have similar amount of moisture in them with an average of at least 3%. Despite that the tensile strength of each specimens varies widely with Walnut having the lowest strength of 6.94 N/$mm^2$, Oku with a tensile strength of 19.44 N/$mm^2$ and Ekki far above them with a tensile strength of 150.83 N/$mm^2$. This tensile strength of the various specimens is based on their load bearing capacity, with Walnut being able to carry only 0.25KN, Oku with a load of 0.7KN and Ekki being the highest able to withstand up to 5.43KN on average. The graph of the results are shown in figure 5 and 6.

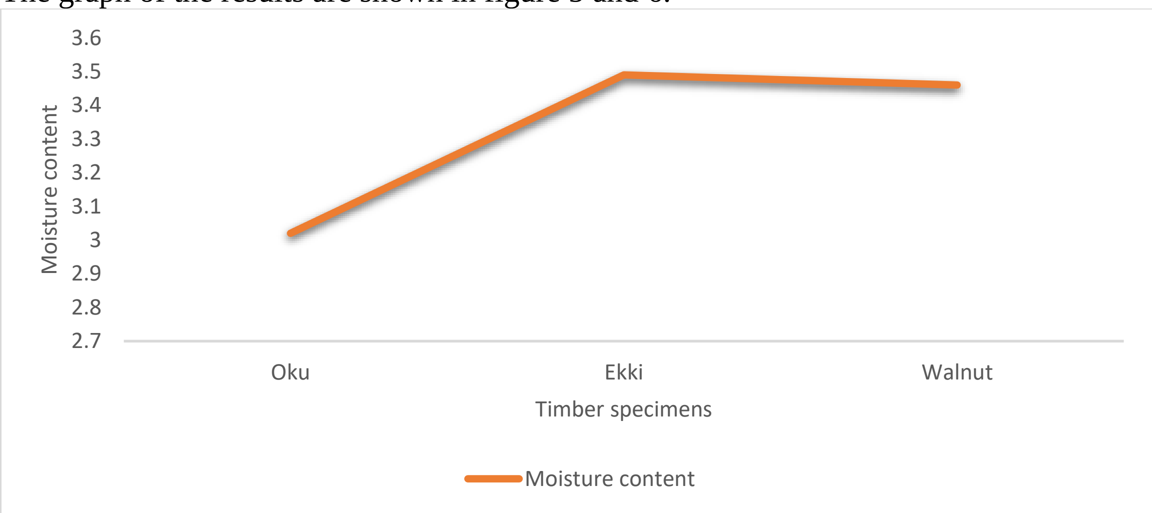


**Figure 5: Graph Showing the Moisture Content of the Timber Specimens for Tensile Test**

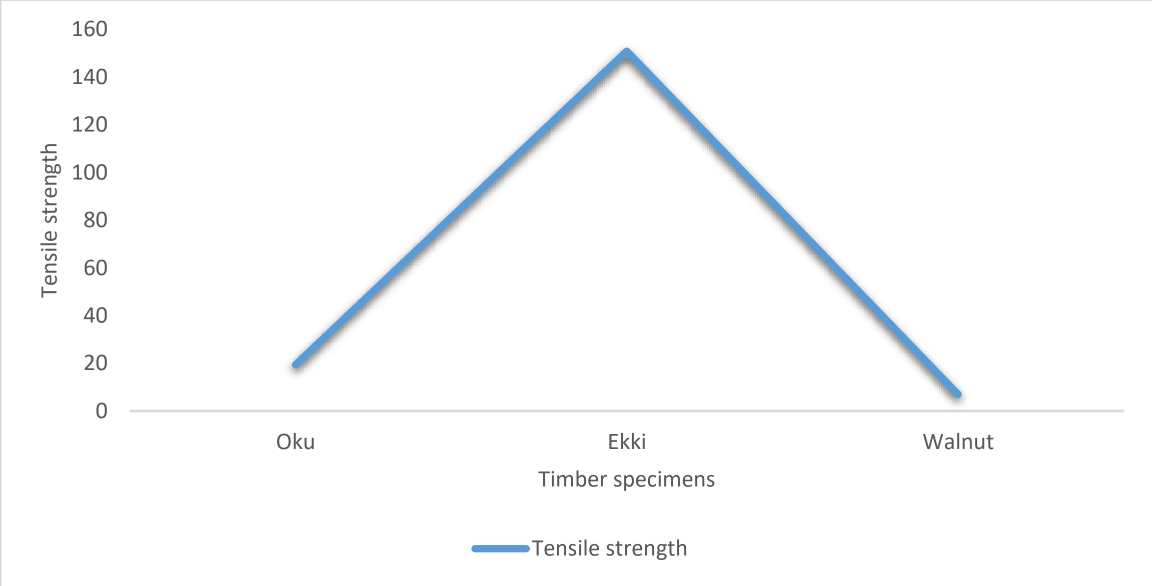


**Figure 6: Graph Showing the Tensile Strength of the Timber Specimens**

### 3.2 Compressive strength test

This was performed on three different timber specimens through three test trials on samples sawn to standard according to BS 373:1957. The data gotten from this test is recorded in tables 4, 5 and 6.

**Table 4: Compressive Test Result of Each Samples and Respective Specimens**

| Timber specimen | Test 1 | | | Test 2 | | | Test 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Load (KN) | $W_1$ (g) | $W_0$ (g) | Load (KN) | $W_1$ (g) | $W_0$ (g) | Load (KN) | $W_1$ (g) | $W_0$ (g) |
| Oku | 21.77 | 16.36 | 14.70 | 21.99 | 17.05 | 15.27 | 21.60 | 16.76 | 15.01 |
| Ekki | 21.78 | 19.96 | 18.21 | 23.54 | 20.62 | 18.82 | 20.20 | 21.47 | 19.66 |
| Walnut | 11.99 | 14.26 | 13.12 | 16.11 | 16.46 | 15.08 | 16.01 | 15.87 | 14.54 |

Table 4 shows the range of the wet weight and dry weight of each timber specimen having conducted a total of three trial test. Ekki once again being the highest weighing specimen ranging from 19.96g to 21.47g when wet and 18.21g to 19.66g when oven dried, the Walnut specimen with being the lowest weighing specimen with wet weight ranging from 14.26g to 16.46g and dry weight ranging from 13.12g to 15.08g and lastly Oku specimen ranging from 16.36g to 17.05g when wet and 14.70g to 15.27g when dried.

