International Journal for Research in Engineering Application & Management (IJREAM)
ISSN : 2454-9150 Vol-05, Issue-08, Nov 2019

Experimental Study on Properties of Bamboo

[1]Ms. Deshmukh Prajakta S., [2]Mr. Shaikh Alfaj N., [3]Mr. Shelar Vishal E.,
[1,2,3]Assistant Professor, Dnyanshree Institute of Engineering & Technology, Sajjangad road, Satara, Maharashtra, India.
Mr. Deshmukh Nikhil S., Engineer, Neilsoft Ltd., Pune, Maharashtra, India.

Abstract - In India, 70% people lives in villages. Though India consists of many small villages, there is need of low cost houses considering their low income. There is need of development of suitable low cost housing system so that people can satisfy their shelter need. As low income group people cannot bear to satisfy cost of conventional construction system, there is necessity to decrease cost of construction with the help of an eco-friendly as well as affordable construction system. However, due to lack of technological advancement and known commercial use, the use of bamboo has been largely restricted to the level of household use. Due to lack of technology and awareness about bamboo, people have not used bamboo on large scale for construction. The major use of bamboo in India is in paper industry, which consumes sizeable proportion of the total annual bamboo production. To minimize all these problems and to achieve an economy in the construction, we have to think about the utilization of bamboo in construction. Bamboo consists of various properties such as Physical and mechanical properties. Determination of these properties is very important to use any material in construction and design. In this paper, an attempt has been made to do experimental study on properties of Bamboo as a construction material.

Keywords - Affordable construction material, Economy, Household use, Low Cost housing system, Properties of bamboo, Technological advancement.

I. INTRODUCTION

In a developing country like India where 70% population lives in rural area, shelter is basic need. Though India consists of many small villages, there is need of low cost houses considering their low income. There is need of development of suitable low cost housing system so that people can satisfy their shelter need. As low income group people cannot bear to satisfy cost of conventional construction system, there is necessity to decrease cost of construction with the help of an eco-friendly as well as affordable construction system [3]. However, due to lack of technological advancement and known commercial use, the use of bamboo has been largely restricted to the level of household use. Due to lack of technology and awareness about bamboo, people have not used bamboo on large scale for construction. The major use of bamboo in India is in paper industry, which consumes sizeable proportion of the total annual bamboo production. To minimize all these problems and to achieve an economy in the construction, we have to think about the utilization of bamboo in construction. Determination of these properties is very important to use any material in construction and design. Bamboo consists of various properties such as Physical and mechanical properties. Determination of these properties is very important to use any material in construction and design.

II. PROPERTIES OF BAMBOO

Bamboo consists of various properties such as Physical, mechanical properties. Determination of properties is very important for using any material in construction and design.

i] Physical properties:
- a] Moisture Content
- b] Water absorption
- c] Mass density
- d] Shrinkage

ii] Mechanical properties:
- a] Compressive Strength
- b] Tensile Strength
- c] Static bending Strength
- d] Shear Strength parallel to grain

Various treatment processes on bamboo like water leaching, application of paint coating, brushing, swabbing, spraying, dipping, smoking, baking[6] etc. are practiced for the protection of bamboo. Water leaching and baking result in partial removal of starch which attracts insects. The other treatments do not impart much toxicity because of poor penetration and retention of chemicals. Leaching,

 DOI : 10.35291/2454-9150.2019.0514

Smoking and lime washing are age-old treatment methods. Sometimes protection is also given by use of natural dyes and lacquers. From all this various treatment processes, dipping process is used for the treatment of bamboo by considering parameters like availability of space and equipment, labour, facility etc.[12]

Therefore, sample used for testing and for construction are treated by dipping method.

2.1 MOISTURE CONTENT TEST: (According to IS 6874:2008)

To determine moisture content in bamboo[4]: Weight of bamboo specimen shall be taken as (m_i) to an accuracy of 0.01g. And then dried in hot- air oven at a temperature 103±2ºC for 24hrs. The bamboo specimen shall then be weighed and drying continued thereafter. The weight of specimen shall be taken and recorded every 2hrs. until the difference between successive weighing does not exceed 0.01g, when the drying shall be completed. After drying, the final mass shall be considered as the oven dry mass (m_0).

Care shall be taken to prevent any change in moisture content between the cutting of the specimen and the first weighing, and between the removal from the oven and subsequent weighing.

