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ORIGINAL ARTICLE

Failure Behavior and Failure Locations of Oxytenanthera Abyssinica Bamboo Culms under Bending Load

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Abstract: Bending failure modes in solid stem wood and solid culm bamboo varies depending on material and geometric properties. Solid culm cross-sections of *Oxythenantera Abyssinica* round bamboo resemble to wood, but are anatomically different in their mode of growth and tissue organization. The bending stress gradient and failure behavior has highly related with the culm internal voids termed as hollowness which depends on age of bamboo. Hollowness (k) refers the relative proportion of void volume to solid volume with in a culm. Full culm beam specimens with length of 3.5 m were subjected to bending under 4-point static loading according to ISO 22155. Pattern of vertical deflection varies depending on the maturity of the culm. A statistical and experimental results showed that, for K values between 12-15% a mixed mode of local buckling with a longitudinal shear splitting failure mode was resulted in 4-year age bamboo specimens with a slight (14 mm) shift from the shear center inducing large vertical deflection (142 mm) at midspan. A kink buckle and green stick modes were observed in 2-year and 3-year ages culms at failure point of 124 and 158mm at length 'L' (L/2.5 to L/4.5) from shear center with a k value 25-27% and 18-22% respectively.

Keywords: Hollowness ratio; failure behavior; failure location; bending stress; longitudinal shear; shear center

1 Introduction

Bamboo is an economical building material with a wide range of uses and a quick rate of growth. There are about 1500 species of bamboo, and they can grow in lowland, highland, tropical forests, and even desert areas. Few of the various varieties of bamboo are used in Ethiopia to build traditional homes. Ethiopia's native bamboo species, *Oxytenanthera Abyssinica* ("Lowland Bamboo") and *Yushania Alpina* ("Highland Bamboo"), cover about 14744.63 Km^2 of land [1]. The two-bamboo species grows in the country's northwestern and southern regions, making about 80 percent and 20 percent, respectively. Twenty additional varieties of bamboo have been introduced domestically [2]. Bamboo, in its round form, is to be characterized as a pole and its dimensional characteristics should also be considered in the process of characterization. Diameter and wall thickness of bamboo culm are important geometric characteristics that must be specified as part of a grading procedure in ISO 19624 (ISO, 2018) [3].

Material and geometrical characteristics of stemmed plants and solid bamboo culm greatly

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influences its mechanical properties and bending failure modes. The material properties of the culm depend on the fiber density and distribution along the culm affecting both tensile and compressive and tensile strength. In other study, compression capacity was correlated with fiber volume and wall thickness in a series of buckling analyses of tapered culms [4]. The geometrical characteristics depend on the dimensional characteristics of the culm and its maturity with age [5]. Common reasons for failure of bamboo pole include the size of the members, the geometry of the structural systems, and inadequate arrangement [6]. Due to the highly varied nature of natural structural elements, the standard techniques of structural testing and design for manufactured components have come under scrutiny. Furthermore, the failure to precisely quantify this variability may result in problems like stress concentrations, unsatisfactory building tolerances, and other aspects that may impair the durability and dependability of a structure [7].

In fully tubular bamboo culms like Guada type, consisting of thin culm wall, when subjected to three-point bending loads, the failure locations are near to the either support due inability of the thin culm wall to resist shear effect [8]. Four-point loading loads are preferable to minimize this effect causing either of crushing of fibers or buckling of fibers in leading collapse of culm in the center [9]. The critical bending moment for three bamboo species, Moso, Guadua, and Kao Jue, was conducted through deriving analytical expressions to display bending failure maps. The critical bending moment is shown in the failure maps as a function of shape factor, which is calculated from the ratio of external diameter to thickness. According to the study, Kao Jue is more likely to fail under longitudinal compression, while circumferential tension-induced splitting is the crucial failure mechanism for Moso. Guadua is capable of failing in either scenario [10].

Bending strength of solid culm bamboo can be equivalently predicted as its culm characteristic resembles to wood. Failure mechanism of solid stemmed wood member was characterized in three failure modes depending on the ratio of trunk wall thickness (t) and trunk radius (R), t/R. Brazier buckling (Mode I), tangential cracking followed by longitudinal splitting (Mode II) and conventional bending failure (Mode III) for $0 < t/R < 0.06$, $0.06 < t/R < 0.27$ and $0.27 < t/R < 1$, respectively [11]. In another recent research, parametric analysis was used to predict the bending strength of bamboo. Impacts of the inherent variability of bamboo poles was considered to ensure the structural reliability of those poles. In a number of experimental third-point bending tests supported by digitization techniques and mechanical testing on bamboo samples analytical evaluations were used to quantify the effects of three assumed causes of this nonlinearity. The study revealed that ovalization, local buckling, and bending (axial and longitudinal shear) stresses are not the main causes [12]. Kink buckling and green sticky failure were shown to be two prevalent failures [13].

When attempting to comprehend the flexural stiffness and failure locations of solid stemmed plants, the geometrical robustness character of these plants cannot be ignored. *O. abyssinica's* full culm consists of three distinct geometrical regions: a solid section, a semi-solid section, and a hollow section, with the proportions of each changing with age [14]. In past research, the compressive strength and bending stiffness of solid culm bamboo were compared to certain commercially imported trees. The middle region had a higher bending stiffness MoR (Modulus of Rupture) value of 191 N/mm^2 which decreased toward the top in 3-year-old culms [14]. The results are superior to Mao Jue and Kao Jue bamboo compressive and bending strengths having 79 and 117 N/mm^2 values, respectively [15].