From the results gotten Ekki has the highest load bearing capacity ranging from 20.20KN to 23.54KN, Oku right below it with load bearing capacity ranging from 21.6KN to 21.99KN and Walnut ranging from 11.99KN to 16.11KN.

**Table 5: Average Values of Data from the Compressive Strength Test**

| Timber Specimen | Load (KN) | $W_1$(g) | $W_0$ (g) |
|---|---|---|---|
| Oku | 21.79 | 16.72 | 14.99 |
| Ekki | 21.84 | 20.68 | 18.90 |
| Walnut | 14.70 | 15.53 | 14.25 |

**Table 6: Moisture Content, Specific Gravity and Density Result of Compressive Test Samples**

| Timber | Moisture content in % | Specific gravity (g/$cm^3$) | Density (g/$cm^3$) | Compressive strength (N/$mm^2$) |
|---|---|---|---|---|
| Oku | 11.54 | 0.62 | 0.71 | 54.48 |
| Ekki | 9.42 | 0.79 | 0.94 | 54.60 |
| Walnut | 8.98 | 0.59 | 0.67 | 36.75 |

The cross-sectional area of samples for compressive strength = 20mm × 20mm = 400 $mm^2$
Table 6 shows the results from calculations of moisture content, specific gravity, density and compressive strength of the timber specimens. Oku timber has the highest moisture content of about 11.54%, a density of 0.71 g/$cm^3$ and compressive strength of 54.48 N/$mm^2$. Despite Oku timber having the highest moisture content it's specific gravity/density and compressive strength is much higher than that of Walnut which has the lowest moisture content of 8.98% and lowest specific gravity/density of 0.59 g/$cm^3$ and 0.67 g/$cm^3$ respectively and compressive strength of 36.75 N/$mm^2$. Ekki with a moisture content of 9.42%, has a specific gravity/density of 0.79 g/$cm^3$ and 0.94 g/$cm^3$ respectively. With the highest compressive strength of 54.6 N/$mm^2$. The graph of these results are shown in figure 7, 8 and 9.

