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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 are used extensively for building materials along with thousands of uses as a highly versatile raw material. The advantage of bamboo is- it is cheap, flexible, tough, high tensile, light weight material than the other materials like steel and can be used in various building works. Bamboo structures are light weight, earthquake resistant and cheaper. Bamboo can be used as a reinforcing material in various structural members. Bamboo is a green material for sustainable development and has various advantages over the other construction materials and is needed to use widely in construction.

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. This paper investigates the tensile property of Male Bamboo. Various grip supports were examined to carry out tension test.

Keywords- *bamboo; dendrocalmus strictus; tension test; grips; green building; suistanable development*

I. 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 goes up to 40 m and it still withstands the wind pressure.

The advantage of bamboo is- it is cheap, flexible, tough, high tensile, light weight material than the other 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.

II. DENDROCALMUS STRICTUS

Dendrocalmus Strictus occupies 53 per cent of total bamboo area in India. It is one of the predominant species of bamboo in Uttar Pradesh, Orissa, Madhya Pradesh and Western Ghats. Abundantly found in India in dry zone along plains and hilly regions up to an altitude of 1000 m. D. Strictus is commonly cultivated throughout the plains and at the foot of hills. It is widely adaptable to temperatures from -5^{o}C to 45^{o}C. This species is mainly found in drier deciduous forests in hilly and alluvial plains. It grows in drained, poor, grained and stony soils. It occurs naturally in the regions of as low as 750 mm of rainfall and also in extensive in mixed forests and teak plantations. Indian vernacular names of Dendrocalmus Strictus are: Andhra - Sadanapa Veduru; Tamilnadu - Kalmungil; Tripura - Lathi bans; Kerala – Kallumula;. Bengal - Karali, Gujarat - Nakur bans; Kiri bidiru; Maharashtra - Male bamboo.

A. Description

Dendrocalmus Strictus is a deciduous densely tufted bamboo. The culms are 8-16 m in height and 25 to 80 mm in diameter, pale blue green when young, dull green or yellow on maturity, curved above half of its height; nodes swollen, lower nodes with branches; internodes 30-45 cm long and thick-walled. Leaves are small in dry localities and up to 25 cm long and 3 cm broad in moist areas. Leaves are rounded at the base into a short petiole and the tip is sharply acuminate having twisted point, rough and hairy above, softly hairy beneath.

B. 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 flowering 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) 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.

C. Physical And Mechanical Properties

Mechanical properties vary according to the age, position of culm and locality. Average properties from various locations in India are - Specific gravity 0.719, moisture content 7-10.7 per cent, modulus of elasticity 1.59 kN/mm2, modulus of rupture 118.4 N/mm2, crushing strength 64.5 N/mm2; parallel to grain (Sekar and Gulati, 1973).

As compared to teak wood, bamboo has higher basic strength. The impact strength of bamboo is about 15-20% of the impact strength of mild steel. Bamboo specimens have poor torsional shear strength in comparison to the torsional shear strength of mild steel. Bamboos have maximum stiffness along the fibres and less stiffness transverse to the fibres. The variation of modulus ratio (E1/E2) for bamboo specimen is similar to the variation of modulus ratio of fibre reinforced composites.

III. TENSION TEST ON BAMBOO SPLINTS

D. International Standards

The fascinating properties and the uses attracted the engineering researchers quite late and various researchers started working on bamboo for its use as a structural material. The standards for determination of physical and mechanical properties of bamboo were not available till 2000. The International Organisation for Standardisation (ISO) issued draft of test procedures (ISO/TC165N314) and laboratory manual (ISO/TC165N315) on 28-11-2001. The final ISO standards for determination of physical and mechanical properties (ISO/TR 22157-1:2004) and the laboratory manual (ISO/TR 22157-2:2004) were published. The laboratory tests are carried as per ISO specifications.

ISO recommends that specimens shall be taken from the bottom part, middle part and top part of each culm. These specimens shall be marked with the letters B, M and T respectively. Tension tests parallel to fibre shall be made on specimens with one node, which shall be in the gauge section. This limitation is valid in the case of testing for commercial purposes; in the case of scientific research one is free to determine otherwise.

