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Physical and Mechanical Properties of Bamboo (Dendrocalmus Strictus)

Dinesh Bhonde, Dr. P. B. Nagarnaik, Dr. D. K. Parbat, Dr. U. P. Waghe

Abstract— Bamboo is the fastest growing plant in the world having growth up to 60 cm or more in a day. Bamboo has social, economic and cultural significance and is used extensively for building materials along with thousands of uses. It is highly versatile raw material for different works. The bamboo is light weight, flexible, tough, high tensile, cheap material than the other building materials like steel. Bamboo can be used in various building works. Bamboo structures are flexible, earthquake resistant, light weight and cheap. Bamboo can be used as reinforcement in various structural members. Bamboo is a green material for sustainable development and has various advantages. Use of bamboo may be promoted for green buildings and sustainable development

There are various species of bamboo found all over the world. Dendrocalmus Strictus is the predominant specie found in India. Male Bamboo or Dendrocalmus Strictus occupies total 53 percent of total bamboo area in India. Various mechanical properties of bamboo are required for its use as a structural material. Various physical and mechanical tests are conducted by the author on the specie. This paper investigates the various properties of Dendrocalmus Strictus which will be useful for the engineers in design of structural components.

Index Terms— bamboo, mechanical properties, physical properties, dendrocalmus strictus, green building, sustainable development, compression test, shear test

1 Introduction

Bamboos are the fastest growing plants in the world having growth up to 60 cm or more in a day. Bamboos belong to grass family and are columnar rather than tapering in nature. Bamboos have social, economic and cultural significance in East Asia and South East Asia and are used extensively for building materials, food source and as a highly versatile raw product. The bamboos have good bending strength and flexibility. The height of bamboo plant can go up to 40 m and it still stands against the wind pressure.

The advantage of bamboo is- It is light weight, flexible, tough, high tensile, cheap material than the other building materials like steel and can be used in various building works. Bamboo has various advantages over the other construction material and it is needed that it should be widely used in construction.

Researchers, engineers and architects should take efforts to develop various building components using bamboo as a main construction material. The bamboo should be used in high cost constructions so that its adaptability may be increased amongst rich people to wipe out its discrimination as poor man's wood.

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2 Dendrocalmus Strictus

2.1 Description

Dendrocalmus strictus exihibits 53 per cent of total bamboo area in India. This is predominant species of bamboo in Madhya Pradesh, Maharashtra, Uttar Pradesh, , Orissa and Western Ghats of India. Widely distributed in India in semi dry and dry zone along plains and hilly tracts usually up to an altitude of 1000 m. It is commonaly cultivated throughout the plains and foot hills. It is widely adaptable to temperatures as low as -5°C and as high as 45°C.

This species is mainly found in drier open deciduous forests in hill slopes, ravines and alluvial plains. It prefers well-drained, poor, coarse, grained and stony soils. It occurs naturally in tracts receiving as low as 750 mm of rainfall and also in extensive gregarious patches or as an understorey in mixed forests and teak plantations. Vernacular names of D Strictus are Bengal - Karali, Gujarat - Nakur bans; Kiri bidiru; Maharashtra - Male bamboo, narvel; Orissa - Salia; Tamilnadu - Kalmungil; Andhra - Sadanapa Veduru; Tripura - Lathi bans; Kerala - Kallumula. Dendrocalmus Strictus is a deciduous densely tufted bamboo. The culms 8-16 m high, 25 to 80 mm in diameter, pale blue green when young, dull green or yellow on maturity, much curved above half of its height; nodes somewhat swollen, basal nodes often rooting, lower nodes often with branches; internodes 30-45 cm long, thick-walled. Leaves small in dry localities, up to 25 cm long and 3 cm broad in moist areas, rounded at the base into a short petiole, tip sharply acuminate with twisted point, rough and often hairy above, softly hairy beneath; ligulae very short. [1]

