MICROSCOPIC FAILURE OF *Dendrocalamus asper* (BULUH BETONG) LOADED IN TENSION

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Abstract: Microscopic failure in relation to strength of Dendrocalamus asper (Buluh Betong) loaded in tension parallel to grain at different culm portion and between internodes and nodes were investigated. The microscopic failure for internodes when loaded in tension occurred primarily at parenchyma region especially at radial direction. The vascular bundles in internodes are stronger compared to parenchyma and are reinforcing the structure in bamboo. The long and parallel orientation of fibers in internodes increased the resistance of vascular bundles to tension load and this led to the higher tension strength in internodes. At tangential direction for internodes, the failure occurred on both vascular bundles and parenchyma region. On the other hand, the microscopic failure for nodes occurred at both vascular bundles and parenchyma cells on both directions. This might be due to the uneven orientation of vascular bundles. The short, forked and crossed fibers in node had also reduced the strength and led to the lower tension strength in nodes. As a comparison, there is an increased in tension strength properties such as Maximum Tension Stress, Tension Stress at Proportional Limit and Tension Modulus of Elasticity from bottom to top portion due to the increment of fibers amount at the respective portion. Specimens with node are lower in tension strength due to the present of uneven orientation of vascular bundles as well as short, forked and crossed fibers, compared to the even orientation of vascular bundles, long and parallel orientation of fibers in internodes.

Keywords: Vascular bundles, Fibers, Parenchyma, Culm portion, Internode, Node

INTRODUCTION

Bamboo is recognized by their fast growth, high output and wide applications. The understanding of its strength and failure properties should be investigated in developing the applications of bamboo. Tension strength test is seldom conducted due to less application of tensile properties in bamboo. In many cases of tension test, tensile failure in bamboo does not occurred by pure tensile stress, but it fail by its low longitudinal shear strength and compression strength transversal to the fibers, a fact that causes considerable problems in grip [8, 9, 10]. Tension strength values are an essential aspect in direct tension and as a basic fundamental and general guide in the application of bamboo in structural or composites materials. The objectives of this research are: (i) to observe the general view of microscopic failure of *D. asper* loaded in tension and (ii) to determine tension strength values of small clear specimen of *D. asper*.

