International Journal of Scientific Research in Science, Engineering and Technology
Print ISSN: 2395-1990 | Online ISSN : 2394-4099 (www.ijsrset.com)
doi : https://doi.org/10.32628/IJSRSET2293184

Stress Wave Propagation in Bamboo Solid Bar

Rithik Manju P, Shreya Jennifer, Moula S H, Lokesha G, Mujeeb Pasha
Department of Mechanical Engineering, Vemana Institute of Technology, Bengaluru, Karnataka, India

ABSTRACT

Article Info
Volume 9, Issue 4
Page Number : 130-140
Publication Issue :
July-August-2022
Article History
Accepted : 01 July 2022
Published: 10 July 2022

Studies on stress waves in solids and liquids, and shock waves in gases are topics to the specialists in our country, find only in very few places in our engineering curriculum. This paper narrates stress wave propagation in solids (bamboo) in general and stresses in compression test using Universal Testing Machine. Theoretical fundamentals for studying stress waves in bars are briefed. The experimental stress-strain results for ball-bar impact on bamboo solid material were studied and discussed. Also uniaxial compression test was carried out on solid bamboo material.
Keywords: Stress Waves, Compression Test, Stress-Strain, Bamboo

I. INTRODUCTION

Stress is the internal resistance of a body to external forces applied on it. In case of an elastic body subjected to external impact, part of the body which is close to the point of application of load is highly stressed while the far end is not aware of the impact [1]. The implication is that the effect of impact gets conveyed from the point of impact of the load to the other segments of the solid body by stress waves.

A stress wave is form of acoustic wave that travels with a finite velocity in a solid body. The stress wave will undergo multiple reflections and eventually attain equilibrium after a certain interval of time, this phenomenon is known as Stress Wave Transmission and Reflections [2]. These disturbance waves created locally will be transmitted to remote areas through the body as well as over the surface and are known as body waves and stress waves respectively. Body waves are compressive-tensile stress waves and surface waves are shear waves.

A uniaxial compression test under quasi-static condition was carried out on solid bamboo material using universal testing machine. Experimental studies were done on five bamboo specimens. A maximum compression of about 18-25mm was applied. The area under the load versus displacement curve tells us the amount of energy absorbed. The respective yield stresses, ultimate stresses and compression strength was calculated and tabulated for the bamboo material.

The material and methods used and some basic theoretical equations used to find the properties of the material were explained in this paper. Experiments were performed and results so obtained are described and discussed.

II. METHODS AND MATERIAL

Bamboo is a natural material which grows abundantly in the tropical countries. It is an anisotropic and heterogeneous material due to the structure composed of lignin matrix reinforced with fibres aligned in the longitudinal direction of the culm and therefore its properties vary at every point [4]. It is of two types, hollow bamboo and solid bamboo. The material used for this experiment is solid Bamboo. It is one of the oldest construction and building material used with vast range of functions and applications like domestic household products, agricultural and industrial use.

An attempt was made in this paper to study the stress waves and to characterize the mechanical property of solid bamboo bar. The method used to study the stress waves and to characterize the properties of the bamboo material are impact of ball-bar on the solid bamboo bar of 1000mm length and diameter 20mm and compression test on solid bamboo bar of length 29mm and diameter 24mm using Universal Testing Machine.

III. RESULTS AND DISCUSSION

a. Compression Test

The case of a solid bamboo bar being compressed is shown in Figure 1.

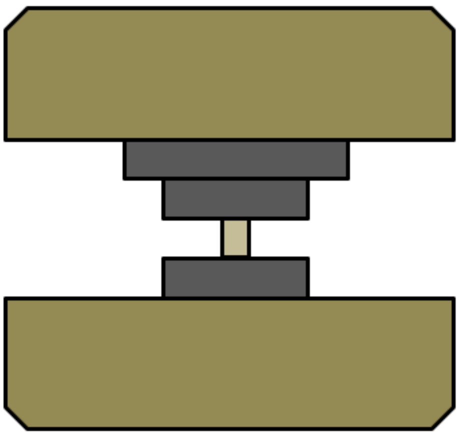

Figure 1. Schematic of bamboo compression test

Tests were carried out using an electronic universal testing machine of 400kN capacity. Specimens were placed on the bottom plate of the machine. Compression was caused by bringing the crosshead down on the specimen in a velocity control mode at a constant crosshead speed of 2mm/min. The experimental parameters such as the crosshead speed, specimen dimensions were input into the computer before start of each test. Loads and displacements measured with the transducers was fitted into the UTM and continuous load versus displacement data is obtained. The data is streamed into a computer which provided real time load - displacement curves. Experimental setup of bamboo for compression test is shown in Figure 2.