2.2 Flowering and Fruiting

Gregarious flowering cycle varies from 25-40 years. All the clumps of a tract do not flower at the same time. It commences flowering for 2-3 years, increasing progressively and the flow-

ering of all the clumps occur in a period of five years. Irregular flowering is seen almost every year. Gregarious flowering shows relation to injury, climatic conditions, nutrition, and soil factors. Biotic interference affects flowering of Dendrocalmus Strictus. When proper silvicultural practices, flowering is delayed by 3 to5 years. Flowers appear from November till February and fruits from February till April. Flowering of 1 to 3 year old seedlings in nurseries and natural forests are occasionally reported. Gregarious flowering has been reported from different parts of the country; various localities of Maharashtra during 1940-1942, 1948-49, 1957-1958, 1961-1962, 1978-1980. "Blatter (1930)"[1] listed the flowering years of this species from various parts of India and adjacent regions for the period 1865-1914. "Ahmed (1969), Uppin (1978) and Kadambi (1949)" reported that non-production of new culms in the preceding years could be an important event which signifies the approach of flowering in this species, but "Banik (1981)" observed that all the clumps produced new culms in the preceding years, some in the first year of flowering and no new Culm production in the second year of flowering.

2.3 Silviculture and Management

Dendrocalamus strictus grows on practically all types of soils with good drainage and not on water-logged or pure clay. Bamboo grows fast in well drained sand loam. The species are predominentaly found in the areas having a rainfall between 750 mm-4000 mm and it flourishes in regions with low relative humidity of air.. The species are rare on precipitous slopes or on flat ground unless it is well-drained. It prefers hilly ground and is resistant to frost and drought.

3 PHYSICAL AND MECHANICAL PROPERTIES

3.1 Dimension Study

The bamboo is composed of various nodes having transverse dipharm beween two nodes. The nodal length of bamboo culm has peculiarity in dimension and height of bamboo. Bamboo sample was collected from the farm and the dimension study was carried out. The culms were marked from bottom to top with numericals in ascending order. The length of full bamboo was measured The length of each node was recorded. The dimensions were recorded with least count of 1 mm. It is revealed that the length of node is smaller at bottom and goes on increasing at middle portion and again decreases in top portion. This is a special pecualirity of bamboo.

TABLE 1
NODE NUMBER AND NODAL LENGTH

N	1	2	3	4	5	6	7	8	9	10
L	185	210	220	242	235	318	324	335	351	373
N	11	12	13	14	15	16	17	18	19	20
L	380	385	380	386	381	385	380	385	375	370
N	21	22	23	24	25	26	27	28	29	30
L	354	355	336	345	339	341	335	346	345	364
N	31	32	33	34	35	36	37	38	39	40
L	365	360	360	361	353	339	332	338	320	306
N	41	42	43	44	45	46	47	48	49	50
L	303	275	273	260	220	227	210	200	192	182
N	51	52	53	L(Tot)						
L	165	166	179	2793						

The graphical representation of nodal length of dendrocalmus strictus against nodal number is as below.

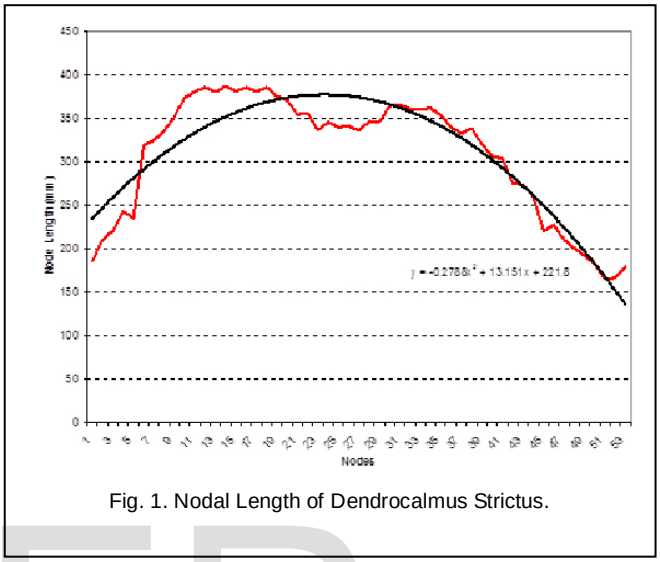

Fig. 1. Nodal Length of Dendrocalmus Strictus.

3.2 Nodal Diameter

The study of diameter of node along the height of a bamboo is studied. The study reveals folling peculiarity.

