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Effect of dimensions of bamboo on their strength properties

■ **S.K. JAIN, S.P. KURHEKAR AND S. KOTHE**

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See end of the Paper for authors' affiliation

Correspondence to :

S.P. KURHEKAR
Department of Farm Structures, College of Agricultural Engineering and Technology, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, DAPOLI (M.S.) INDIA

■ **ABSTRACT :** The average moisture content of fresh bamboo (cv. *Dendrocalamus stocksii*) after harvesting was found to be 58.33 per cent. The shrinkage of bamboo along diameter, thickness and length varied between 2.90 to 5.43 per cent, 3.02 to 10.88 per cent and 0.04 to 0.73 per cent, respectively. Thus, it was found that the shrinkage in thickness was more than diameter and that of shrinkage in thickness was more than length wise. The top portion of bamboo provides more compression and shear strength than bottom portion. The high compression strength was found for smaller length of bamboo as compared to larger length. It was also found that with node bamboo possessed more compression and shear strength than without node and six month old harvested bamboo possessed more compression strength than fresh bamboo.

■ **KEY WORDS :** Shrinkage, Strength, Bamboo

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Bamboo grows most abundantly in the orient where it is native to China, Burma, India, Japan, Europe and Canada. India has annual bamboo production as 4.5 million tones. In Maharashtra bamboo production is 2,47,239 tones. The Konkan region contributes 70,000 tonnes of bamboo production (Choudhary, 2008). It has been reported that about 50 genera and 700 species of bamboo are found all over world. Asia alone accounts for 400 species. About 136 species in 30 genera occur in India (Suri and Chauhan, 1984).

Bamboo is used to design of scaffolding, for construction of frame work, to manufacture furniture, for making clothing fabrics, for construction of building to withstand earthquake. In addition, bamboo is used for the manufacture of wooden flooring panels, support in traditional housing and for the construction of framework.

The strength variation was investigated for the shear test and compression test. However, being a biological material like timber, it is subjected to greater variability and complexity, due to various growing conditions as moisture and soil. This project seeks to determine compressive and shear strength bamboo with nodes and without nodes under load for the *Dendrocalamus stocksii* (mes) variety found in Konkan.

Sekhar and Gulati (1973) studied that the physical properties of *Dendrocalamus strictus* from ten locations in India and stated that specific gravity is 0.719, moisture content 10.7 per cent, modulus of elasticity was 1.59 KN/ mm^2 and crushing strength parallel to grain was 64.5 N/ mm^2. Yu and Yibiu (2007) reported that the moisture content influences the utilization of bamboo in a similar way like that of wood. It was also reported that the compression strength and shear strength for *Phyllostachus pubescens* variety of bamboo was 56 N/mm^2 and 13.9 N/mm^2, respectively and for *Guadua angustfolia* variety of bamboo it was 56 N/mm^2 and 9 N/mm^2. Gyansah *et al.* (2010) investigated increase in height reduces the strength of the bamboo and *vice versa*. Increase in moisture content increases the strength of the bamboo. The height of the fresh bamboo decreases

as the crushing load increases and the time of failure also increase. The effect of thickness does not depend on only the crushing stress but also the amount of moisture in the bamboo. Wakchaure and Kute (2012) determined the compressive strength of top portion of bamboo is always larger than that of middle and bottom.

■ METHODOLOGY

The *Dendrocalamus stocksii* (Mes) variety of bamboo samples was used. The bamboos were used of 4-5 years of age and upto 4-5 m long in length, internodes 15 - 30 cm long and 2.4 - 4 cm broad. The external knot removing machine, bamboo stick sizing, machine, universal testing machine, compression testing machine were used in study.

The shear test die as shown in Fig. A was used for determination of shear strength of bamboo.

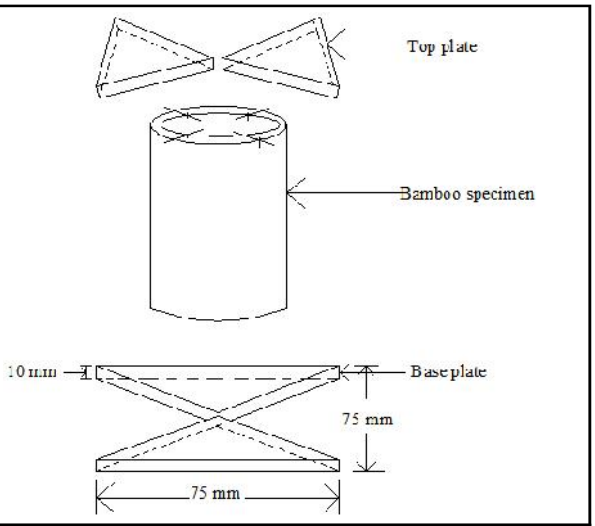

Fig. A : Shear test die

Shrinkage :