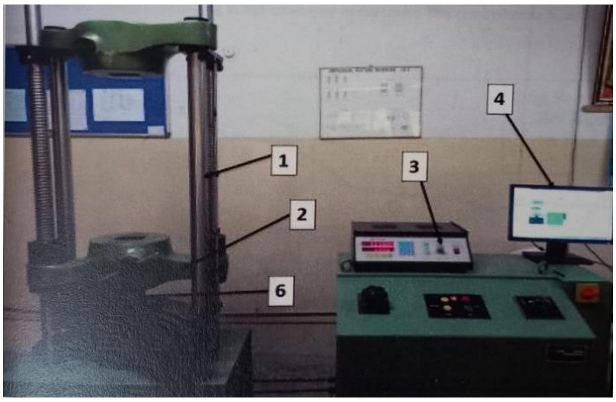

Figure 2. Universal Testing Machine
1) Machine frame 2) Cross head 3) Servo control 4) Desktop 5) Computer control 6) Specimen

The specimens were prepared and polished to be free of dents, nicks and scratches. The solid bamboo bars were cut into the required length of around diameter 24mm and length 29mm. The formula's used for calculating are same as the ball-bar impact test. Experimental studies on solid bamboo bar without nodes for five end preparations subjected to uniaxial, quasi-static compressive loads are reported and discussed. The formula's used to calculate the stress and strain of the material are as the same as of the ball-bar impact test and equation (3) and (4) are used.

Figure 3. Specimen before compression test

Figure 4. Specimen after compression test

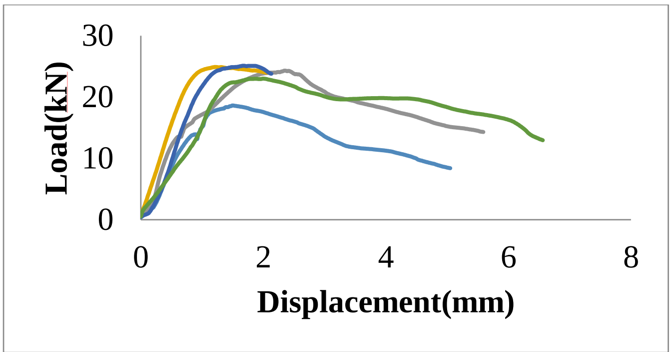

Figure 5. Comparative Load – Displacement curves under uniaxial compression

A typical load versus displacement curve obtained during compression of the specimens is shown in Figure 5. The curve shows a gradual linear increase up to a certain point which is the elastic zone. The highest load point defined as the peak point is around 25kN as seen in the graph. The maximum displacement for the above graph is around 6 - 7mm. The specimen then develops an inverted bulge and several cracks running axially is observed. There were many circumferential delaminated strips curling outwards. The area under load versus displacement graph gives us the amount of energy absorbed during the process.

The test was stopped at a compression load of about 18 – 25mm. From Figure 3 and Figure 4 it is seen that there are many circumferential delaminated strips curling outwards. There is a circumferential crack separating the outer and inner zones. The crushing, deformation and fractures start from the top face in some specimens and from bottom face in some others. The ends move outwards and the central zone bows inside. The material in the deforming zone in the periphery is seen to delaminate, crack (axially) curl and bend outwards.

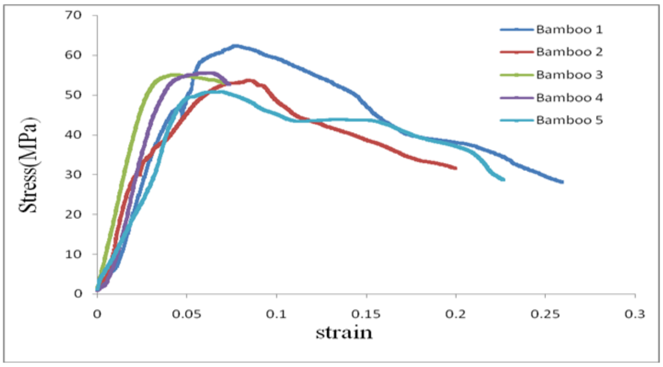

Figure 6. Strain-strain curves for series of specimens

Figure 6 shows the stress-strain curves for a series of specimens. The highest ultimate stress is around 62.32 N/mm^2 as seen from the graph. The range of maximum strain or the fracture point from the graph is around 0 – 0.3. The physical form of the stress-strain curves, the magnitude, stiffness and strength are nominally same. The area under load versus displacement graph gives us the amount of energy absorbed during the process, which is obtained using the HM13 software and tabulated.

