

A study on Physico-Mechanical properties of *Oxytenanthera monostigama* a cultivated bamboo

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Abstract— Physical properties such as the culms, height, number of internodes per culms, internodes length, internodes diameter, culms wall thickness, moisture content and basic density are considered to be the important factors in determining the suitability of bamboo for various applications. The results of mechanical properties like Modulus of rupture (MoR), Modulus of elasticity (MoE) and Compressive strength (Comp St.) of *Oxytenanthera monostigama* species showed the strength properties more at middle portion compared to bottom and top portions.

Index Terms— Bamboo culm, Mechanical properties, Moisture content and density

I. INTRODUCTION

Bamboo is a perennial, giant, woody grass belonging to the group angiosperms (Chapman, 1996) and the order monocotyledon (Latif et al., 1990). The grass family Poaceae (or Gramineae) can be divided into one small subfamily, Centothecoideae, and five large subfamilies, Arundinoideae, Pooideae, Chloridodeae, Panicoideae, and Bambusoideae. In distinction to its name, bamboos are classified under the subfamily Bambusoideae (Chapman, 1996 and 1997). Bamboo is a fast growing species and a high yield renewable resource. Bamboo growth depends on species, but generally all bamboo mature quickly. Aminuddin and Latif (1991) stated that bamboo might have 40 to 50 stems in one clump, which adds 10 to 20 culms yearly. The anatomical characteristics in relation to the mechanical properties of bamboo have been studied by Latif et al. (1990). The three species, 1 to 3 year old *Bambusa vulgaris*, *Bambusa blumeana* and *Gigantochloa scortechinii* were used for the study. The high density of vascular bundles at the top was due to the decrease in culm wall thickness (Grosser and Liese, 1971). The size of vascular bundles was not significantly different with height and age. There was no correlation of vascular bundles with age, but there was a significant decrease with height of the culm. The specific gravity of bamboo varies from 0.5 to 0.79, and this would make the density about 648 kg/m³ (40.5 lb/ ft³). Similarly, reports established that the average specific gravity of bamboo ranged from 0.3 to 0.8. Chew et al. (1992), gives the density of *B. vulgaris* at 630 kg /m³, which is relatively light, compared to other bamboos. Density is the major factor that influences the mechanical properties, and it is closely related to the proportion of vascular bundles. The cell wall thickness has a positive correlation with compression strength, bending stress at proportional limit and MOE, but negatively correlated to

MOR. Physical and mechanical properties of several bamboo species have been studied extensively. In the present study, the physical and mechanical properties of four year old *Oxytenanthera monostigama* at three levels of culm height were investigated..

II. MATERIALS AND METHODS

The bamboo samples collected from bamboo Arboretum of BIAF, S. Lakkahalli near Tiptur taluk of Tumkur district were harvested and utilized for the study. Five bamboo culms were harvested and investigated for physical properties like length, diameter and number of internode etc., were recorded at felling site itself. Whereas mechanical properties like Modulus of elasticity (MOE), Modulus of rupture (MOR) and compressive strength were evaluated at laboratory. Bamboo samples were converted into strips for determining mechanical properties. Each bamboo sample was divided into three portions of bottom (B), middle (M) and top (T). Strength of bamboo viz., compression parallel to grain & static bending were conducted using computer controlled Universal Testing Machine (UTM).

Physical characteristics and their properties

Measurements for some basic physical characteristics and properties were done on site where the culms were taken. The culms height, internode length, internode diameter and culms wall thicknesses were measured from the cut base to the tip. The method used in the physical study was as previously reported (Sulthoni, 1989; Razak et al., 2007).

Moisture content (MC)

Sample blocks representing the 2 age group (4 and 6 years), 3 height portions (bottom, middle and top) and 6 replicates, consisting of thirty-six bamboo samples were used. All sample blocks were cut from fresh culms were 10 mm × 10 mm × culms wall thickness. They were weighed and dried in an oven at 105±2°C for 48 hr until a constant weight was attained. The sample blocks were then placed for 30 min. in a desiccator for cooling-off period before re-weighing.

Basic density

Sample for basic density studies were obtained from the middle portion of each internode at the bottom, middle and top culms portions and also from each node portion. Each sample blocks were cut to the size of 10 mm × 30 mm × culms wall thickness. Six replicates were used in the study. The sample blocks were oven dried for 48 h at 105±2°C until a constant weight were attained. The sample blocks were then weighed to give the oven dried weight.