Solid culm bamboo like *O.abyssinica* subjected to bending may show similar mode of failure as it owns comparable geometric structure of solid stems of trees. However, through age there is a varying geometrical characteristic influencing failure locations and failure modes. External diameter and wall thickness of the culm are related to the internal volume of void termed as 'hollowness'. Hence, the study examines the culm failure location and failure behavior under bending loads dependent on the hollowness of the culm.

2 Material Description

2.1 Culm geometry and Effects on Mechanical Properties

The modulus values and the corresponding method to obtain it those values differ from species to species [16]. The National Building Code of India [17] , categorizes 16 species of Indian bamboo into three groups based on flexural behaviors (modulus of rupture and flexural modulus of elasticity. According to the study report by Correal D and Arbeláez C [18], the compressive modulus of G. angustifolia increased along 15 m lengths from 16 to 17.9 GPa (an increase of 10%), but no similar increase in modulus was observed when the culm was bent over five meters 17.2 GPa at the bottom, middle, and top locations). On the other hand, over 13 m lengths of Moso bamboo, there was an increase in tensile modulus, roughly 50% (from approximately 11.3 to 17.3 GPa) as examined by Amada, et al. [19]. In order to evaluate geometric properties without using more complicated non-destructive procedures, it may be possible to relate easily measured geometric properties, such as diameter and internode length, to culm wall thickness It has been suggested to create a uniform system for grading full-culm bamboo for structural application [20]. As a result, various strategies must be devised to predict the flexural strength of bamboo because the geometric properties of bamboo depend on the species type of bamboo.

Table 1. Properties of Ethiopian Indigenous Bamboo

Culm Properties	Oxythenatera Abyssinica	Yushania Alpina
Max. height	Up to 9 m	Up to 16.75 m
Bottom Culm diameter	4-10 cm	10-12.7 cm
Thickness of wall	1.5-3 cm	2-5 cm
Modulus of Elasticity (MoE)	13,052 Nm^4/mm^2	4138 Nm^4/mm^2
Modulus of Rupture (MoR)	190 Nm^4/mm^2	58 Nm^4/mm^2

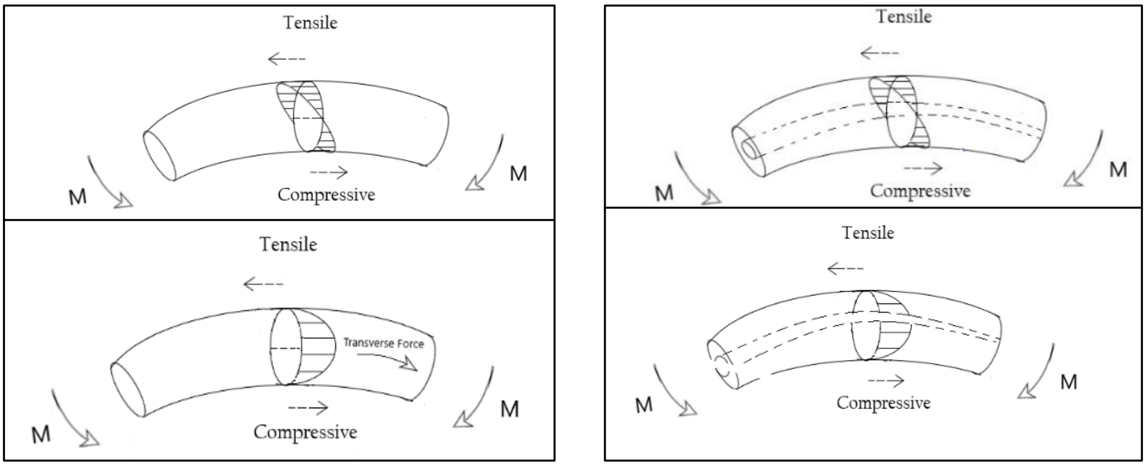
The bamboo species *O. Abyssinica* has thin hollows on the upper sections and thick solid sections in the bottom and middle. The solid filler has thicker cells with secondary growth, cellulose content, and cellulose crystallinity [21]. The outer shell (rind) of the bamboo, *O. abyssinica*, is the sclerema, a stiff component that makes the culm a more resistant and ductile material. The center is a foam-like, parenchymatous, compliant material. Bamboo has a sclerema on the outside, which makes the culm more durable and enables bamboo to be a ductile material. Along the culm, the density decreases from top to bottom while increasing from the outer to the inner core. Density and mechanical characteristics, including stiffness, have a positive relationship [22]. As referred in tab.1 below, *O. abyssinica* bamboo culms have lower diameter and wall thickness values compared to other indigenous specie Yushania Alpina bamboo in Ethiopia. However, it has a superior MoE and MoR values, which a material needs to contain to be utilized as structural member, **Table 1**.

