Analysis of Bamboo Strength for Structural Material

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Abstract: Bamboo is a environmentally accessible available organic plant and among the plants with the quickest growth on earth. It grows up to 60 cm (approx.) a day and it can reach it`s maturity in about four years. It is present in large number of quantities in India. India is of the large producer of bamboo and in every part of India bamboo is easily available. Bamboo has very wide range of application in different areas, the physical and mechanical properties make it ready to use for different applications. This paper helps to find out the properties of Bambusa Balcooa (moisture content, compression and tensile) by referring to International Standard ISO 22157. Bamboo is widely utilized throughout South, Southeast, and East Asia for construction materials, food, and raw resources. It also has significant cultural and economic value in these regions. Bamboo is a natural composite material that is helpful for constructions because, like wood, it has a high strength-to-weight ratio. Bamboo is a renewable source and can be used as a structural material in construction works and also in various applications. The compressive strength of bamboo was between 15.8 MPa to 24.2 MPa. High compressive strength was observed at the bottom section which was thicker then middle and the top section. The lower portion of the bamboo has a higher moisture content and lowest at the top section.

Keywords: Bamboo, Tensile behavior, Compressive behavior, Physical properties, Mechanical properties.

INTRODUCTION:

Bamboo is a naturally occurring plant and is one of the quickest growth plants on the world. Although bamboo is mistaken for a tree, it is actually a grass. This may sound odd that how a grass can be used as a structural material in constructional work and how a grass type has so much wide range of application and has good mechanical properties than some alloy steels, but nothing could be further from truth [1]. Bamboo`s engineering aspects were neglected by engineers and were not in use in modern constructional works. So, more work on bamboo`s material like its engineering design, treated bamboo materials, bamboo scriber, and other bamboo technology is needed. Engineers, researchers, and architects should do more efforts to make various constructional materials, toys, home use etc. There are over 1500 known bamboo species in the world, all species has the similar anatomy which consists of internodes, nodes, and diaphragm. Each species can be identified according to their structural design. As the bamboo grows faster so it has larger harvest cycle, as a result, bamboo's annual yield will grow since it can be harvested quickly [2]. As we all are aware of the fact that bamboo is an environmentally friendly material, and it helps us to reduce the global warming effect. Carbon dioxide is the real issue of global warming which is the reason to increase in the number of death cases because to illnesses and natural calamities [3]. Because of these things also bamboo forest is very important, the ability of bamboo is very high to manage global warming effects. In a study it was found that one hectare of bamboo forestation can occupy larger than 12 tons of CO_2 in free air. So, with the protection of bamboo, we can lead to have a carbon dioxide absorbing machine which is able to absorb such a huge amount of carbon dioxide [4][5].
The ability to bear the applied force on it is very essential. The primary elements are the bamboo's strength and its level of moisture that is going to define bamboo's capability and capacity for both [6]. The aim of this experiment is to investigate the mechanical properties of the bamboo and concentrate on the chances of utilization of bamboo as a raw material in different areas.
In order to lessen their influence on the environment, the construction industry has looked for sustainable alternative building materials. Building using bamboo can lessen its negative effects on the environment and greenhouse gas emissions worldwide. [12][13].
Bamboo structural connections, designed bamboo products, and bamboo preservative treatment are studied in addition to material and mechanical qualities. The study's summary results can be used by the building sector to provide design recommendations for bamboo construction that is sustainable. Overall, the overview of structural capabilities and limitations for further study and improvement of bamboo in contemporary building is provided in this paper. [14].

METHODOLOGY:

Preparation of Materials:

We have mainly focused on bamboo for our project to study the mechanical behavior of bamboo. In our project we have taken Bambusa Balcooa as a bamboo material for different testing purposes, as it was easily available to us. For our test we have collected the specimen from Kunda, Pratapghar. All the specimens were collected from different sections of bamboo (top, middle, bottom) [7]. Some samples are kept left to dry for about 1-month util the color of bamboo turned yellowish and some of the samples are green because they have high content of moisture.
Different samples were shown in figure below.

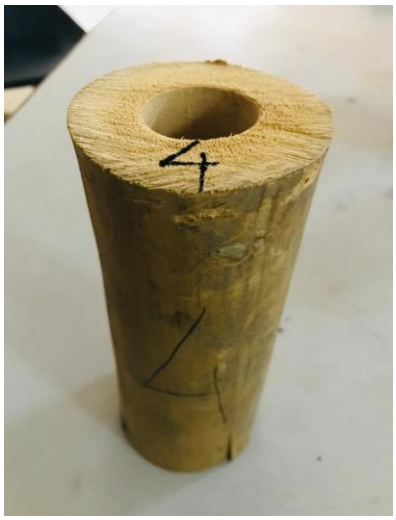

Fig. 1

Fig. 2

Fig. 3

Fig.4

Sample of bamboo cross-sections (Figure 1-4)

Physical and Mechanical Properties:

All the procedures and methods used for the determination of mechanical and physical properties of bamboo were referring to International Standards ISO 22157.

Determination of Moisture Content:

Importance of water and moisture content plays significant role in determining the strength of bamboo and application of bamboo and bamboo-based composites. Bamboo is also affected by changes in moisture content, especially when it comes to mechanical properties [8][9].
Following procedure has been followed to determine the moisture content in bamboo specimen.
We have recorded the initial weight of the bamboo sample before drying and after weight of bamboo after it is left in open air for two months. For each sample the moisture content was calculated using equation (1): -

$$MC\ (\%) = ((m - m0) / m0) \times 100$$

Where m: mass before drying (gm) and m0: mass after drying (gm).