Shrinkage was observed in the outer diameter D, in the wall thickness t and also in the length L of the specimen. The ten specimens of 100 mm length were used to determined shrinkage of bamboo. On each specimen, 4 diameters, 4 wall-thicknesses (two on either end) and 2 lengths were measured. The shrinkage determination method was taken in accordance of IS: 22157-1.The shrinkage, S was calculated by following formula :

$$\text{Shrinkage, S (\%)} = \{\frac{I - F}{I}\} \times 100$$

where,

I = the initial reading of diameter/ thickness/ length,

F= the final reading of diameter/ thickness/ length,

Each of these being the average value for diameter, wall thickness or length.

Compression test :

The bamboo is biological material. The treatment details of compression test are given in Table A.

Table A : Treatment details of compression test

Level	With node			Without node		
Outer diameter (mm)	26-35	36-45	46-55	26-35	36-45	45-55
Length (mm)	100, 200, 300			100, 200, 300		
Variety	*Dendrocalamus stocksii* (mes)					
Replications	2					
No. of samples	36					

The range of outer diameter 26-35 mm was taken from top portion of bamboo. Similarly, the outer diameter 36-45 mm and 46-55 mm was taken from middle portion and bottom portion of bamboo, respectively. The compressive strength was calculated by following formula:

$$\sigma_{ult} = \frac{F_{ult}}{A}$$

where,

σ_{ult} = compressive strength, (N/mm^2)

F_{ult} = maximum load at which the bamboo sample fails, N

A = Cross sectional areas, mm^2.

Shear test :

The treatment details of shear test are given in Table B.

Table B : The treatment details of shear test

Level	With node			Without node		
Outer diameter (mm)	26-35	36-45	46-55	26-35	36-45	45-55
Length (mm)	30, 60	40, 80	50,100	30, 60	40, 80	50, 100
Variety	*Dendrocalamus stocksii* (mes)					
Replications	3					
No. of samples	36					

The range of outer diameter 26-35 mm was taken from top portion of bamboo. Similarly, the outer diameter 36-45 mm and 46-55 mm was taken from middle portion and bottom portion of bamboo, respectively.

The shear test determination method was taken in

accordance of IS: 22157-1. The formula for calculation of shear strength of bamboo is given below:

$$\tau_{ult} = \frac{F_{ult}}{\sum (t \times L)} \text{ MPa}$$

where,

τ_{ult} = Shear strength, (N/mm^2)

F_{ult} = Maximum load at which the bamboo sample fails, N

Σ (t × L) is the sum of the four products of t and L

RESULTS AND DISCUSSION

The average moisture content of selected fresh bamboo sample was 58.33 per cent.

Shrinkage :

The data were recorded for 4 diameters, 4 thicknesses and 2 lengths. The initial data were taken on 22.08.2012, after that data were observed on specific interval at 27.08.2012, 05.09.2012 and 08.09.12. It was observed from data that, there were constant reduction in value of diameter, thickness and length. When constant reading appears, these samples were kept in the oven for oven drying. The variation of shrinkage of bamboo in different parameters is represented graphically in Fig. 1.

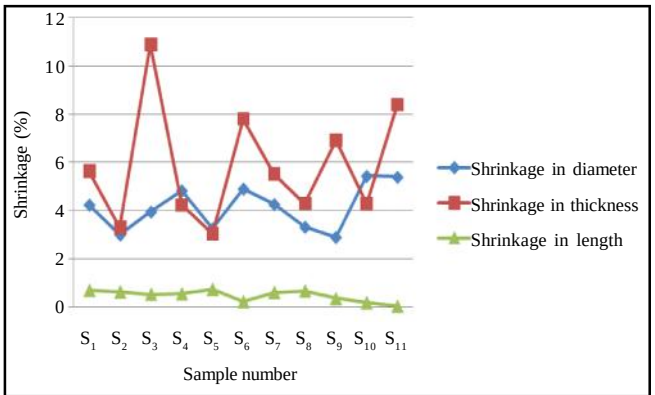

Fig. 1 : Shrinkage of bamboo samples for different parameters

It was found that the shrinkage along the diameter was in the range of 2.90 per cent to 5.43 per cent. The shrinkage along the thickness was found in the range of 3.02 per cent to 10.88 per cent. Similarly, the shrinkage test conducted along the length resulted in shrinkage of 0.04 per cent to 0.73 per cent. Thus, it seems that the shrinkage in thickness was more than shrinkage in diameter and that of shrinkage in diameter was more than length.