2.3 Failure Behavior in solid stemmed culms

The failure behavior of wood and solid stemmed bamboo differs depending on the Material properties in wood including the density, the grain structure matters, and in bamboo the volume of core and the density of parenchyma cells. The bending stress tends to fail flexural members due to the horizontal induced shear stress, as the grain does not provide strong resistance to shear along the grain lines. In addition to material properties, the member geometrical properties like thickness of wall in tubular section is important parameter to predict the failure mode. The extent and form of the circular beam cross section caused variations in the magnitude of the bending moment at different points along the flexural member. The bending moment is maximum close to the support point where the thinner, hollow part is positioned, and it increases linearly in magnitude to the other end of the beam. Shear failure frequently happened along the horizontal centroidal axis in tubular sections causing the member to create longitudinal splitting [23]. Moreover, in solid culms of thin or thick walls, the hollowness ratio, or the ratio of rind thickness to stem diameter, influences how that culm's would fail [24].

The most frequent causes of failure in hollow culm bamboo members subjected to flexural loads are splitting and longitudinal shear failures. Kinking or local compressive buckling failures also involved in the buckling of groups of fibers within solid culm rather than the entire length. Local buckling in hollow is prevented by its nodes as nodes provide transverse reinforcement. Such stems have often developed to be septate, where diaphragms at nodes act to restrain the wall against this form of failure [21].

Failure location in stems mainly at critical section when there are changes in cellulose micro-fibril angle, physical and geometrical properties inducing a stress gradient at the interface. Failure could happen at nodes or internodes when subjected to axial and bending stresses Thick-walled culms with high density cross-section – a green sticky failure mode becomes more common on the tensile face due to the higher horizontal shear stress producing transverse cracks than the bending stress as shown in **Fig. 1(**a). Thin-walled culms with low density cross-section**-** a kink and buckle failure modes on the compressive side will occur as the fiber cannot resist the bending stress shown in **Fig. 1(**b) adapted from Ennos and van Casteren [23].



(a) (b)

Fig. 1. Bending tress distribution: (a) Pure bending on solid culms and hollow culms; (b) Combined shear and transverse forces on solid culms hollow culms.

2.4 Stress Concentration

Stress concentration in bamboo culm sections is different from steel, plastic and concrete materials. Failure of timber and bamboo members subjected to bending will not take place in expected and the failure modes cannot be predicted using classical mechanics due the variations of densities and wall thicken throughout the culm. Researches showed that a progressive stress is observed from top to bottom forming fractures in flexural members of bamboo. Thin bamboo poles under bending load induces uneven stress distribution that leads to splits culms due to the weak lignin matrix and loss of tangential fibers. Moreover, Janssen (2000) investigated the mode of failure in hollow culms in is not fracture of the fibers but rather longitudinal splitting of the material due to fracture of the weaker lignin.

Buckling and bending capacity is related with hollowness ratio. Thin-walled sections with hollowness ratio less than 0.15 failed due to buckling when subjected to compressive or bending stresses [25]. However, thick-walled sections fail due to material yield or fracture [16]. Hence, the core provides buckling resistance under axial compression and resistance to kinking failure under bending load.

3. Materials and Method

A total samples of 72 full culm of *O.abyssinica* bamboo grown around 'Pawe' (North West part of Ethiopia) at the ages of 2, 3 and 4 were cut and air dried to attain a moisture content of 10-13% at Bahir Dar Institute of Technology, civil engineering lab rooms. The age of bamboo samples was estimated by field personnel who are acquainted with this bamboo species through visually inspecting color and sheaths in the culms. A longitudinal cross-section through center on 12 full culms were prepared from each age category to observe the geometrical properties of *O. abyssinica* bamboo. The full culm longitudinal sections consist of three distinct regions, solid section, semi-solid section, and hollow sections. The length of solid section varies with age, showing 2-2.5 meters in the 2-year age category while the length increases 2.3-3.4 meters for the age group of 3 and 4 year. A schematic diagram of geometric properties on cross-section is shown from the preliminary observation. **Fig. 2** depicts the cross and longitudinal section the bamboo culm. Based on the distinct longitudinal cross-sectional geometry of the culm, three categories of samples are prepared in the solid, semi-solid and hollow sections to conduct its flexural strength.

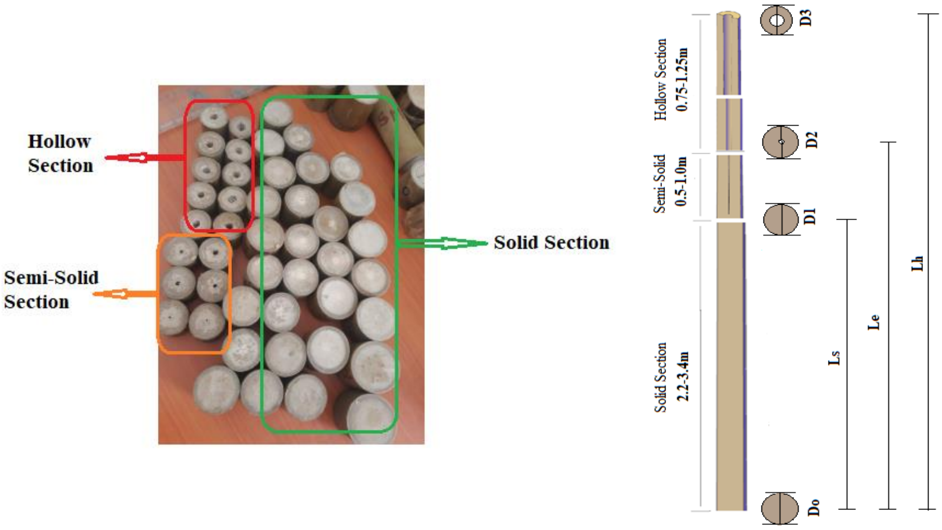
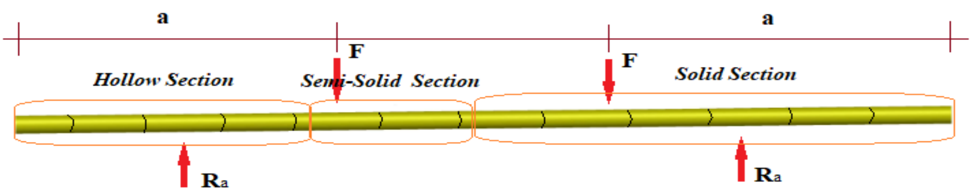