Table 1. Experimental results under uniaxial compression of bamboo

Specimen no.	Area of specimen (mm^2)	Yield Stress (N/mm^2)	Ultimate Stress (N/mm^2)	Energy absorbed (Joules)
Bamboo 1	298.768	46.6	62.32	64.125
Bamboo 2	452.571	30	53.69	99.169
Bamboo 3	452.571	31.29	55.01	40.593
Bamboo 4	452.571	32.57	55.46	37.651
Bamboo 5	452.571	30.18	50.82	115.228

b. Ball- Bar Impact

A spherical metal ball of diameter 30mm is coaxially impacting a solid bamboo bar at velocity 'v' which has quarter bridge strain gauges with 350Ω mounted on them is shown in Figure 7.

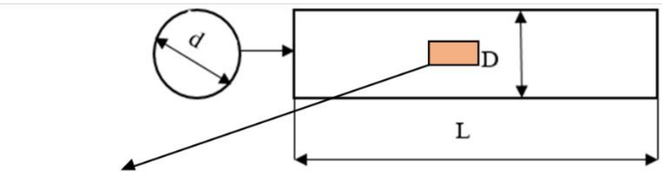

Figure 7. Schematic of Ball-Bar Impact

It comprises of test bar (solid bamboo), the striker ball, angle velocity measurement, strain gauges, strain gauge amplifier and oscilloscope. Strain gauges (quarter bridge configuration) is mounted on the test bar. A 30mm steel ball bearing is used as the impactor to strike the bar. The angle of release is noted and the height of the pivot from the centre of the ball provides the velocity of impact. A straight bar of solid bamboo of 20mm diameter with 1200mm length is considered. The setup has wooden plank base with number of vertical posts that helped to suspend the strain gauged test bar and the striker. To strike the bar with the ball, the latter that is hung by threads tied pivoted to the first two posts on the base was pulled, holding the threads and released.

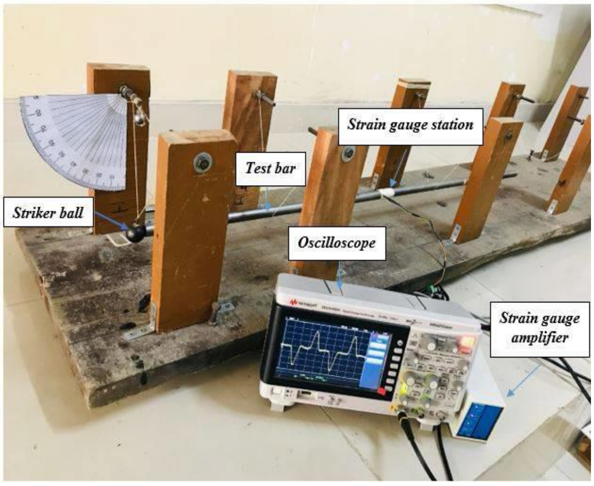

Figure 8. Experimental setup

A uniaxial compressive wave is introduced in the test bar by impacting the striker ball coaxially to the test bar. The stress wave propagates to specimen. The stress waves in the test bar are monitored by strain gauges mounted at the central section of the bars and amplified using a strain gauge amplifier. The output is recorded on a digital storage oscilloscope in the form of velocity versus time graph. This graph is later converted into stress versus strain graph. The formulas mentioned below were used for theoretical calculations.

