Experimental Investigation of Bending Strength of Oxytenanthera Abyssinica and Yushania Alpina Bamboos

Fentahun Ayu Muche(✉) and Yonas Mitiku Degu

Faculty of Mechanical and Industrial Engineering, Bahir Dar Institute of Technology, Bahir Dar University, Bahir Dar, Ethiopia
fentahunayu30@gmail.com, yonasm@bdu.edu.et

Abstract. Bamboo has a long and well-established in many structure such as tradition building material, furniture and bicycle structure throughout the world. To use bamboo for industrial use and product fabrication, its bending strength is determinant mechanical property. The bending strength of these two species of bamboo was not studied sufficiently in Ethiopia. This research is mainly focused on the bending strength of two species of bamboo which is found abundantly in Ethiopian. Highland bamboos which are hollow and lowland bamboos are solid having scientific name of Yushania Alpine and Oxytenantheria Abyssinica respectively. Bending strength of bamboo for bending loading was experimentally tested and characterized with respect to its age and species typeSamples were prepared according to ISO standards and experiments were conducted on universal testing machine. The test results show that as the age of bamboo increased the bending strength of both Yushania alpine and Oxytenantheria abyssinica species bamboo were increased. Among the two species, Oxytenanthera abyssinica has a better bending strength compared to Yushania alpine. The bending strength of Oxytenanthera abyssinica were found 1.6, 2.9 and 2.0 times stronger than the Yushania alpine at year two, three and four respectively.

Keywords: Bending strength · Oxytenanthera abyssinica · Yushania alpina · Solid bamboo · Hollow bamboo · Highland bamboo · Lowland bamboo

1 Introduction

Bamboos are natural perennial grass-like composite and contain ligno-cellulosic-based natural fibers. Bamboos are abundantly found in tropical, subtropical and mild temperature regions. It has a fast growth rate and attains good mechanical property in short period of time. Ethiopia has got two bamboo species; both of them are native to the country, namely lowland bamboo (Oxythenanthera abyssinica) and highland bamboo (Yushania alpine). Although Ethiopia is well known in bamboo resources, the use of this resource is usually limited to traditional house construction, fences, and some rudimentary furniture and household utensils [1]. Bamboo is mainly characterized by two parts, the culm and rhizome which are steam above the ground under the ground respectively. The structure of bamboo is shown in Fig. 1 [2].

N. G. Habtu et al. (Eds.): ICAST 2019, LNICST 308, pp. 707–715, 2020.
https://doi.org/10.1007/978-3-030-43690-2_54

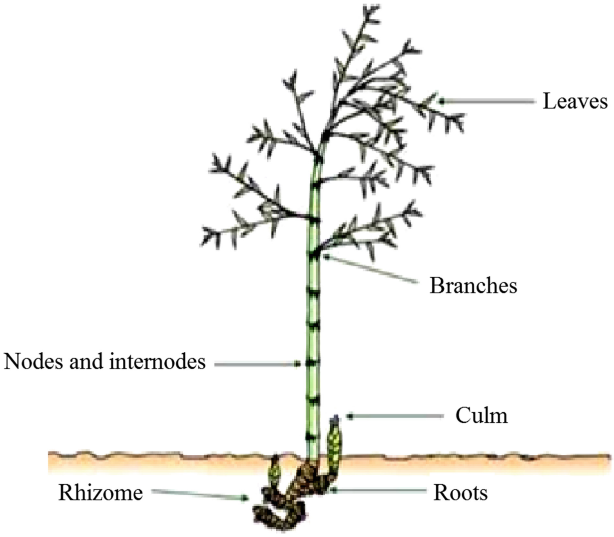

Fig. 1. Structure of bamboo plant [2]

The growth rate of bamboo is dependent on local soil and climatic conditions, as well as types of species [3].

Bamboo culms are a cylindrical shell divided by solid transversal diaphragms at nodes and have some exciting properties such as high strength in the direction parallel to the fibers, and low strength in a direction perpendicular to the fibers. Both physical and mechanical characteristics vary with respect to age, type, position along culm and moisture content in the bamboo [4, 5].

Any structure subjected to bending load has to withstand and provide the intended service for the designed life period. Hence it is critical to know the bending strength of a material before it comes to industrial or similar uses. Bending strength is the resistance of a material for bending load/lateral loading. Different researchers verified that the bending strength of various species of bamboo without node having higher bending strength than culms with nodes [6].