Fig. 2. Longitudinal and cross -section samples at different height of a culm.

Flexural test of full culm for the *O.abyssinica* bamboo specie under 4-point static loading will be conducted on the remaining samples. The load arrangement on the full culm specimen was according to ISO 22157 [3] where, the shear span is 10 times the culm diameter 'D'. The test setup in this experimental study uses the ratio of shear span to diameter of the culm. As depicted in **Fig. 3**, the shear span ratio '*a*' for full culms in the solid and semi-solid section was 4 and 8 respectively. A universal test machine with a load capacity 500 kN in Bahir Dar Institute of Technology Laboratory will be used to investigate the mechanical performances of the beams under bending. The rate of loading will be adjusted to 1 kN/min. The specimens will be subjected to load until failure with a loading speed of 5 mm/min.

(a) Test rigs



(b) Schematic diagram of different section on full culm

Fig. 3. Test rigs and Schematic diagram of different section on full culm.

There are three dependent test variables selected to conduct in this study, the hollowness of the culm, failure location and failure behaviors depending on the maturity of the culm. The hollowness '*k*' refers the relative proportion of void volume to solid volume with in a culm depends on culm geometry and relative proportion of solid, semisolid and hollow section (L_s, L_e and L_h) as shown in **Fig. 4**. The study investigates age wise relative percentage of hollowness and the resulting failure type and location on a 3.5 beam culm subjected to pure bending.

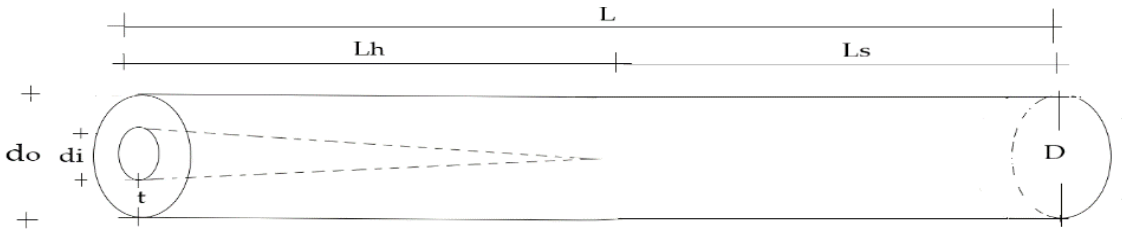


Fig. 4. Schematic diagram to estimate void volume of full culm.

Where V_t= total culm volume, V_v= void volume inside core, do, outside diameter, di, inside diameter, L total length, L_s= Length of solid section, L_h= length of hollow section.

$$\text{Hollowness } (k)=\frac{V_t-V_v}{V_t}\times 100 \quad (1)$$

3. Results and Discussion

3.1 Results

Table 2 shows the bending strength and deflection patterns of full culm bamboo at failure. The applied bending load induces different values of vertical deflection for samples of slenderness (t/D).

Table 2. Experimental test results

Age (years)	Sample Code	External Bottom Diameter (mm)	Wall thickness of top section (mm)	Slenderness	Solid Section Length (mm)	Hollowness Ratio (%)	Flexural Strength (MPa)	Maximum Deflection (mm)	Failure Location (mm) (From geometric center)
	SI1	42.23	15.4	0.36	2.35	90.91	89	60.5	154.8
	SI2	38.62	18.5	0.48	2.43	82.50	90.8	70.9	158.5
2	SI3	40.8	19.8	0.49	2.48	84.98	112.8	80.4	205.2
	SI4	40.21	21.02	0.52	2.46	89.10	108	76.6	209.5
	SI5	40.28	14.8	0.37	2.51	84.59	121.8	94.4	215.8
	SII1	58.29	17.02	0.29	2.48	79.24	114.2	89.2	254.2
	SII2	62.62	19	0.30	2.56	82.38	118.9	111.3	258
3	SII3	49.56	19	0.38	2.59	81.61	126.5	100.8	250.8
	SII4	53.4	16.8	0.31	2.61	75.48	129	112.5	242.5
	SII5	40.28	20.7	0.51	2.82	53.67	132.5	108.2	267.3
	SIII1	58.25	22.5	0.39	2.83	75.52	152.3	123	274.2
	SIII2	55.49	21.8	0.39	2.79	74.58	154.6	121.8	280.1
4	SIII3	58.64	19.8	0.34	2.96	69.67	162.2	134.2	278.2
	SIII4	64.57	20.4	0.32	3.02	69.53	167.5	138.4	290.3
	SIII5	62.42	20.6	0.33	2.86	76.25	165.9	134.9	288