- $V = \sqrt{2 * g * h}$ ---------------------- (1)

  Where, v = velocity of the ball

  g = acceleration due to gravity

  h = height from the equilibrium position

- h = $l - l * \cos\theta$ ----------------------- (2)

Where, h = height from the equilibrium position
l = length measured from ball center to hinge point
θ = drop angle of the suspended ball in degrees

- Strain, ε = $\frac{\Delta v}{V * Gain * G.F * B.F}$ ----------------------- (3)

Where, Δv = change in output voltage
V = velocity of the ball
Gain (G) = amplifier gain: 1000
Gauge factor (G.F): 2.0
Bridge factor (B.F): 2.6

- Stress, σ = ε * E ------------------------ (4)

Where, ε = strain
E = modulus of elasticity

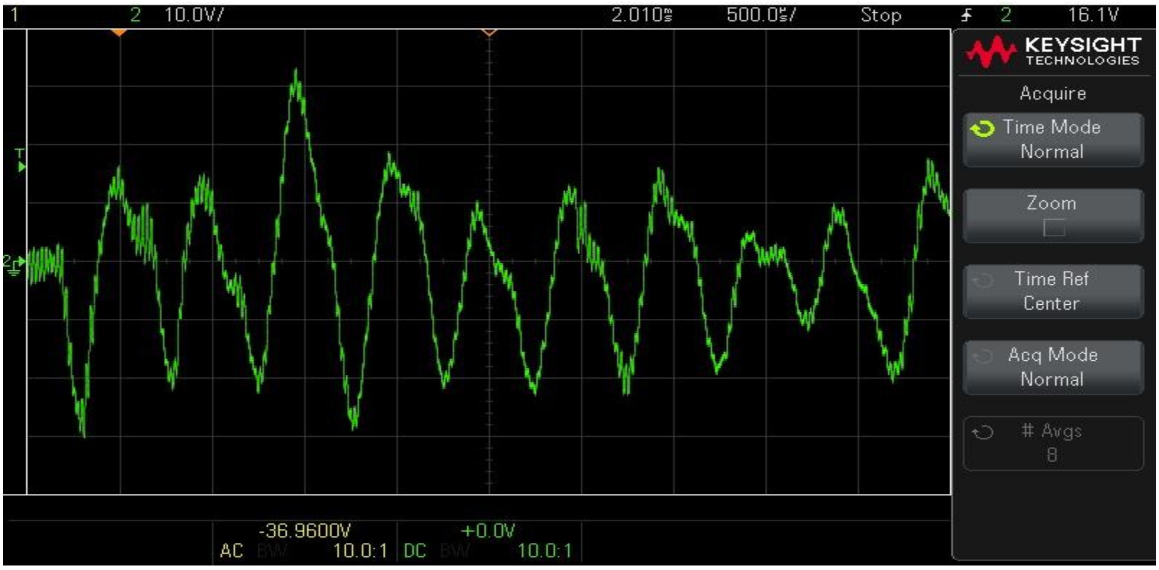

Figure 9. Experimental graph (voltage – time data from DSO)

In DSO (Figure 9), we will get voltage versus time graph. The ball is impacted on bamboo bar there will be no signal and only straight line will be seen in DSO. When the ball is impacted on the bamboo bar the wave starts to propagate inside the bar and once the waves passes through strain gauges it will pick the signal continuously. The waves are more disturbed because of the vibrations in the bamboo bar or it is because of the ball which has not been hit at the centre of the bar. The down side wave is incident waves and the upside wave is the reflected waves. These nature of waves will be continued for certain interval of time until it gets stilled.