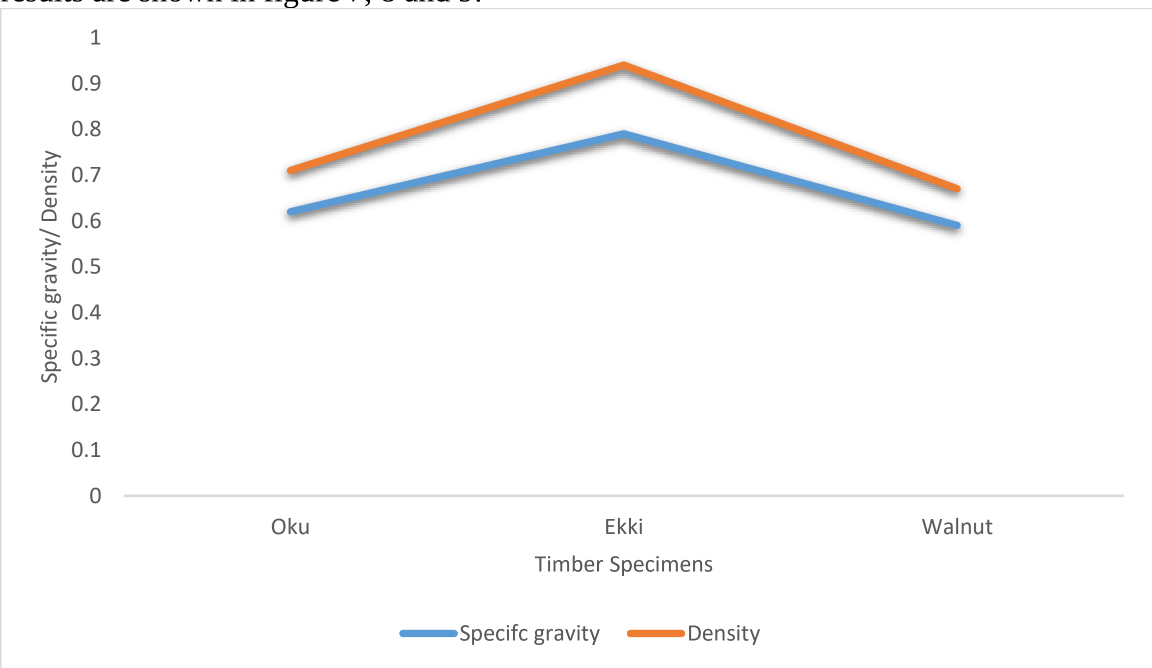


Figure 7: Graph Showing Specific Gravity/Density of Timber Specimens for Compression Test