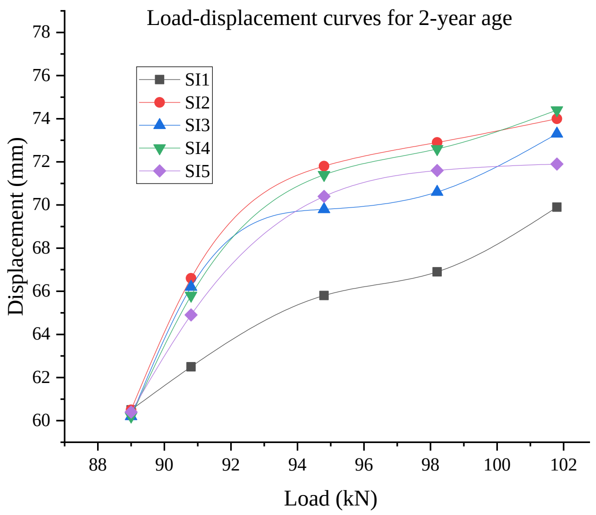
3.2 Discussion

3.2.1 Slenderness and Load-Displacement

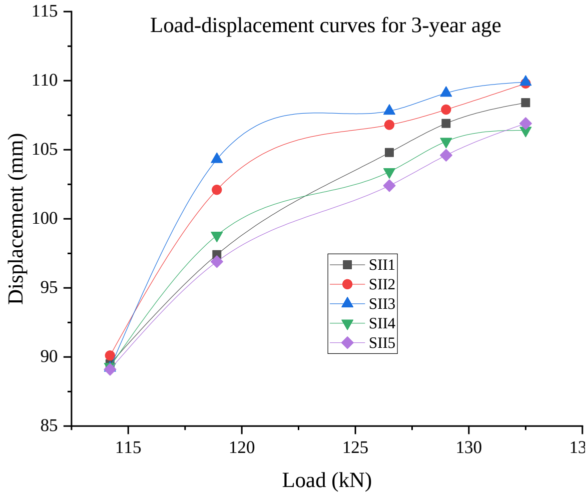
A range of slenderness 0.36 to 0.52 was observed for the samples SI1 to SI6 in 2-year age. Increased slenderness in sample SI4 = 0.52 and sample SI3 = 0.49 resulted a bending strength of 108 and 112 MPa with a corresponding vertical deflection value of 76.6 mm and 80.4 mm respectively shifted from geometric center towards the upper portion of beam. The sturdiness nature of the culm shifted moment of inertia to top part decreasing its section modulus from bottom to top.

For 3 years age sample category maximum slenderness of 0.51 is observed in specimen SII5 with a corresponding bending strength of 132.5 MPa. Due to the increase in age, there is no apparent difference of slenderness, but its bending strength resulted an average 18.4%. As bamboo age increases the outer parenchyma cell and the inside core becomes stronger and denser [26]. Moreover, there was 108.8 mm vertical deflection measured just before failure. The position of maximum deflection was 72 cm from the geometric center towards the upper portion of the culm. Maximum slenderness is recorded in specimen SII1 and SII2 under the age group of four year with a bending strength of 152.3 MPa and 154.6 MPa respectively. A maximum vertical deflection of 123 mm and 121.8 mm was resulted respectively shifting its failure position 70mm from geometric center towards the top portion.

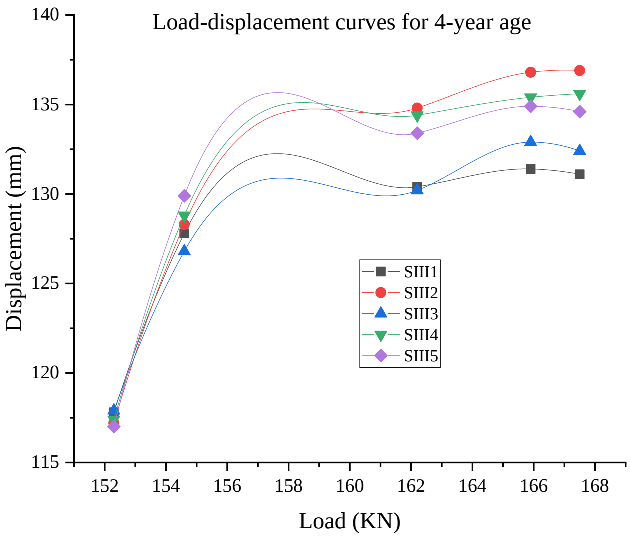
The load versus displacement curves for different age is shown in **Fig. 5** (a)-(c) with five replicates. Similar pattern of with lower deflection was initially observed for the age groups of 2- and 3-years specimens. The pattern of the curves in these age group specimens resembles to soft wood displacement patterns. For increasing load, 4-year specimens showed a linear increasing of displacement originating at lower slope but high strength and deflection at ultimate load as flexural members by estimating the regions of failure.