Calculation:

Moisture Contents = $(m_i-m_o)/m_o \times 100$

Where, m_i = Initial mass of the test specimen in gm and

m_o = Oven dry mass, in gm

Fig.2.1 Sample in oven at 103±2ºC for 24 hrs.

Observation Table:

A] For Solid bamboo sample:-

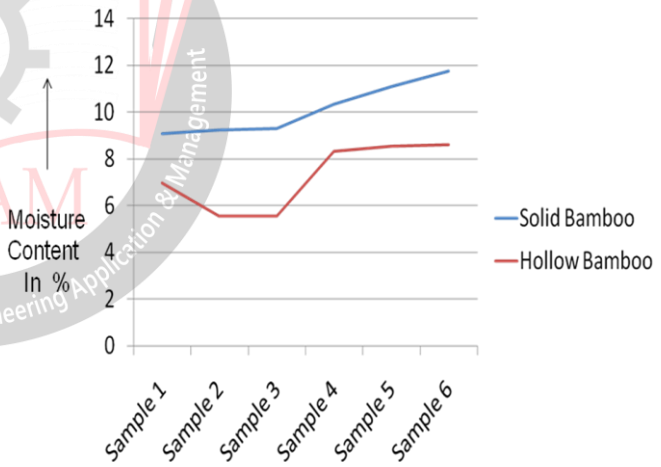
Table 2.1(A)

Sample No.	No. of nodes present	Initial mass (mi) (gm.)	Oven dry mass after 24h. (m_o) (gm.)	Moisture Content in %
1	01	96	88	9.09
2	01	118	109	9.26
3	01	94	86	9.3
4	00	64	58	10.34
5	00	80	72	11.11
6	00	76	68	11.76

B] For Hollow bamboo sample:-

Table 2.1 (B)

Sample No.	No. of nodes present	Initial mass (mi) (gm.)	Oven dry mass after 24h. (mo) (gm.)	Moisture Content in %
1	01	92	86	6.97
2	01	76	72	5.55
3	01	76	72	5.55
4	00	52	48	8.33
5	00	76	70	8.57
6	00	63	58	8.62



Graph (2.1.) Moisture content

Conclusion of the test:

From Graph 2.1.A:

- Solid bamboo sample has max. moisture content than that of hollow bamboo sample by 2.90%.
- Every bamboo sample has different moisture content in it.

2.2 WATER ABSORPTION TEST:

To determine water absorption in bamboo [4] : Three samples of uncoated messi bamboo with 1 and 2 nodes or without node samples with different dimensions were selected for determining water absorption capacity. Dry weights of samples were noted and placed in water. The weights were recorded after 1, 2, 4, 7,9 and 10 days the samples were

 DOI : 10.35291/2454-9150.2019.0514

removed from water and wiping the surface with a cloth. The percentages of water absorption for 12 samples on different days are tabulated in following observation table.

Calculations:

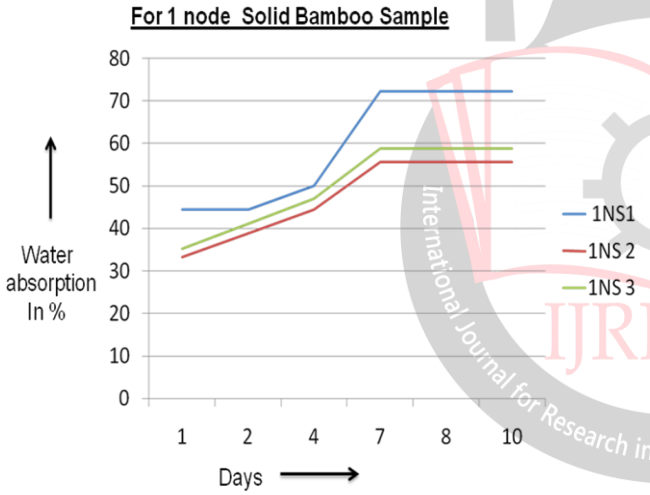
Water absorption = [Wet wt. – Dry wt.]/ Dry wt. X 100

Observation Table:

A] For Solid bamboo sample:-

Table 2.2 (A)

Sample No.	No. of nodes present	Dry wt. of sample (gm.)	Wt. of sample after days (gm.)					
			1	2	4	7	8	10
1	01	36	52	52	54	62	62	62
2	01	36	48	50	52	56	56	56
3	01	34	46	48	50	54	54	54
4	00	30	42	44	46	48	50	50
5	00	22	30	32	36	38	38	38
6	00	24	34	36	36	38	40	40