E. Preparation of Sample

A well seasoned bamboo of Dendrocalmus Strictus specie of bamboo from the farm 40 km away from Nagpur was selected for the tension test. The bamboo was seasoned and various 10 splint samples were prepared. The splints 15 mm wide and 50-70 cm long with 100 mm grip portion on either side were prepared. The portion of bamboo splint at the grip is curved and crushes while testing, hence it was necessary to prepare proper grip for the testing.

Figure 1. Tension Test Specimen

F. Investigation of various grip supports

The test specimen has curvature and that crushes when the grips are tightened. Three types of grips supports were tested. The grip curvature was filled with epoxy Araldite and sand mixture and the tests were conducted. The grip found leaving bond between the epoxy and the sample and the epoxy spilled out. The grip portion of the specimen was wrapped with binding wire and proved to be a good remedy against slipping of specimen from the grip. The grips as mentioned in ISO 22157 were also tested. Some samples were tried without grip support and were successful.

G. Test Procedure

The cross sections of the test specimen at three sections in a gauge length were measured and the mean cross section was considered for each test. Gauge length 5.64 x $(A)^{1/2}$ was marked and the sample was fixed in the Jaws of Universal Testing Machine. Various grip supports were used for the test. The extensometer with dial gauges on either sides was fixed to record the elongation at loading intervals. A load was applied at minimum range with constant rate of loading. The load and elongation reading at two gauges attached to extensometer were recorded. The mean value of extensometer readings was considered for plotting load elongation graph.

Figure 2. Tension Test on Bamboo Splint

The graph between load and elongation was plotted. The graph moves linearly upwards and moves to maximum value then it starts moving down fast. The bamboo splints are composed of longitudinal fibres and have good strength along the length however the bond between the longitudinal fibres is weak. Some samples split at failure in longitudinal direction. The splints take load linearly with uniform elongation upto certain limit. The bamboo tissues take load upto certain limit, this is the point of ultimate load. The engineering curve shows decline in load with increase in elongation after ultimate load, it indicates that the size of test sample at failure section reduces with rupture of tissues. At the end, the material ruptures completely and fails. When tested under electronic microscope, damages and anatomic rupture of tissues due to tensile force can be viewed.

Some samples are found breaking in knot and others due to splitting and pulling out fibre from knot. Knot was a weaker portion in some splints. Perhaps it's the anatomical structure and the extent of concentration of vascular bundles that decides the strength of the knot.

The load elongation behavior of splint sample under tension test is shown in Fig 3.

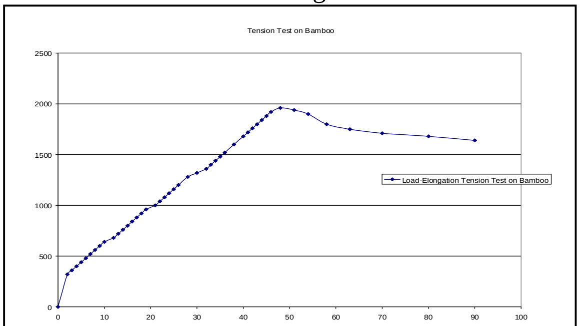

Figure 3. Load Elogation Curve

H. Test Results

The test results for various samples are recorded as below.

TABLE I. 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	Knot
b11/2	211.35	80	18560	87.82	Knot
b11/3	191.45	80	19600	102.38	Split & Knot
b11/4	176.86	80	17600	99.51	Knot
b11/5	253.93	90	26400	103.97	Split & Knot
b11/6	189.57	80	15300	80.71	Knot
b11/7	208.15	80	22400	107.61	Split & knot
b11/8	211.95	80	18600	87.76	Knot
b11/9	253.93	90	20700	81.52	Knot
b11/10	206.12	81	22320	108.29	Split & Knot

The average Ultimate Tensile Strength is found to be 95.81 MPa and standard deviation 9.93. The modulus of elasticity E is calculated from stress strain curve for sample b11/3 is 20050 MPa.

IV. CONCLUSION

Male Bamboo or Dendrocalmus Strictus has a good tensile strength and modulus of Elasticity. It can be used in structural members due to its high strength weight ratio. The specie can be used in RCC members with treatment to control water absorption and to increase the bond. The durability analysis shall be done before employing it in important construction. Tensile strength of the bamboo shall be tested before designing structural members as it varies on soil condition, topography, water table, water absorption etc. However, the use of bamboo shall be encouraged by engineers and architects as it is a 'Green Material' for sustainable development.

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