(a) SI1-SI5



(b) SII1-SII5



(c) SIII1-SIII5

Fig. 5. Load Vs Deflection offset from mid-span.

Age of bamboo influences not only the extent of deflection but also the failure location. Failure location of specimens within the same age group less varied than between the age groups. Two main reasons for varying failure location are the diameter and the internal cavity/hole distribution within a culm. Lower diameters on each age group resulted larger defection offsets at failure from mid-span. The average deflection offset location from mid-span for age 2, 3 and 4 years was 654 mm, 458 mm, and 389 mm respectively as shown in **Fig.6**. The structural engineer can systematically bundle *O. abyssinica* bamboo based on the maturity of its culms.

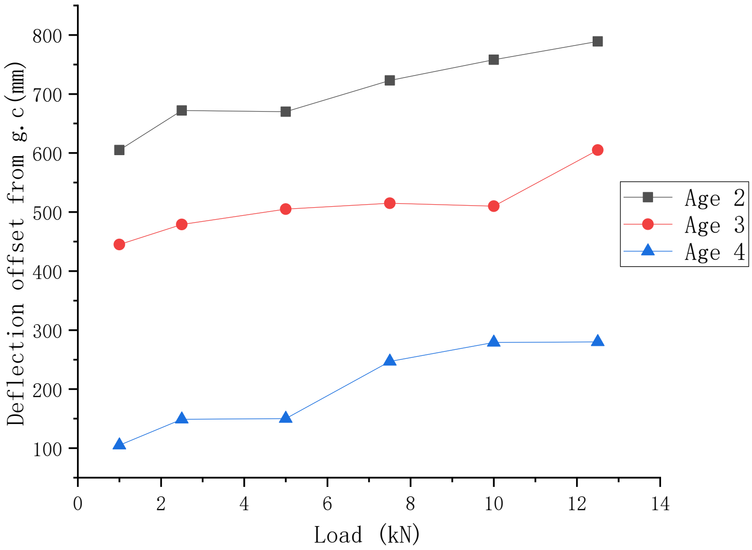
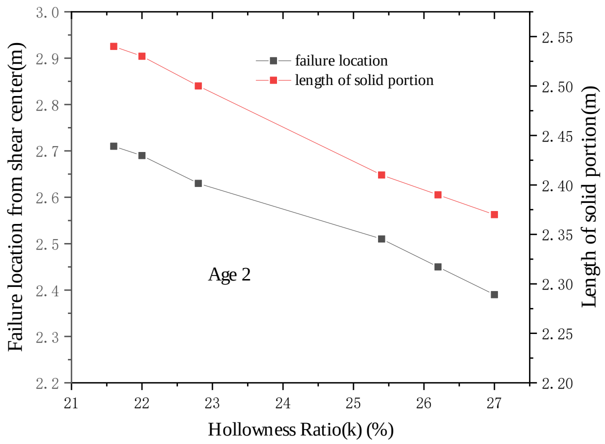


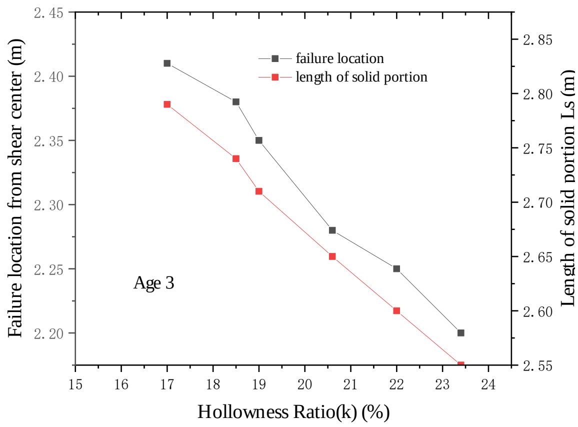
Fig. 6. Load Vs Deflection offset from mid-span.

3.2.2 Comparison of failure Location and solid length

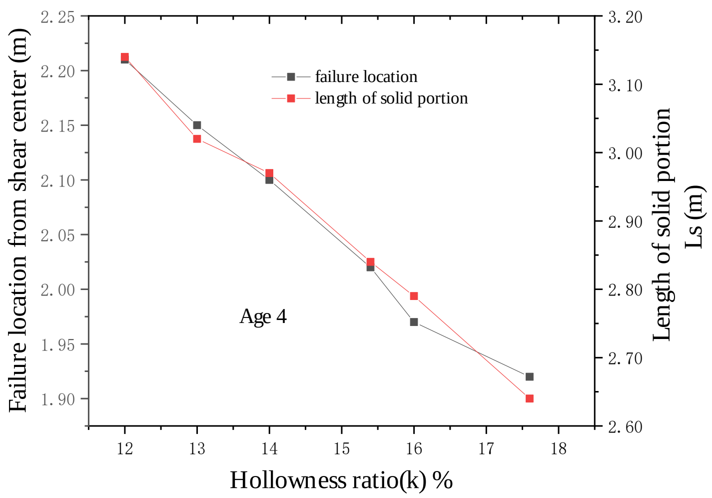
The graphs in **Fig. 7** (a)-(c) below shows the effect of hollowness of culms on failure locations, length of solid portion. The hollowness ratio 'k' varies with age and inversely related with failure location and length of solid portion along the bamboo culm. The greater slop in 2-year age specimens compared to 3-year and 4-year specimens showed that higher influence hollowness at lower age on both sloid length and failure locations. It is evident that culms containing higher hollowness, the length of solid portion becomes increasing, however its effect is more apparent in 2-year age compared to 3-year and 4-year specimens. The increased vertical gap between failure location and length of solid in 2-year age specimen indicates that shift the failure point on the culm is the increased shift towards the end or support compared to 3-year and 4-year age culms. Failure points in 4-year age specimens are much closer to the midspan compared to 2-year and 3-year age specimens. Hence maturity in *O.abyssinica* bamboo is not only indicator of higher solid length but also a balanced deflection wave nearly similar to steel and concrete beams is observed.