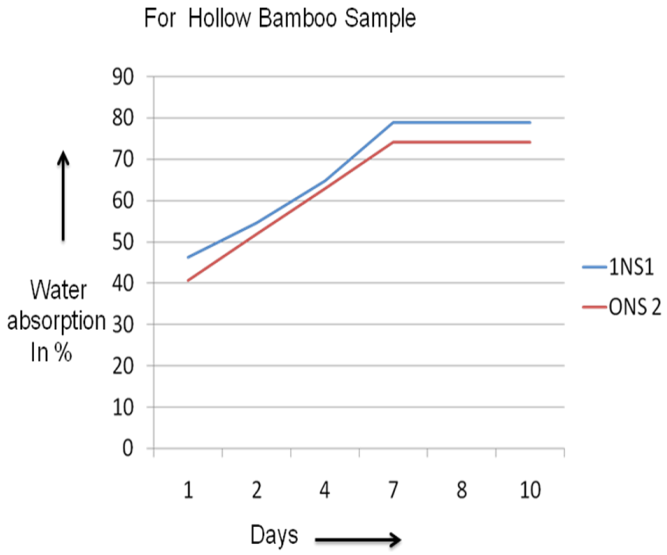


Graph (2.2.A) For 1 node solid bamboo sample

B] For Hollow bamboo sample:-

Table 2.2 (B)

Sample No.	No. of nodes present	Dry wt. of sample (gm.)	Wt. of sample after days (gm.)					
			1	2	4	7	8	10
1	01	36	54	58	62	68	68	68
2	01	36	50	52	56	62	62	62
3	01	24	36	38	40	42	42	42
4	00	18	26	28	30	32	32	32
5	00	18	26	28	30	32	32	32
6	00	18	24	26	28	30	30	30



Graph (2.2.B) For Hollow bamboo sample

Conclusion of the test:

From Graph (2.2.A) and Graph (2.2.B):

i) After 7 days, there is no any change occurs in water absorption capacity, it remains constant.

ii) Water absorption capacity of node bamboo sample is greater than without node bamboo sample by 5.64%.

2.3. COMPRESSIVE STRENGTH PARALLEL TO GRAIN: (According to IS 6874:2008)

To determine Compressive strength of bamboo[4] :Bamboo for compressive strength tests shall be taken from the undamaged ends of specimens. The length of the bamboo specimen shall be taken approximately equal to the outer diameter. The bamboo sample shall be placed in such a way that the centre of the movable head is vertically above the centre of the cross section of the sample and a small load of not more than 1KN shall be applied to set the sample. Three different types of specimens are selected for the examination. The three specimens contains central node, end node and without nodes. The dimensions of samples are measured and samples were placed in compressive testing machine. The load is applied parallel to fibers of bamboo in gradual increments until the sample failure. From the ultimate load, compressive strength is determined for solid and whole bamboo sample.

Calculation:

The maximum compressive strength (N/mm^2) shall be determined as follows:

Maximum compressive strength = F_{ult} / A

Where,

F_{ult} = Maximum load in N

A = Area of sample in mm^2

Observation table:

A] For Solid bamboo Sample

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Table 2.3 (A)

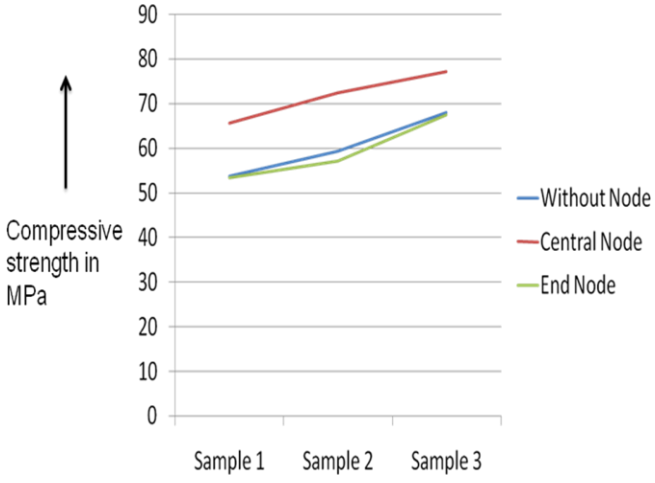
Sr. No.	Type of sample	Sample No.	Diameter of sample (mm)	Area (mm^2)	Load in N	Strength (N/mm^2)	Avg. strength (N/mm^2)
1.	Without node	1A	36	1017.87	55800	53.778	60.416
		1B	34	907.92	55000	59.427	
		1C	36	1017.87	70600	68.043	
2.	Central node	2A	40	1256.63	82560	65.705	69.40
		2B	34	907.92	67000	72.393	
		2C	36	1017.87	80000	77.102	
3.	End node	3A	36	1017.87	55400	53.393	59.324
		3B	37	1075.31	62600	57.114	
		3C	36	1017.87	7000	67.464	