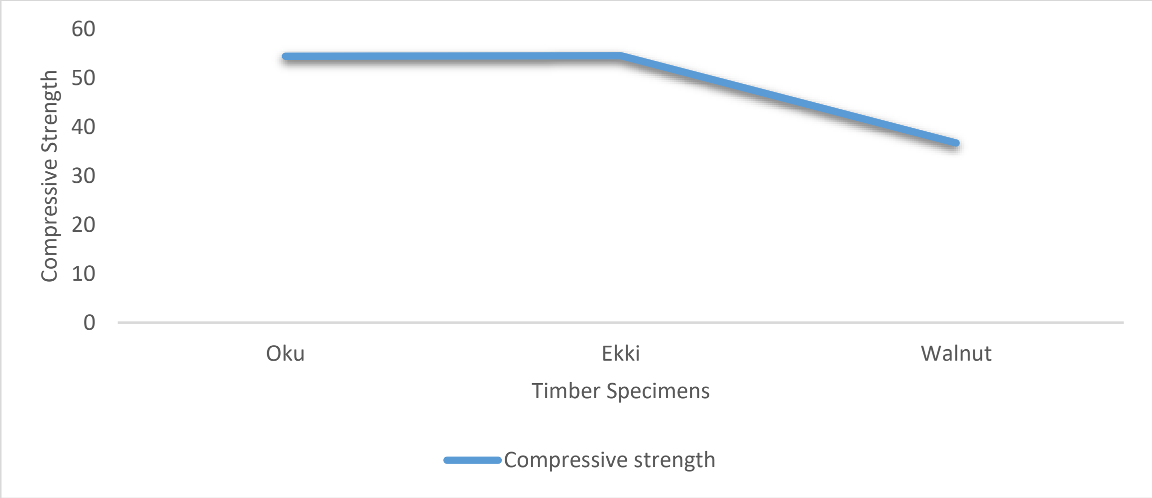


**Figure 8: Graph Showing the Compressive Strength of the Timber Specimens**

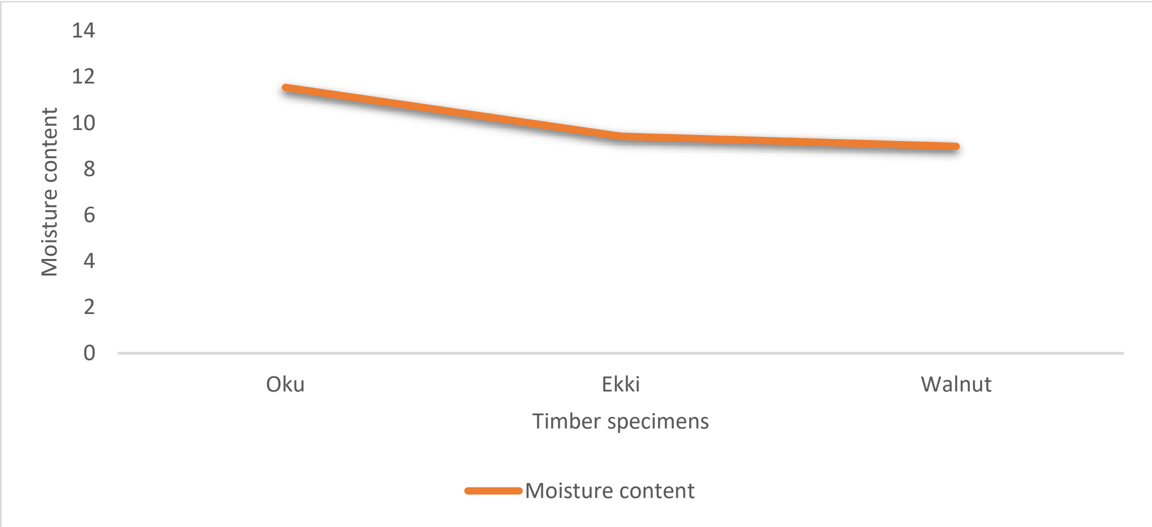


**Figure 9: Graph Showing the Moisture Content of the Timber Specimens for Compressive Strength Test**

### 3.3 Bending strength test

Data gotten from this test are recorded in table 7-10. This test was conducted on three different timber specimens and three test trials were done on the various samples.