Mechanical Testing:

All testing procedure Using the International Standards ISO 22157-1 and ISO 22157-2 as a reference, the mechanical characteristics of bamboo were obtained.
We have cut all bamboo samples into small samples; the height of the bamboo was about 17cm. For the compression and tensile test, we have selected all the sample free from internodes of bamboo for the uniformity of specimen. The outer diameter was used for the compression test which was measured from two opposite faces of the sample or say it as opposite points of outer surface [10]. The compression test was carried out by using Universal Testing Machine (UTM), where we have tested all our specimens of bamboo under a constant rate of load, and we have recorded the maximum load that our specimen can bear just before failure [11]. Specimens from different section of bamboo were used under this test.

Compression Test:

Compression test was carried out with the help of Universal Testing Machine, total 9 specimens were used for the testing, all are cut from the top, middle, and bottom part of bamboo. The maximum compression stress then was calculated by using equation (2):

$$\sigma_c = F_m / A$$

where σ_c: compressive stress (MPa), F_m: maximum load, A: cross-sectional area

Fig 5

Fig 6

Tensile and compressive testing in UTM machine (Figure 5 and 6)

Result and Discussion:

Compression Test and Moisture Content

Moisture content generally determines the level of water content contained in a bamboo specimen which will affect the strength of bamboo under different parameters, it also influences the physical properties like weight, density, and other. From the result obtained the moisture content at the top section seems to be low as compared to bottom and middle section. And the moisture content at the bottom section is found to be greater than the top and middle section. Therefore, the moisture content decreases as we go bottom to top of bamboo.
The results were classified into three sections which has top, bottom, and middle section of bamboo specimen and the result is shown in Table 1.

Table 1. Result of moisture content

Sections	No. of Samples	Initial Mass	Final Mass	Moisture Content (%)
Bottom	1	266.2	190	40.10
	2	260.4	189	37.7
	3	270.5	200.4	34.98
Middle	1	240.5	204.6	17.5
	2	200.2	167	19.3
	3	190	154.7	22.8
Top	1	248.2	217.1	14.37
	2	260	222.6	16.8
	3	253	208.05	21.6

This graph illustrated about the different sections of bamboo samples collected from top, bottom, and middle and their different moisture content percentage.

In the compression test standard bamboo specimen is loaded under the compressive force until it gets rupture, or a crack appears on the specimen. In our test we have tested different specimens from different section of bamboo and observed the results. The top section of bamboo shows less compressive strength compared to middle and bottom whereas the bottom section has greater strength then the middle and top.
The results were shown in Table 2.

Below is the mode of failure of specimen under compressive test, some specimen shows buckling properties in which the moisture content was more whereas some of the specimen has vertical cracks, and the fibers were compressed because of large compressive force as the mode of failure and it has been observed that these specimens are low in moisture content.

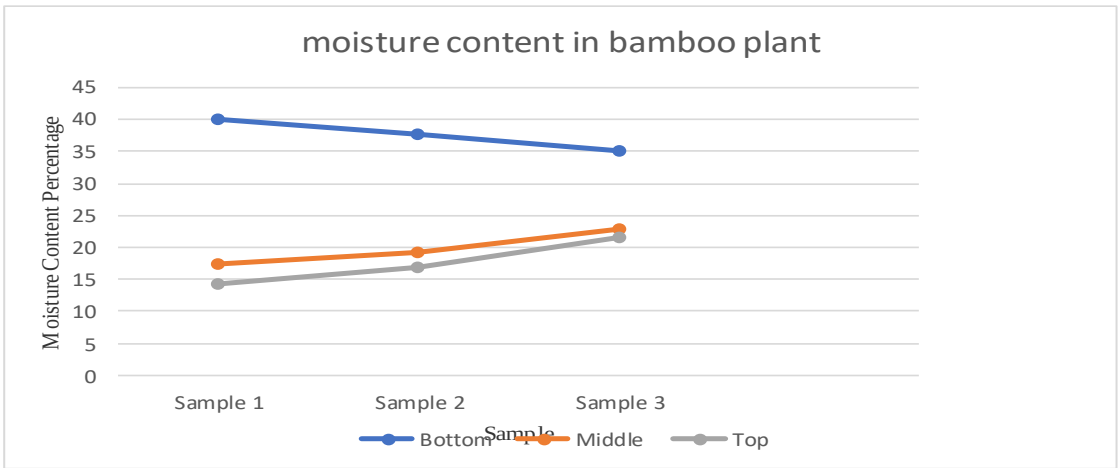

Figure 7 (Comparison of bamboo moisture content)

Fig 7 (Failure of bamboo)

Table 2. Result of Compression Test

Sections	Sample No.	Cross Sectional Area(mm^2)	Load (KN)	Thickness (mm)	Compressive Strength (MPa)
Bottom	1.	2710.48	65.59	30.84	24.2
	2.	2460.47	57.58	25.40	23.40
	3.	2741.42	61.4	30.5	22
Middle	1.	1748.12	37.62	20.23	21.52
	2.	2014.18	42.6	24.57	21.15
	3.	2210	47.7	26.65	21.58
Top	1.	1986.84	31.39	23.90	15.8
	2.	1829.83	31.47	21	17.2
	3.	1695.43	33.4	18.55	19.7

Conclusion:

This study has put forward that the bamboo has the high ability to be used as a constructional material and bamboo should be used widely in every needful place. The compression test shows that the compressive strength of bamboo is high at the bottom section and low at the top section whereas if seeing the moisture content, the bottom section has greater moisture content as compared to middle and top. Also, many properties of bamboo depend on to moisture content of bamboo specimen. Also, the strength properties vary with varying thickness of bamboo specimen. Use of bamboo in toughen constructional material, various industries are applicable. As bamboo is a natural, eco - friendly and renewable source so it can be used as a feasible material for making green building. These test results are worthwhile to the civil engineers and architect for further use.

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