TABLE 2
NODE LENGTH AND NODAL DIAMETER

Node No	Nod. L (mm)	d1 (mm)	d2 (mm)	d3 (mm)	Average (mm)
1	77	49.1	46.4	46.12	47.2
2	210	46.3	44.8	43.5	44.9
3	230	46.7	42.7	43.3	44.2
4	260	45.4	37.5	37.8	40.2
5	285	39.1	39	39.8	39.3
6	305	41.2	38	38.1	39.1
7	313	41.4	38.1	37.8	39.1
8	325	40.5	37.5	37.6	38.5
9	340	40.5	37.6	37.5	38.5
10	354	40.5	37.9	37.5	38.6
11	358	39.1	39	38.2	38.8
12	370	39.2	39.7	37.2	38.7
13	375	40.4	39.6	39.6	39.9
14	390	39.1	39	38.5	38.9

The graphical representation of variation of nodal diameter with respect to length as as below.

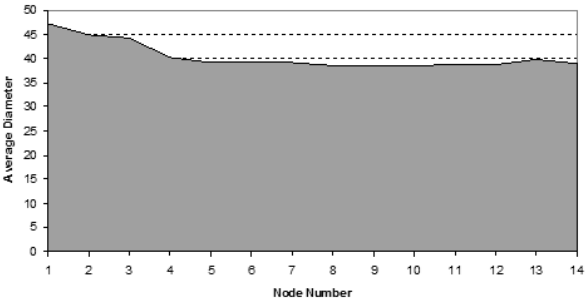

Fig. 2. Node number and nodal diameter

3.3 Specific Gravity

The specific gravity of the samples of dendrocalmus strictus is found in laboratory. The test observations and results are as below.

TABLE 4
SPECIFIC GRAVITY SAMPLE READINGS

Sr. no.	Items	Specimens
1.	Weight of saturated & surface dry specimens.(A)	130 gram
2.	Weight of pycnometer + specimens + Distilled water. (B)	1498 gram
3.	Weight of pycnometer + distilled water. (C)	1522 gram
4.	Weight of oven dried sample. (D)	120 gram

Specific gravity Gs = D/[A-(B-C)] =120/[130-(1498-1522)]
= 0.799

3.4 Water Absorption Test

Water absorption is used to determine the amount of water absorbed under specified conditions. Factors affecting water absorption include: type of plastic, additives used, temperature and length of exposure. The results data sheds light on the performance of bamboo materials in water or humid environments. The sample of bamboo was dried in an oven at 110^0 to 115^0 and dry weight was taken. Bamboo samples were taken out from oven and were allowed them to cool till they attain room temperature. Each bamboo sample were weighed and were immersed completely in a tank filled with water at 15* C to 30* C for 24 hrs. Weight of each specimen to nearest to gram within 3 min. after removal of specimen from than tank was taken.

Percent Water Absorption = [(Wet weight - Dry weight)/ Dry weight] x 100

Water Absorption after 24 Hours :- {W2-W1/W1} X 100
= {161-121/121} *100
= 33.06%

3.5 Moisture Content Test

The tests were conducted in the month of April 2010 in summer

Weight of saturated sample (W1) = 130 gm
Weight of oven dried sample (W2) = 121gm
Moisture Content = W1-W2/W1 x100
= 130-121/130 x100

= 6.92%

4 MECHANICAL PROPERTIES

4.1 Compression Test

Bamboo specimen of 50 mm length were cut from the full bamboo. Specimen from the middle section of bamboo were selected for compression test. The inner and outer diameters at top and bottom portion of the samples were taken. The average diameter was considered for calculating crushing strength.

TABLE 5
COMPRESSION TEST RESULTS

SN	L (mm)	Diameter (mm)		Area Sqmm	Crus-ing Load (KN)	Crushing Strength (N/Sq mm)
		Inner	Outer			
1	40	20.9	37.35	752.58	59	78.39
2	40	20.1	38.55	849.87	65	76.87
3	38	21.3	37.45	790.26	61	77.18
4	40	21.35	37.35	737.65	59	79.98
5	40	21.15	37.35	744.32	58.5	78.6
6	40	21.3	37.45	745.2	57.5	77.16
Average Crushing Strength in MPa						78.03

The test samples were tested under UTM until crushing and the crushing loads were recorded.