Compression test :

The data recoded for 3 different diameters, 3

Table 1 : Compression strength of bamboo

Sample code	Replications	Compression strength (N/mm^2)			
		Fresh bamboo		Six month seasoned	
		With node	Without node	With node	Without node
CL_1CD_1	1	82.43	70.29	85.77	75.73
	2	73.14	65.16	83.91	73.48
CL_1CD_2	1	57.70	56.42	69.19	57.15
	2	64.79	57.14	65.81	62.00
CL_1CD_3	1	41.23	36.04	53.62	42.97
	2	43.01	37.04	45.49	38.21
CL_2CD_1	1	55.72	57.00	63.19	52.55
	2	59.99	51.18	56.64	60.62
CL_2CD_2	1	47.53	42.67	48.35	51.20
	2	47.05	47.63	50.11	42.35
CL_2CD_3	1	36.47	34.52	45.58	36.71
	2	38.29	35.53	40.64	37.32
CL_3CD_1	1	47.67	43.90	54.35	46.41
	2	49.31	46.16	48.25	45.92
CL_3CD_2	1	38.38	35.84	41.33	39.78
	2	39.43	37.78	42.42	36.72
CL_3CD_3	1	34.63	32.89	37.46	32.50
	2	33.48	30.72	34.23	34.14

CL_1=100 mm, CL_2=200 mm, CL_3=300 mm, CD_1=26-35 mm, CD_2=36-45 mm, CD_3=46-55 mm.

different lengths and with node and without node type of bamboo samples. These data were taken for the fresh bamboo samples and six months seasoned bamboo samples. The compression strength reading for the fresh bamboo sample with node is shown in Table 1.

It was found that, for 26- 35 mm diameter range, the average compressive strength for 100 mm, 200 mm and 300 mm length of fresh bamboo sample with node was 77.79 N/mm^2, 57.86 N/mm^2 and 48.49 N/mm^2, respectively. For 36- 45 mm diameter range, the average compressive strength for 100 mm, 200 mm and 300 mm length of bamboo sample with node was 61.25 N/mm^2, 47.29 N/mm^2 and 38.91 N/mm^2, respectively. For 46- 55 mm diameter range, the average compressive strength for 100 mm, 200 mm and 300 mm length of bamboo sample with node was 42.12 N/mm^2, 37.38 N/mm^2 and 34.06 N/mm^2, respectively.

It was found that, for 26- 35 mm diameter range, the average compressive strength for 100 mm, 200 mm and 300 mm length of fresh bamboo sample without node was 67.73 N/mm^2, 54.09 N/mm^2 and 45.03 N/mm^2, respectively. For 36- 45 mm diameter range, the average compressive strength for 100 mm, 200 mm and 300 mm length of bamboo sample without node was 56.78 N/mm^2, 45.15 N/mm^2 and 36.81 N/mm^2, respectively. For 46- 55 mm diameter range, the average compressive strength for 100 mm, 200 mm and 300 mm length of bamboo sample without node was 36.54 N/mm^2, 35.03 N/mm^2 and 31.81 N/mm^2, respectively.

It was found that, for 26- 35 mm diameter range, the average compressive strength for 100 mm, 200 mm and 300 mm length of six month seasoned bamboo sample with node was 84.84 N/mm^2, 59.92 N/mm^2 and 51.30 N/mm^2, respectively. For 36- 45 mm diameter range, the average compressive strength for 100 mm, 200 mm and 300 mm length of bamboo sample with node was 67.50 N/mm^2, 49.23 N/mm^2 and 41.88 N/mm^2, respectively. For 46- 55 mm diameter range, the average compressive strength for 100 mm, 200 mm and 300 mm length of bamboo sample with node was 49.56 N/mm^2, 43.11 N/mm^2 and 35.85N/mm^2, respectively.

It was found that, for 26- 35 mm diameter range, the average compressive strength for 100 mm, 200 mm and 300 mm length of six month seasoned bamboo sample without node was 74.61 N/mm^2, 56.59 N/mm^2 and 46.16 N/mm^2, respectively. For 36- 45 mm diameter range, the average compressive strength for 100 mm, 200 mm and 300 mm length of bamboo sample without node was 59.58 N/mm^2, 46.78 N/mm^2 and 38.25 N/mm^2, respectively. For 46- 55 mm diameter range, the average compressive strength for 100 mm, 200 mm and 300 mm length of bamboo sample without node was 40.59 N/mm^2, 37.02 N/mm^2 and 33.32 N/mm^2, respectively.