**Table 7: Results for Bending Test on the Timber Samples.**

| **Timber specimen** | **Test 1** | | | **Test 2** | | | **Test 3** | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Load (KN)** | $W_1$ **(g)** | $W_0$ **(g)** | **Load (KN)** | $W_1$ **(g)** | $W_0$ **(g)** | **Load (KN)** | $W_1$ **(g)** | $W_0$ **(g)** |
| Oku | 0.36 | 54.90 | 53.20 | 0.4 | 57.35 | 55.40 | 0.42 | 56.04 | 54.30 |
| Ekki | 0.34 | 76.99 | 75.10 | 0.4 | 79.33 | 77.30 | 0.4 | 72.53 | 70.70 |
| Walnut | 0.18 | 54.50 | 53.30 | 0.2 | 52.71 | 51.70 | 0.1 | 52.42 | 51.20 |

Table 7 shows the range of the wet weight and dry weight of each timber specimen having conducted a total of three trial test for the bending strength test. Ekki being the highest weighing specimen ranging from 72.53g to 79.33g when wet and 70.70g to 77.3g when oven dried, the Walnut specimen with wet weight ranging from 54.42 to 54.5g and dry weight ranging from 51.2g to 53.3g and Oku specimen ranging from 16.36g to 17.05g when wet and 14.70g to 15.27g when dried.
From the results gotten Oku has the highest flexural load bearing capacity ranging from 0.36KN to 0.42KN, Ekki right below it with load bearing capacity ranging from 0.34KN to 0.4KN and Walnut ranging from 0.1KN to 0.2KN.

**Table 8: Average Values of Data from the Bending Strength Test**

| **Timber Specimen** | **Load (KN)** | $W_1$**(g)** | $W_0$ **(g)** |
|---|---|---|---|
| Oku | 0.39 | 56.10 | 54.30 |
| Ekki | 0.38 | 76.28 | 74.37 |
| Walnut | 0.16 | 53.21 | 52.07 |

Table 8 shows the average values from the results recorded in table 4.8. Oku timber with an average weight of 56.1g when wet and 54.3g when dry and load of 0.39KN, Ekki with an average weight of 76.28g when wet and 74.37g when dry and a load bearing capacity of 0.38KN, while Walnut timber has an average wet weight of 53.21g and dry weight of 52.07g and load of 0.16KN.

**Table 9: Results for Moisture Content Specific Gravity and Density for Bending Test**

| **Timber** | **Moisture content in %** | **Specific gravity (g/$cm^3$)** | **Density (g/$cm^3$)** | **Bending stress (N/$mm^2$)** |
|---|---|---|---|---|
| Oku | 3.31 | 0.94 | 1.45 | 406.25 |
| Ekki | 2.57 | 1.27 | 2.21 | 395.83 |
| Walnut | 2.19 | 0.89 | 1.35 | 166.67 |

Table 9 shows the results from calculations of moisture content, specific gravity, density and compressive strength of the timber specimens. Oku timber has the highest moisture content of about 3.31%, a density of 1.45g/$cm^3$, specific gravity of 0.94g/$cm^3$ and flexural strength of 406.25N/$mm^2$. Ekki timber having a moisture content of 2.57% specific gravity of 1.27g/$cm^3$, density of 2.21 g/$cm^3$ and bending stress of 395.83N/$mm^2$. Finally Walnut timber with a moisture content of 2.19%, specific gravity/density of 0.89 g/$cm^3$ and 1.35 g/$cm^3$ respectively and bending stress of 166.67N/$mm^2$.
These results have been gotten from the various table above has been converted into different graphs (Figure 10, 11 and 12) for comparison and proper visual understanding of the data.