Test Set-up:

Without node **Central node** **End node**

Fig.2.3 Bamboo sample at the time of testing

For Solid Bamboo Sample



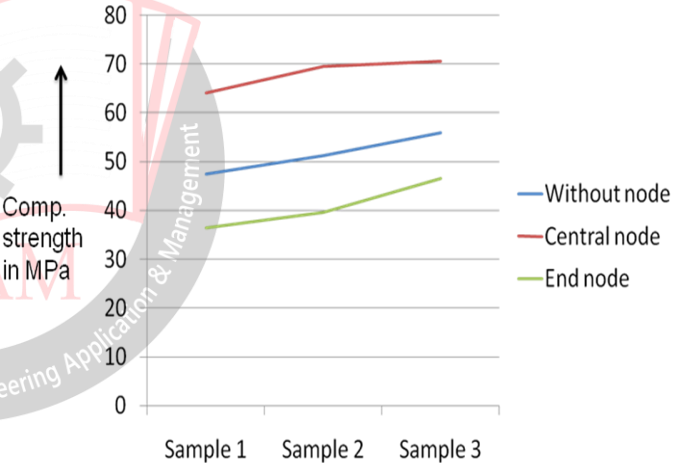
Graph (2.3.A) For Solid bamboo sample

Observation table :

B] For Hollow Bamboo Sample:

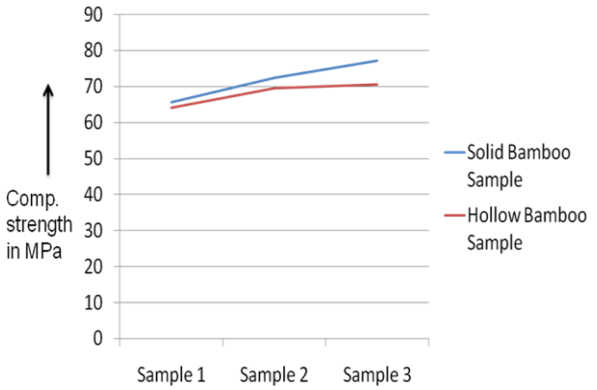
Table 2.3 (B)

Sr. No.	Type of sample	Sample No.	Diameter of sample (mm)	Area (mm^2)	Load in N	Strength (N/mm^2)	Avg. strength (N/mm^2)
1.	Without node	1A	46-30	955.044	46200	47.456	51.526
		1B	46-25	765.763	40000	51.243	
		1C	46-30	955.044	54400	55.878	
2.	Central node	2A	40-26	725.707	47400	64.075	68.04
		2B	40-26	725.707	51400	69.482	
		2C	40-26	725.707	52200	70.563	
3.	End node	3A	35-22	581.980	21600	36.409	40.841
		3B	36-24	565.486	22800	39.553	
		3C	36-20	703.716	33400	46.530	



Graph (2.3.B) For Hollow bamboo sample

FOR CENTRAL NODE:



Graph (2.3.C) for central node solid and hollow bamboo sample

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Conclusion of the test:

1. From Graph (2.3.A) and Graph(2.3.B):

   Central node bamboo has maximum compressive strength than that of other two samples in both the cases.

2. From Graph (2.3.C) :

   The stress values obtained from hollow bamboo sample is less than that of solid bamboo sample by 16.66%.

2.4 TENSILE STRENGTH PARALLEL TO GRAIN: (According to IS 6874:2008)

To determine tensile strength of bamboo[4]:The test specimen shall be with one node in the centre. The general direction of the fibres shall be parallel to the longitudinal axis of the test specimen. The length of the specimen shall be 1000mm and the width shall be 10 to 20 mm, so that the test specimen is more or less flat. The grips shall press the test specimen perpendicular to the fibres and in radial direction.

The load shall be applied continuously and the movable head of the testing machine shall travel at a constant rate of 0.01mm/s. The maximum load shall be recorded.