The bending test measures the magnitude of force required to bend specimen under three points/four point loading. In this study three point loading method was used for testing. The three point bending test induced maximum stress at the midpoint of the specimen span length. The main advantage of a three point bending test is an ease of the specimen preparation and testing [7]. Bending test is employed, in which a specimen having either a circular or rectangular cross section is bent until fracture or yielding.

So far, the bending strength of Oxytenanthera abyssinica and Yushania alpine is not studied sufficiently. The objective of the research is to test and characterize the bending strength of the two species of bamboo which are abundantly found in Ethiopia.

2 Methods and Materials

2.1 Methods

The experimental investigation was conducted following the following procedure:

The test method and specimen preparation, were done according to ISO/TR22157-2: 2004 (E) standard. This standard relates the sample length to its diameter as depicted in Fig. 2. It states that the length of the specimen should be equal to thirty times of its diameter plus half of the culm length [8].

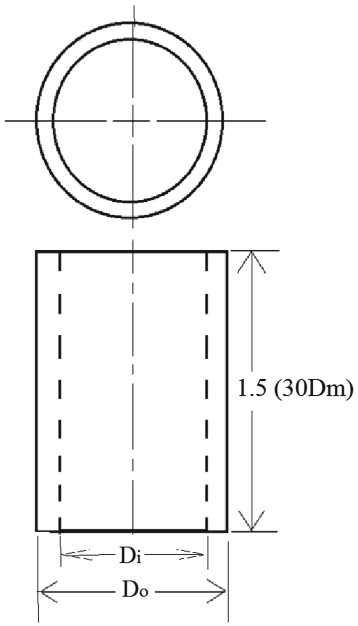

Fig. 2. Standard specimen dimensions for bending test [8]

When a beam with a straight longitudinal axis is loaded by lateral forces, the axis is deformed into a curve, called the deflection curve of the beam. The deflection (δ) at the center of the beam along the axis of the beam can be calculated using Eq. (1).

$$\delta = \frac{PL^3}{48EI} \quad (1)$$

Where:

P - Central load [N]
L - Length of the specimen [m]
E - Young's modulus, [N/m^2]
I - Second moment of area [m^4]

Second Moment of Area (I) of a hollow circular shape of the beam analyzed by using Eq. (2). For the solid bamboo consider the value of inner diameter zero.

$$I = \frac{\pi\left(Do^4 - Di^4\right)}{64} \quad (2)$$

where:

D_o – average outer diameter of bamboo [m]
D_i – average inner diameter of bamboo [m]
D_m – Mean diameter i.e. 0.5 ($D_o + D_i$)

The bending stress induced can be analyzed analytically using Eq. (3)

$$\sigma_b = \frac{MC}{I} \quad (3)$$

$C = \frac{Do}{2}$ [m]
σ_b – bending stress [N/m^2]
M – maximum bending moment [Nm]

Figure 3 shows simply supported beam subjected to a point load at middle of the span length. And the induced stresses and deflection of a beam indicated.

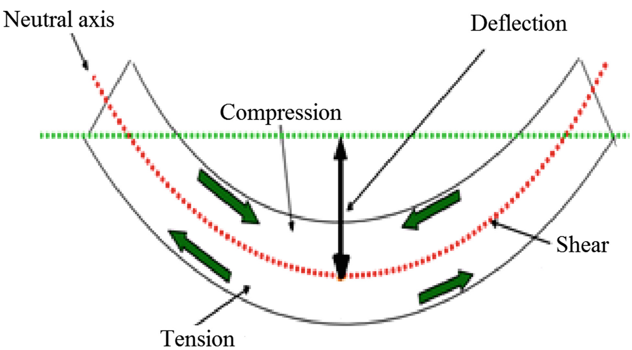

Fig. 3. Deflection and stress induced in a beam subjected to transverse load

2.2 Material

Solid bamboo and hollow bamboo were collected from Jawi and Injibara vicinity respectively for experimental investigation of the bending strength of. Specimens were prepared from the two species of Ethiopian bamboo from age two, three and four years.

A total of twenty four specimens were prepared from both species. Lowland bamboo (Oxytenantheria abyssinica/solid bamboo) and highland (Yushania alpin/hollow bamboo) bamboo found in Amhara Region around Jawi *Woreda* and at Injibara respectively.