The result revealed that, the compression strength of bamboo increased from bottom to top portion of bamboo. The smaller length of bamboo possessed more compression strength than larger length. The results are according to findings of Wakchaure and Kute (2012).

By comparing with node and without node bamboo samples, it was found that the with node bamboo sample possessed more strength than without node. By comparing fresh bamboo samples and six month seasoned samples data for same sample dimensions, it was found that the six month seasoned bamboo had more compressive strength than the fresh bamboo.

Shear test :

The shear test data recorded for three different diameter ranges were 26-36 mm, 36-45 mm and 46-55 mm. For the range of 26-35 mm diameter two lengths were taken for experiment that is 30 mm and 60 mm. For the range of 36-45 mm diameter two lengths were taken for experiment that is 40 mm and 80 mm. For the range of 46-55 mm diameter two lengths were taken for experiment that is 50 mm and 100 mm. The experiment was carried for with node and without node. The reading

Table 2 : Average shear strength for different dimensions of bamboo samples

Diameter range (mm)	Sample number	Average shear strength (N/ mm^2)	
		With node	Without node
26-35 (Top portion)	RD_1RL_1	19.43	14.02
	RD_1RL_2	9.78	8.78
36-45 (Middle portion)	RD_2RL_3	17.65	10.91
	RD_2RL_4	8.11	7.21
46-55 (Bottom portion)	RD_3RL_5	9.79	8.89
	RD_3RL_6	8.01	6.54

RD_1= 26-35 mm, RD_2= 36-45 mm, RD_3= 46-55 mm, RL_1= 30 mm, RL_2= 60 mm, RL_3= 40 mm, RL_4= 80 mm, RL_5=50 mm, RL_6= 100 mm.

of this experiment is shown in Table 2 and the average shear strength for different dimensions of bamboo samples is graphically represented in Fig. 2.

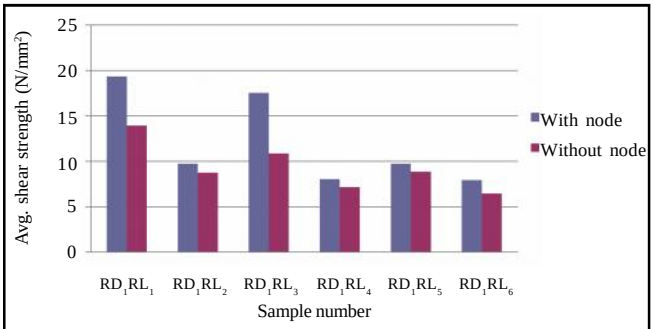

Fig. 2 : Average shear strength for different dimensions of samples

It was found that, for 26- 35 mm diameter range, the average shear strength for 30 mm and 60 mm length of bamboo sample with node was 19.43 N/mm^2 and 9.78 N/mm^2 and the average shear strength for 30 mm and 60 mm length of without node bamboo sample was 14.02 N/mm^2 and 8.78 N/mm^2.

In the 36- 45 mm diameter range, the average shear strength for 40 mm and 80 mm length of bamboo sample with node was 17.65 N/mm^2 and 8.11 N/mm^2 and the average shear strength for 40 mm and 80 mm length of bamboo sample without node was 10.91 N/mm^2 and 7.21 N/mm^2.

In the 46- 55 mm diameter range, the average shear strength for 50 mm and 100 mm length of bamboo sample with node was 9.79 N/mm^2 and 8.01 N/mm^2 and the average shear strength for 50 mm and 100 mm length of bamboo sample without node was 8.89 N/mm^2 and 6.54 N/mm^2.

It seems that the bamboo sample with node possessed more shear strength than bamboo sample without node. The shear strength of bamboo decreased with increase in length of bamboo. By observing, it was also found that the top portion of bamboo possessed more shear strength than bottom portion.

It was observed that due to decrease in moisture content shrinkage occurs. Thus, due to shrinkage, the fibres of bamboo become strong. Thus, it leads to conclusion that when shrinkage stops naturally the strength of bamboo will also remain constant and further it may start decreasing.

Conclusion :

- The shrinkage in thickness was more than shrinkage of diameter and that of shrinkage in diameter was more than shrinkage in length.
- Bamboo with node possessed more compression and shear strength than without node bamboo.
- The compressive strength and shear strength of bamboo decreased with increase in length of bamboo.
- The compressive strength and shear strength of bamboo decreased from top to bottom portion of bamboo.
- The six month old bamboo possessed more compression strength than fresh bamboo.

Authors' affiliations:

S.K. JAIN AND S. KOTHE, Department of Farm Structures, College of Agricultural Engineering and Technology, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, RATNAGIRI (M.S.) INDIA

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