(a) Age 2



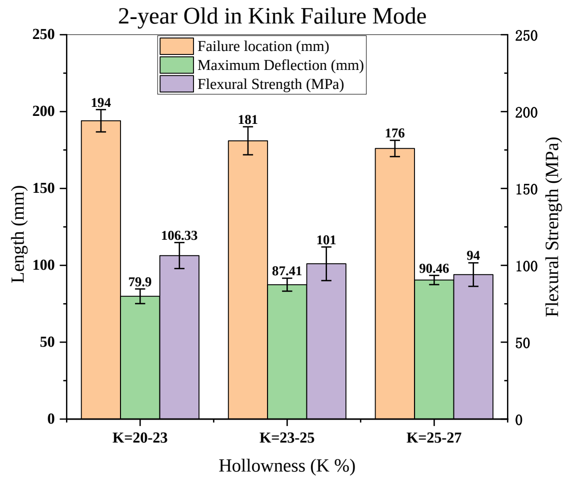
(b) Age 3



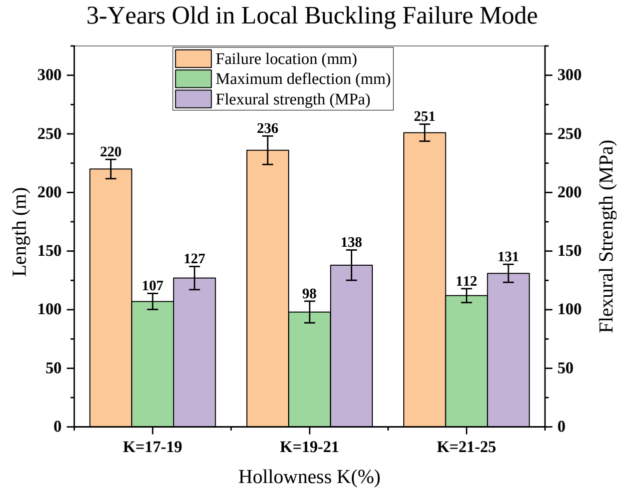
(c) Age 4

Fig. 7. Hollowness Vs Failure Length and Solid Length for age of (a) 2 years; (b) 3 year and (c) 4 years.

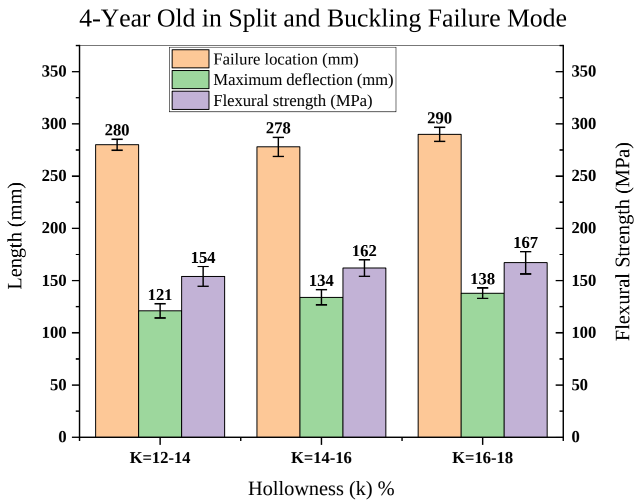
3.2.3 Comparison of Flexural Strength and Failure Behavior



(a) 2 years



(b) 3 year



(c) 4 years

Fig. 8. Hollowness of culms Vs Failure Strength, and Failure Modes

The graphs in **Fig. 8** (a)-(c) below shows the effect of hollowness of culms on flexural strength and maximum deflection, and failure modes among three age groups. It is apparent that as the age of bamboo increase its fiber strength and density becomes increased resulting a high bending strength. The bending strength in *O.abyssinica* full culm bamboo with varying hollowness across age becomes different. The variation in percentage of hollowness has lower effect on bending strength in lower ages than matured ones. As shown in **Fig. 8** (a), within specimens' age group, 2-year age specimens' the increased hollowness resulted a less influence on bending strength than 3-year and 4-year age specimens' group. Moreover, the effect of hollowness on extent of deflections becomes more across each age specimen' groups compared to within age group specimens. Additionally, from the standard errors shown in **Fig. 8** (b), 3-year age becomes more indicating higher variability compared to the 2-year and 3-year age specimens.