Bamboo found around Injibara is hollow (Yushania alpine) and it has larger diameter compared to the solid (Oxytenantheria abyssinica) bamboo. Figure 4 shows the culm of both solid and hollow bamboo found in Ethiopia.

Fig. 4. Culms of hollow bamboo (left) and solid bamboo (right)

Lowland bamboos were found in Assosa is known as solid bamboo and it is distributed to Amhara region which is found at Awi *zone* around Jawi *Woreda* and around north Gonder at Kuara *Woreda*. The two species of bamboo are similar in their growth character. The lowland bamboo has a completely solid culm, with high bulk density and greater stability while the highland bamboo has a hollow culm, which is easier to process [1]. Figure 5 shows the cross section of a hollow bamboo and solid bamboo.

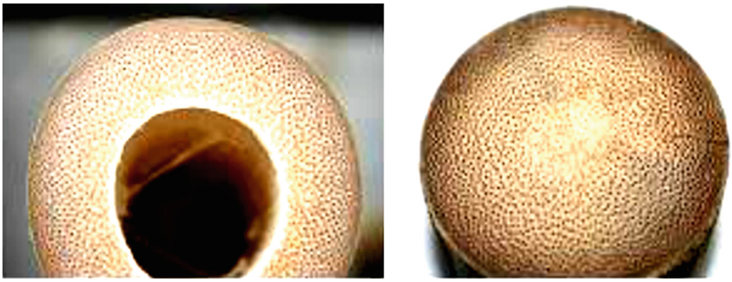

Fig. 5. Transversal cross section of hollow bamboo (left) and solid bamboo (right) [1]

Universal testing machine (UTM), hand tools and measuring instruments were used for the specimen preparation and testing. Digital vernier caliper, steel rule and tape meter were used for measuring the dimension of the specimen during preparation and wood saw was used to cut bamboo to the required size.

Universal testing machine model type YF Zhejiang Tugong PN0206000031 WAW-1000B microcomputer controlled was used to test the three point bending strength of bamboo specimens. The capacity of the machine is 1000 kN with the load applying rating of 0.05 kN/s.

2.3 Experiment

From the bending test, deflection and bending stress of the beams subjected to lateral load can be measured but during the experiment the ultimate stress of the material were taken from the test.

The specimen preparation and test procedure followed the ISO standard. The steps followed during the sample preparation provided with seven steps.

1. Cut one meter from the bottom end of the bamboo, and measure a length of 30 times of its diameter and add half of it to get the final dimension of the specimen ().
2. Measure the diameter and thickness of the specimens at both ends and consider the average values for second moment of area and other analysis.
3. Mark the midpoint of the specimen along the span length.
4. Code the specimen for easy management of the data recording.
5. Fix the specimen on the test jig aligning the marked point of the test specimen to the load applicator (refer Fig. 6).
6. Applied steady load at the marked point until failure occurs.
7. Store results in the computer system for further analysis.

The test was conducted a three-point load method in which the load is applied at the center and two reaction loads are at the ends as shown in Fig. 6.

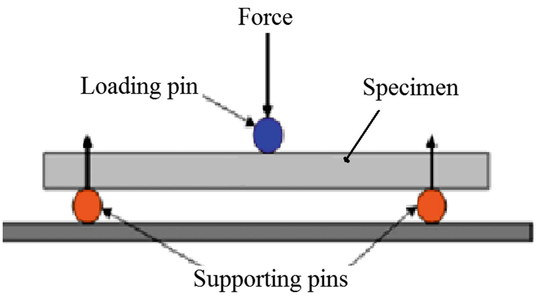

Fig. 6. Schematics for three point bending test set up

All specimens were coded based on species, position, and specimen number. Generally, the coding of both samples was given as follow:

SBYxy: SB stand for solid bamboo, Y: year, x: age in years and y: for specimen number.
HBYxy: HB stand for hollow bamboo, Y: year, x: age in years and y: for specimen number.

The two species of bamboo specimens were prepared for testing as shown in Fig. 7.

Fig. 7. Bamboo specimens ready for bending test [Photo by the authors]

3 Results and Discussions

3.1 Results

Bending test was carried out in order to determine the maximum bending strength of bamboo due to load applied in the lateral direction. The bending test was carried out by considering age and species type as shown in Fig. 8. The ultimate strength data were recorded from the universal testing machine. The variation of bending strength with respect to age and types of species are given in Fig. 9.