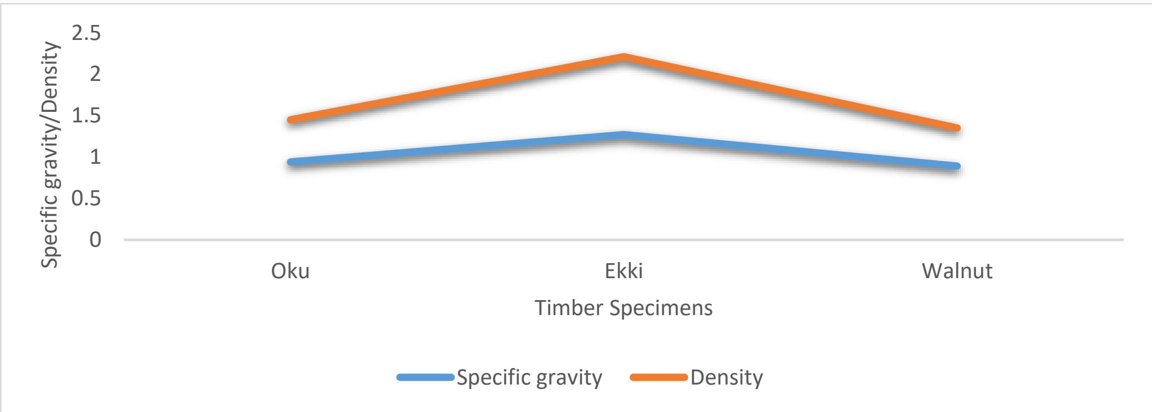


**Figure 10: Graph Showing Specific Gravity/Density of Timber Specimens for Bending Test**

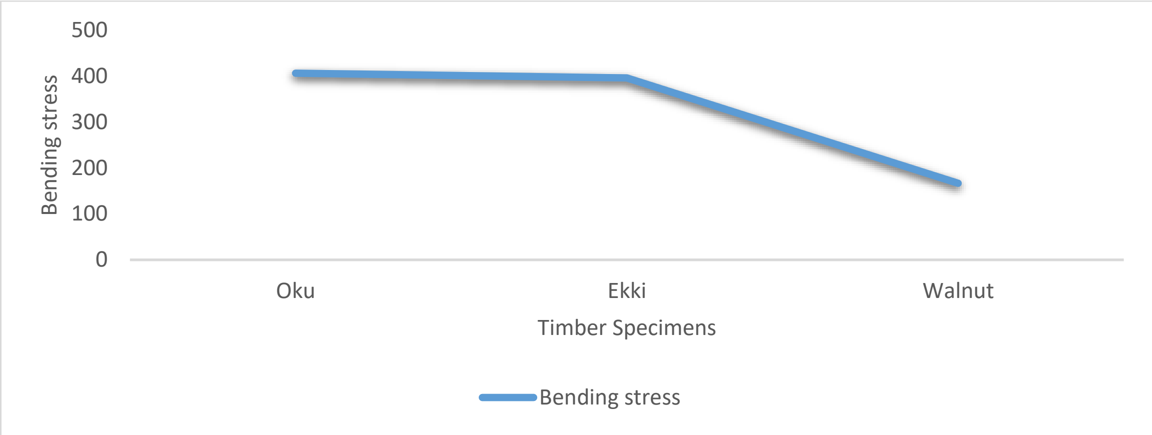


**Figure 11: Graph Showing the Bending Stress of the Timber Specimens**


**Figure 12: Graph Showing the Moisture Content of the Timber Specimens for Bending Strength Test**

## 4. Conclusion

From the review of past study and in accordance with the BS 373:1957 standard for testing timber specimens, timber with high density are more suitable for construction purposes like structural support beams, roofing elements etc. Hardwood mostly have higher density compared to soft wood. For timber required in construction a high bending, shear and compressive strength is necessary. Timber is a highly sustainable material reducing the carbon emission hence fostering a much cleaner environment. With proper testing, treatments and maintenance timber can serve as standard building material for various level of construction.

After the various tests were conducted on timber specimens it is visible that the compressive, flexural and tensile strength of timber greatly depends on its density and mass. From the results acquired Ekki timber has the highest tensile strength (150.83N/$mm^2$). and compression strength (54.6N/$mm^2$) only being below Oku which has a higher bending strength (406.25N/$mm^2$). These makes Ekki and Oku the best for construction when compared to Walnut timber. Walnut having the lowest weight of the three specimens alongside its mechanical properties would be more suitable for lightweight construction work or furniture making.

It is safe to say hardwood (Ekki) are preferable for heavier construction practices than softwood (Walnut) due to their high density and resistance properties. On the other hand, softwood are best for furniture making and other lightweight construction due to their lower density and lightweight.

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