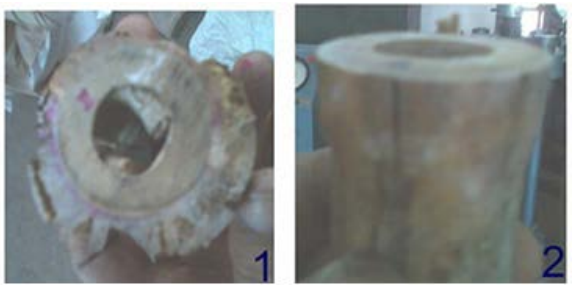

Fig. 3. Sample 1 and 2 after compression Test

4.2 Tension Test

A specimen of length 70 cm was prepared with a grip portion of 10 cm on each side of the specimen. The curved por-

tions of the bamboo split at the end were filled with sand and high strength epoxy resin Araldiate as shown in picture.

Fig. 4. Tension Test Samples.

The portion between the grips was marked with a distance of one cm interval. Average area was calculated on three sections, two at ends and one at centre. Gauge length 5.64 x (A)1/2 was marked and the extensometer was fixed to record the elongation at loading intervals.

The loading range of UTM was adjusted and the rate of loading was selected. The load was continuously applied till the specimen was broken. The cross section of the specimen at failure was observed. The two broken pieces of the specimen were joined and the final guage length was measured to calculate % elongation of the specimen. The graph of stress v/s strain was plotted.

The test results for various samples are recorded as below[2].

TABLE 5
TENSION TEST RESULTS

Sample No	Area (Sqmm)	Gauge Length (mm)	Maximum Load (N)	Tensile Strength (MPa)	Failure Type
b11/1	188.92	80	18560	98.24	Node
b11/2	211.35	80	18560	87.82	Node
b11/3	191.45	80	19600	102.38	Split & Node
b11/4	176.86	80	17600	99.51	Node
b11/5	253.93	90	26400	103.97	Split & Node
b11/6	189.57	80	15300	80.71	Node
b11/7	208.15	80	22400	107.61	split
b11/8	211.95	80	18600	87.76	Node
b11/9	253.93	90	20700	81.52	Node
b11/10	206.12	81	22320	108.29	Split & Node

Average Tensile Strength= 95.781 Mpa

The average Ultimate Tensile Strength is found to be 95.81 MPa and standard deviation 9.93. Dendrocalmus Strictus has a good tensile strength and modulus of Elasticity. However it is observed that most of the failures are from the node. Node is the weakest point for tesile strength. The strength of bamboo fibres is quite high as compared to that at node. Hence codes recommend to use samples having nodes for testing.

4.3 Shear Test

Circular samples of 10 mm diameter were prepared to conduct shear tests. Shear tests were conducted on various samples of bamboo for single shear and double shear.

TABLE 6
SINGLE AND DOUBLE SHEAR TEST

SR. NO	TYPE	DIAMETER	AREA mm^2 (A)	SHEAR LOAD in N (P)	SHEAR STRESS N/mm^2
1.	Single Shear	11.46	103.51	8800	85.31
2.	Double Shear	13.56	144.41	14400	99.71

However the ultimate shear is aling the grains and bamboo is weak along longitudinal fibres. Shear test parallel to fibres is conducted for ultimate shear shrength.

5 CONCLUSION

The culm dimensions of bamboo shows peculiar properties. The nodal lengths of bamboo culms are short at the bottom, more in middle and reduce in top portion. The diameter of bamboo goes on reducing from bottom to top. The specific gravity of Dendrocalmus Strictus is found to be .799 The water absorption tests carried out on the samples show that bamboo is highly porous material absorbing water at the range of 33%. The moisture content of the bamboo tested in summer is found to be 6.92%. Dendrocalmus strictus have exhibited good mechanical properties such as high tensile and compressive strength. The average tensile strength of the samples tested is found to be 95.781 MPa. The compression test across the length is found 77-79 MPa. The shear strength in single shear was found to be 85.3 MPa and the same in double shear was found to be 99.71 MPa. Dendrocalmus Strictus has favourable mechanical properties and it can prove a good eco friendly, sustainable material for green building. Use of bamboo in construction, various structural members and as a reinforcing material shall be encouraged amongst the engineers for sustainable development and green buildings. The test results will be useful to the structural engineers for further analysis and design.

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