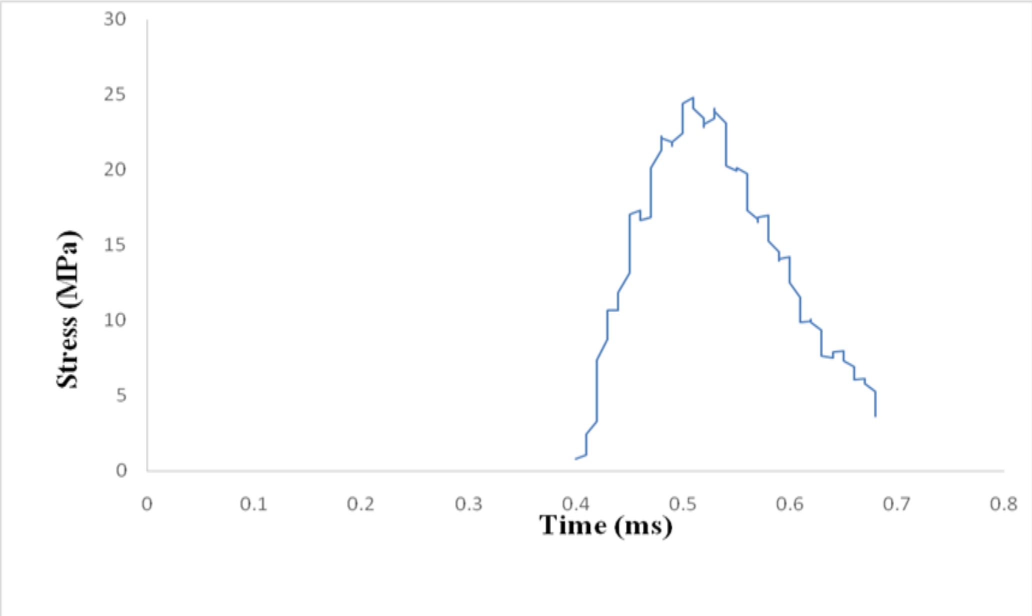

Figure 10. Analytical graph

Figure 10 shows us the stress versus time graph. It is only one wave form, Incident wave which is first picked by the strain gauge once the ball is impacted on the bamboo bar. The following table shows the results for the series and test for same angle and impact for the bamboo bar. It in seen that the results are consistent . The Young modulus obtained from the experimental were is 5GPa aggreable with literature[4].

Table 2. Experimental results for Ball-Bar impact

Test No.	Release angle (degree, θ)	Stress (MPa)	Strain	Young's modulus (GPa)
1	90	169.2	$3.384*10^{-3}$	5
2	90	171	$3.67*10^{-3}$	5
3	90	174.3	$3.8*10^{-3}$	5
4	90	172.7	$3.71*10^{-3}$	5
5	90	173.4	$3.76*10^{-3}$	5

IV.CONCLUSION

In the ball-bar impact test the values for stress, strain and Young's modulus were calculated for solid bamboo bar at same release angle (ɵ) and velocity of the striker ball. The stress versus strain graph was extracted from velocity versus time graph. In the compression test it is seen that none of the specimens tested failed in Euler buckling mode. This is because of the aspect ratio (length to diameter) was nominally kept as 1. The maximum load, the point at which the cracks begin to appear was noted down. The values of yield stress, ultimate stress and tensile strength was calculated and tabulated.

V. ACKNOWLEDEGMENT

The authors thanks Karnataka Reddy Jana Sangha for their continue support in the field of research. The authors thanks to Mr.Ashok Kumar C N for supporting in experimental work.

IV. REFERENCES

[1]. H. Kolsky, "Stress waves in solids", Dover publications Inc. 1952.

[2]. Sannisetti Dinesh, Syed Mujhtaba Mushaid, Syed Mustaqhim, Usama Abdul Hadi, " Stress wave propagation in metal bars using SHPB, VIT, Bangalore 2018-2019.

[3]. https://www.sciencedirect.com/science/article/abs/pii/S1359836818300544

[4]. Lokesha G Reddy, “Experimental and analytical study of a natural composite and mimicking the same”, VIT, Bangalore 2018.
[5]. W. R. Reeves and D Greenspan, ‘An analysis of stress wave propagation in slender bars using a discrete particle approach’, Butterworth & Co. Publishers, 1982.
[6]. Tarin Vanichayangkuranont, Kuntinee Maneeratana and Nuwong Chollacoop ‘Simulations of Stress Wave Propagation from Dynamic Loads’, Article 2005.
[7]. Edgar Vivek Mendonca, Prashant Basappa Shahapur, T. Y. Reddy, ‘Elementary Experimental Studies on Stress Wave Propagation in Bars’, AM Publications 2019.
[8]. Karl F.Graff “Wave Motion in Elastic Solids”, Clarendon Press – Oxford 1975.
[9]. W. Johnson, “Impact strength of materials”, Edward Arnold Ltd., London, UK, 1972
[10]. Tim Svensson and Filip Tell, ‘Stress wave propagation between different materials’ Master Thesis, 2015.

Cite this article as :

Rithik Manju P, Shreya Jennifer, Moula S H, Lokesha G, Mujeeb Pasha, "Stress Wave Propagation in Bamboo Solid Bar", International Journal of Scientific Research in Science, Engineering and Technology (IJSRSET), Online ISSN : 2394-4099, Print ISSN : 2395-1990, Volume 9 Issue 4, pp. 62-68, July-August 2022. Available at doi : https://doi.org/10.32628/IJSRSET2293184
Journal URL : https://ijsrset.com/IJSRSET2293184