MoR and MoE:

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Bamboo samples were converted into strips for determining MoR and MoE at three portions of bottom (B), middle (M) and top (T) under three point loading using UTM.

Compressive strength:

Compressive strength of round bamboo samples were derived at three portions of bottom (B), middle (M) and top (T) using UTM.

III. RESULTS AND DISCUSSION

The physical characteristics of two age group bamboo studies are presented in Table 2. revealed that there are not much differences between the height, the number of internodes, internodes length, and culms wall thickness of the 4 years old culm. There was however a slight increase in length of the internodes 26cm and internodes diameter 3.17cm in 4 years old bamboo culms.

Table 2. Physical and Morphological characteristics *Oxytenanthera monostigma*

Sl. No	Bamboo species/ Characteristics	<i>Oxytenanthera monostigma</i>	
1	Culm height (m)	10-12	
2	No. of internodes/ culm	19-27	
3	Internode length (cm)	Bottom	24
		Middle	26
		Top	24
		Avg	24.66
4	Internode diameter (cm)	Bottom	3.17
		Middle	2.96
		Top	2.40
		Avg	2.84
5	Culm wall thickness (mm)	Bottom	14.65
		Middle	8.14
		Top	5.16
		Avg	9.31

Moisture content:

Moisture content is an important factor in governing the mechanical properties of bamboo. The mean moisture contents (MC) in green conditions of the cultivated *Oxytenanthera monostigma* decreased from 96.3 to 81.3 in 4 years old culms, respectively. The differences in moisture content for the 4 years old culms at various internodes (Table 3) shows the mean moisture content at cross-section along the culm length of *Oxytenanthera monostigma* in green condition.

Table 3. Moisture content (%) at green condition

Bamboo species/Portions	<i>Oxytenanthera monostigma</i>
Bottom	96.3
Middle	96.6
Top	81.3
Average	91.4

Basic density: the results for basic density of cultivated three bamboo species *Oxytenanthera monostigma* was studied for both node and internode at three different level of the bamboo

culm are presented in the table-4. The basic density increases from node to internode at different height of the bamboo culms. The density of *Oxytenanthera monostigma* species was found 650 Kg/m³ at bottom of the node with 545 Kg/m³ at middle and 405 Kg/m³ at top and internode density was also showing that 540 Kg/m³ at bottom 539 Kg/m³ at middle and 395 Kg/m³ at top of the culm. It is found that density is varies from node to internode portion as the fiber quantity will be more at the nodal region.

Table.4 Density of *Oxytenanthera monostigma* Bamboo culm

<i>Oxytenanthera monostigma</i> Bedd	
Node	Internode
650	540
545	539
405	395

The mechanical properties of bamboo are the study of material behaviour, when subjected to loads these results in the deformation of the materials. In the present investigations the mechanical behaviour of *Oxytenanthera monostigma* were tested at laboratory using Universal Testing Machine (UTM) and results are recorded (table 5). The mechanical behaviour of *Oxytenanthera monostigma* species showing MOR value is 149.3 mpa in middle portion followed by 146.4 mpa in bottom and 145.3 at top portion of the culm. Similarly the MOE value was found 11854 mpa in middle portion followed by 11396 mpa at top portion and 8442 in bottom portion of the bamboo culm. Similarly the compressive strength properties results were found for *Oxytenanthera monostigma* species was 69.05 mpa in the middle portion followed by 52.72 mpa at bottom 45.62 mpa at top portion of the culm. from the results it is indicated that all the mechanical properties are high in the middle portion compare to bottom and top because of lower culm wall thickness at top and higher culm diameter at bottom portion respectively.

Table 5. Mechanical properties of *Oxytenanthera monostigma*

Species	<i>Oxytenanthera monostigma</i>		
Properties	MoR, Mpa	MoE, Mpa	Comp St, MPa
Top	145.3	11396	45.62
Middle	149.3	11854	69.05
Bottom	146.4	8442	52.72
Mean	147	10564	55.79

CONCLUSION

Based on the analysis of physical and mechanical properties of *Oxytenanthera monostigma* species exhibited higher modulus of rupture and modulus of elasticity in middle portion compare to bottom and top portion, whereas all the physical properties presented in the results showed higher density and moisture content at middle portion only. This indicates that both physical and mechanical properties comparatively did not show much variation from bottom to top portion of the bamboo culm.

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