Fig. 8. Hollow bamboo specimen failure during bending test

3.2 Discussions

Bending Strength with Respect to Age: As depicted in Fig. 9, the bending strength of bamboo varies with the age increased. Lower bending strength was recorded at early age bamboos and the strength increases with the increase of age. These kinds of behavior

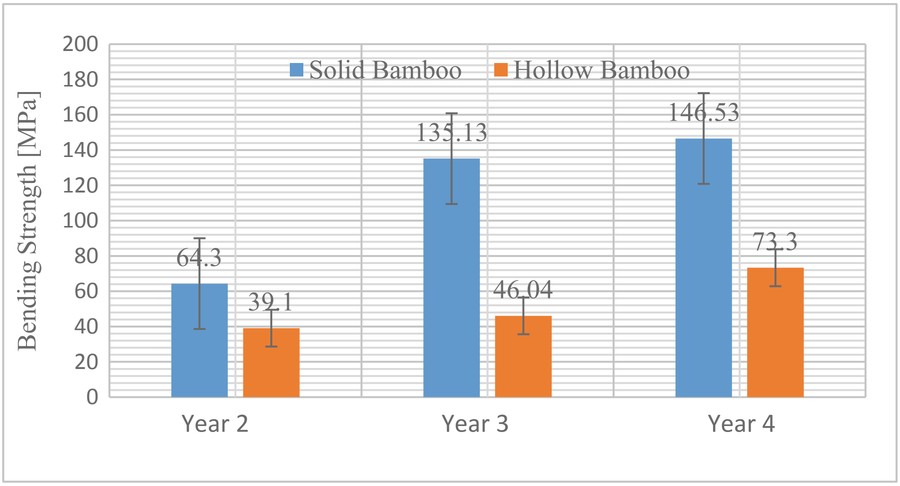

Fig. 9. Bending strength vs age and species bamboo

were observed for both solid bamboo and hollow bamboo. This is due to the fact that bamboo has higher moisture content at the early age and as the age increases fibers become interconnected with each other hence the bending strength will increase.

Bending Strength with Respect to Species: Solid bamboo is higher in bending strength than hollow bamboo. This is due to the fiber distribution of the plant. Solid bamboo is naturally dense and having more fibers than hollow bamboo which leads it to have a higher strength.

4 Conclusions

Bending strength of solid bamboo (Oxytenantheria abyssinica) for year two, three and four were 64.30 MPa, 135.13 MPa, and 146.53 MPa respectively and for hollow bamboo (Yushania alpine) of year two, three and four were 39.1 MPa, 46.04 MPa and 73.3 MPa respectively. The test result depict that for both species of bamboo higher bending strength were recorded at the age of four relative to year two and three for bending loading. This implies that both of species are recommended for higher load carrying application at year four. From the test results Oxytenantheria abyssinica has higher bending strength than the Yushania alpine species bamboo.

References

1. Bakala, F., Bekele, T., Woldeamanuel, T., Auch, E.: Value chain analysis of lowland bamboo products: the case of Homosha District, Northwestern Ethiopia. Ind. Eng. Lett. **6**(10), 1–15 (2016)
2. Baldaniya Babulal, H., George, E., Patel, S.B.: Test of bamboo material for structural purpose. Indian J. Res. **2**(4), 134–137 (2013). 2250-1991

3. Retrieved From Google, 20 January 2019. http://www.Dassoxtr.Com/Bamboo
4. Barmavath, S., et al.: Flexural strength of concrete by replacing bamboo in RCC beam. Int. J. Civ. Eng. Technol. (IJCIET) **8**(6), 10–18 (2017)
5. Singh, A., Kumar, S.K., Singh, A.K.: Experimental investigation on flexural strength of bamboo reinforced concrete beam. Int. J. Innov. Res. Sci. Eng. Technol. **5**(5) (2016)
6. Shao, Z.P., Zhou, L., Liu, Y.M., Wuand, Z.M., Arnaud, C.: Differences in structure and strength between internode and node sections of Moso bamboo. J. Trop. Forest. Sci. **22**(2), 133–138 (2010)
7. Baglietto, J., Kelly, C., Johnson, C.: Wood Bend Test Retrieved from Google (2013)
8. International Standard Organization/Technical report, 2.-2. Determination of physical and mechanical properties of bamboo part 2 laboratory manual (2004)