Test Set-up:

Fig. 2.4.A. Arrangement of specimen in testing machine

Calculation:

The maximum tensile strength (N/mm^2) shall be determined as follows:
Maximum tensile strength = F_{ult} / A
Where,
F_{ult} = Maximum load in N
A = Area of sample in mm^2

Observation table :

Table 2.4

Sample No.	Area (mm^2)	Load in N	Stress (N/mm^2)	Elongation in (mm)	Total change in length (mm)
1	220	20000	90.9	10	21
2	240	23000	95.93	10	15
3	250	15000	60.00	5	5
4	320	25500	79.687	2	2

Fig.2.4.B. Failure of specimen during testing

Fig.2.4.C. Failure mode of specimen observed after testing

Conclusion of the Test:
By Testing:

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- ✓ DIFFERENT FAILURE MODES ARE OBSERVED.
- ✓ THERE IS NO SUDDEN DAMAGE DUE TO WIDELY SPACED FIBRES.
- ✓ IT GIVES WARNING OF FAILURE BEFORE SUDDEN DAMAGES.

2.5 STATIC BENDING STRENGTH TEST: (ACCORDING TO IS 6874:2008)

To determine static bending strength of bamboo[4] :A suitable testing machine capable of measuring load to the nearest 100N and deflection to the nearest 1mm should be used. The test carried out on four-point bending test. The test specimen shall be mounted on suitable saddles (Separate attachment is prepared) in such a way that the reaction forces at the supports are transmitted to the nearby nodes. The bamboo culms shall be allowed to rotate freely at the supports. The load shall be divided into two halves by an appropriate beam resting on saddles in such a way that the loads are applied to the nodes of specimen. The length of the specimen shall be suitable to have a clear span of 30 times its diameter at the middle point. The loading of the test specimen shall be carried out uniformly at constant speed. Deflection at the middle span shall be noted by means of a dial gauge at load increments of every 500 N. The load shall be recorded at the points of sudden changes in deflection, at the time of failure and at maximum level, if different from the load at failure. Crack development and the form of failure shall be noted.

Test Set-up :

Fig. 2.5.A. Test set-up in testing machine

Observation table:

Table 2.5 (A): For sample 1

Dia. In mm	Load in N	Deflection at mid span in (mm)
35	50	0.9
	100	2.3
	150	3.5
	200	4.0
	300	5.3
	400	5.5
	500	5.8
	750	8.0
	1000	9.0
	1200	>10

TABLE 2.5 (B): FOR SAMPLE 2

Dia. In mm	Load in N	Deflection at mid span in (mm)
35	50	1
	100	2.4
	150	3.6
	200	4.5
	300	5.5
	400	6.5
	500	8.8
	800	> 10

Table 2.5 (C): For Sample 3

Dia. In mm	Load in N	Deflection at mid span in (mm)
35	50	3.0
	100	3.4
	150	4.0
	200	4.8
	300	5.3
	400	5.9
	500	6.9
	750	7.7
	1000	8.65
	1570	>10

 DOI : 10.35291/2454-9150.2019.0514

Fig.2.5.B. Failure during testing

Fig. 2.5. C. Failure mode of sample observed after testing

Conclusion of the test:

By testing:

- Sample shows bending action but still not completely damaged.
- Sample shows bending as well as slight crack on surface of sample but not sudden failure.

III. CONCLUSION

This paper highlights different tests carried out on bamboo for the determination of their properties. Experimental study work on bamboo shows through the results obtained from this work that Bamboo is suitable for construction as a low cost material. Bamboo treatment by dipping process gives improvement in properties and life of the material is increased due to treatment. Due to determination of properties of bamboo, unique behavior of bamboo has been observed. Properties of bamboo obtained from an experimental study are helpful for the design and construction parameters.

ACKNOWLEDGMENT

I must mention several individuals and organizations that were of enormous help in the development of this work. **Dr. Prof. ATTAR A. C.** my mentor, philosopher and personality with a Midas touch encouraged me to carry this work. His continuous invaluable knowledgably guidance throughout the course of this study helped me to complete the work up to this stage and hope will continue in further research.

I also very thankful to **Dr. A. D. Jadhav and Prof. R. D. Wangde** for their valuable suggestions, critical examination of work during the progress, I am indebted to them.

In addition, very energetic and competitive atmosphere of the **Civil Engineering Department** had much to do with this work. I acknowledge with thanks to faculty, teaching and non-teaching staff of the department, **Central library** and Colleagues.

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