Statistical analysis on age wise failure behavior of specimen at the three-age group was analyzed. Three modes of failures as shown in **Table 3** was observed. The kink buckle, green stick and a mixed of local buckling with longitudinal shear failures were observed. The analysis shows that Kink buckle failure modes were dominantly observed in the compressive zone of 2-year age culms. Kink failure behavior in solid stem plants usually observed by high moisture content or in thin-walled sections [27]. Moreover, effect of less fiber strength and increasing k values are predominant cause of the kink failure mode. Low standard errors in 2-year age specimens proved that as height increases fiber density and strength of bamboo becomes decreased. Green sticky failure modes were resulted in 3-year age culms exhibiting a crack due to the transverse shear. Thick-walled stem with higher filler density in upper section leads to the green sticky failure modes as thick fiber wall bamboos have higher density than those which have thin wall thickness [6]. Combined effect of transverse shear at center and compressive action on top fibers induce a mixed failure mode of local buckling and longitudinal shear in four-year age culms. The presence of high-density parenchyma fiber in bamboo outer cross-section [23] proved this consistent with the study in lowland bamboo specious. Relatively lower standard errors are resulted in 3-year and 4-year age specimens ensuring that the occurrence of failure types depending on the hollowness ratio.

Table 3. Statistical Analysis

	Age (years)	L_h (m)	L_s (m)	k (%)	Failure location (mm)	Failure mode
Mean		0.80	2.44	84.55	194.68	
SD	2	0.21	0.04	4.65	5.50	Kink
Std Error		0.08	0.01	1.90	1.41	
Mean		54.16	18.87	0.35	255.71	
SD	3	7.60	1.55	0.07	7.89	Local Buckling
Std Error		0.10	0.63	0.03	0.22	
Mean		59.87	21.02	0.35	282.16	
SD	4	3.22	0.98	0.03	6.06	Split and buckling
Std Error		1.44	0.44	0.01	2.71	

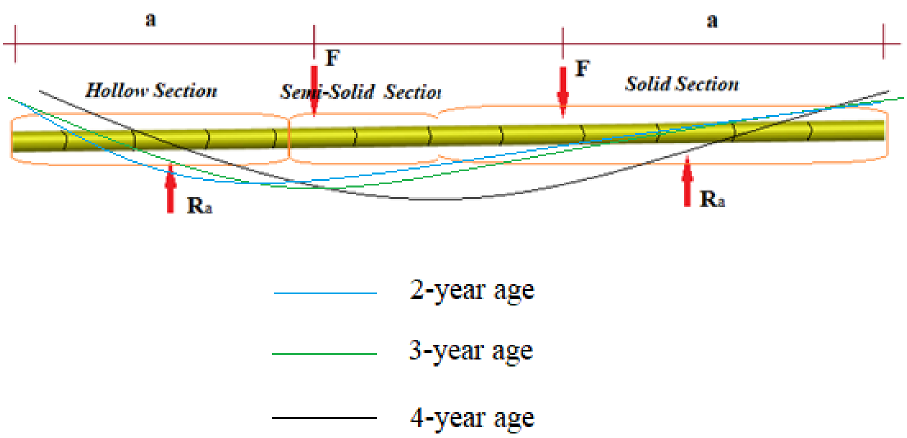


Fig. 9. Failure locations at different ages of the culm.

Furthermore, it can be seen that with in a sample beam length of 3.5 m, as the bending force increases, the vertical deflection is also increased shifting from shear center (solid section) to upper semi-solid and hollow sections in all specimens due to the culm geometry, size of bottom diameter, and proportion of each section region shown in **Fig. 9**. Due to the higher proportion of cavities in 2-year age, the hollow location is the critical region where failures had happened in kink buckle. However, due to the larger portion of solid regions in age 3-year and 4-year a less shifts of failure location from geometric center were observed with green stick and mixed mode of failures at semisolid and solid regions respectively.

4. Conclusions

The limit for deflection is often a governing criterion for ductile materials. However, for natural materials like bamboo and wood, knowledge on the failure locations and failure behavior along a culm is important parameters in order to provide a reasonable vertical support, like in the construction of slab decks. A longitudinal sectional view on the culm shows that there are three major sections that influence the bending strength of the culm. Due to the geometrical variation along the culm of *O. abyssinica* bamboo, the failure location and behavior varies depending on the maturity of the culm. The relative volume of voids (hollowness) represented by 'k' is a good predictor of solid section length and failure behavior. Different failure modes were at different failure locations along the beam were observed at different values of k. A 2-year age bamboo shows higher volume of voids a value of k =25-27%, exhibiting a kink buckle failure behavior with a maximum vertical deflection of 250 mm shifting 120 mm from shear center. Lower k values, k =18-22% three-year age bamboo culm resulted a green stick failure mode at maximum vertical deflection of 320 mm shifting the failure location 74 mm from shear center. Lowest value of k (12-15%) was observed in matured four-year culms. A mixed failure modes observed nearly at mid span with a maximum deflection of 428 mm and a maximum failure location at 14 mm shift from the shear center with similar balanced failure curves observed in steel beams.

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CRediT authorship contribution statement

Tadesse Mergiaw: Investigation, Formal analysis, Writing – original draft. **Denamo Addissie**: Supervision, review & editing. **James Goedert**: Supervision, review & editing.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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