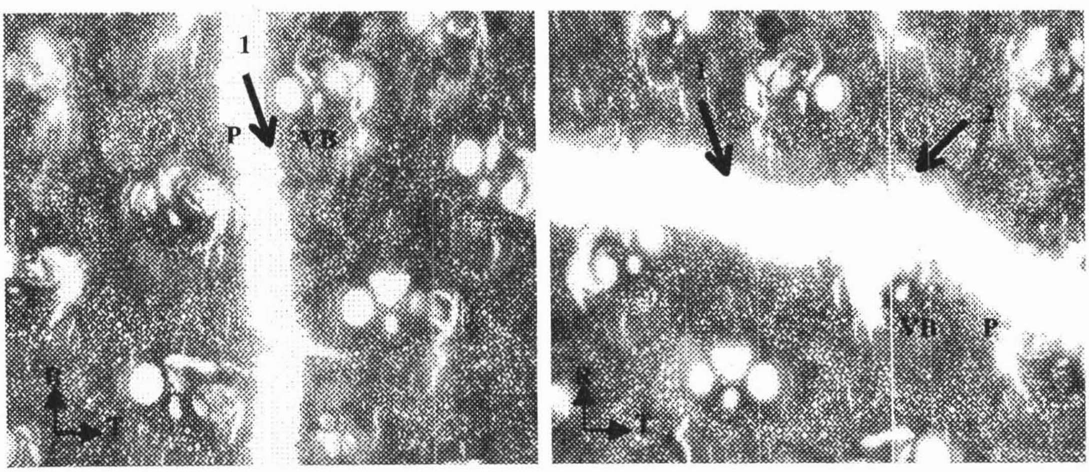
MATERIALS AND METHOD

Ten culms of 3-years old *D. asper* (Buloh Betong) species growing in Felda Mempaga at Bentong were selected. Each culm was then cut into three equal portions of bottom, middle and top. The specimen was taken from each portion with absence and presence of nodes at the middle section of specimens. Tension parallel to grain test was carried out based on ASTM D 143-94 [5] with adjustment of specimen dimension. The thickness and width of specimen at necked-down location was 5 mm and the length was 75 mm. Microscopic failures were observed in general at cross-section, radial and tangential view. Method described by Mansur [11] and Hoadley [13] was referred as a general guide in microscopic slide preparation. The microscopic failures were observed on Leica DMLS light microscope (4x objective lens). Tension strength values such as Maximum Tensile Stress ($T\sigma_{ml}$), Tensile Stress at Proportional Limit ($T\sigma_{pl}$) and Modulus of Elasticity (TE) were analyzed at different culm portion and between internode and nodes.

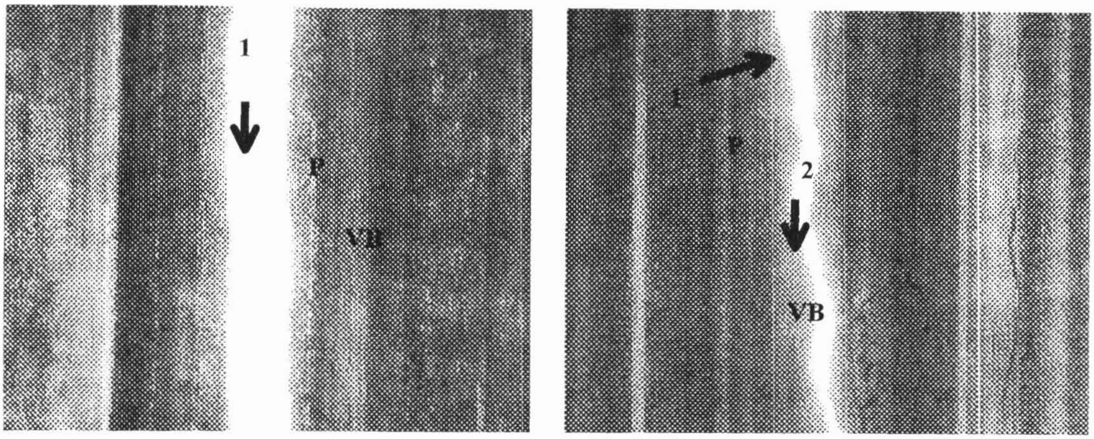
RESULTS AND DISCUSSIONS

The general views of microscopic failures for *D. asper* at internode and node are presented in Figure 1 and 2 respectively. In most occasions, the failures developed at the middle section of specimens. At internode of all portions, splitting failure occurred primarily at parenchyma region especially at radial direction, as shown in Figure 1 (A) and (C). The vascular bundles in internodes are stronger compared to parenchyma and are reinforcing the structure in bamboo. The long fibers [6] and axial orientation of vascular bundles in internodes [4, 14, 15] increased the resistance of vascular bundles to tension load and this led to the higher tension strength in internodes. Figure 3 shows that mean $T\sigma_{ml}$, $T\sigma_{pl}$ and TE value of internode are generally higher than node. The long fibers and axial orientation of vascular bundles in internode [4, 14, 15] contributed as load resistance and functioned as mechanical support [16] rather than parenchyma region that functioned as water and food strorage [1, 16]. At tangential direction for internodes of all portions, the splitting failure occurred on both vascular bundles and parenchyma region, as shown in Figure 1 (B) and (D).

In Figure 2, the splintering failure at nodes of all portions occurred at both vascular bundles and parenchyma cells on both directions. This is caused by the uneven orientation of vascular bundles [6, 14, 15]. The short, forked and crossed fibers in node [4, 6] had also reduced the strength of vascular bundles and led to the lower mean $T\sigma_{ml}$, $T\sigma_{pl}$ and TE value in nodes compared to internode, as shown in Figure 3. Liese (1992) and Liese and Yulong (1994) also reported the reduction of strength at node is based to the shorter, thicker and forked fibers and the randomly oriented vascular bundles in the nodal part [12].

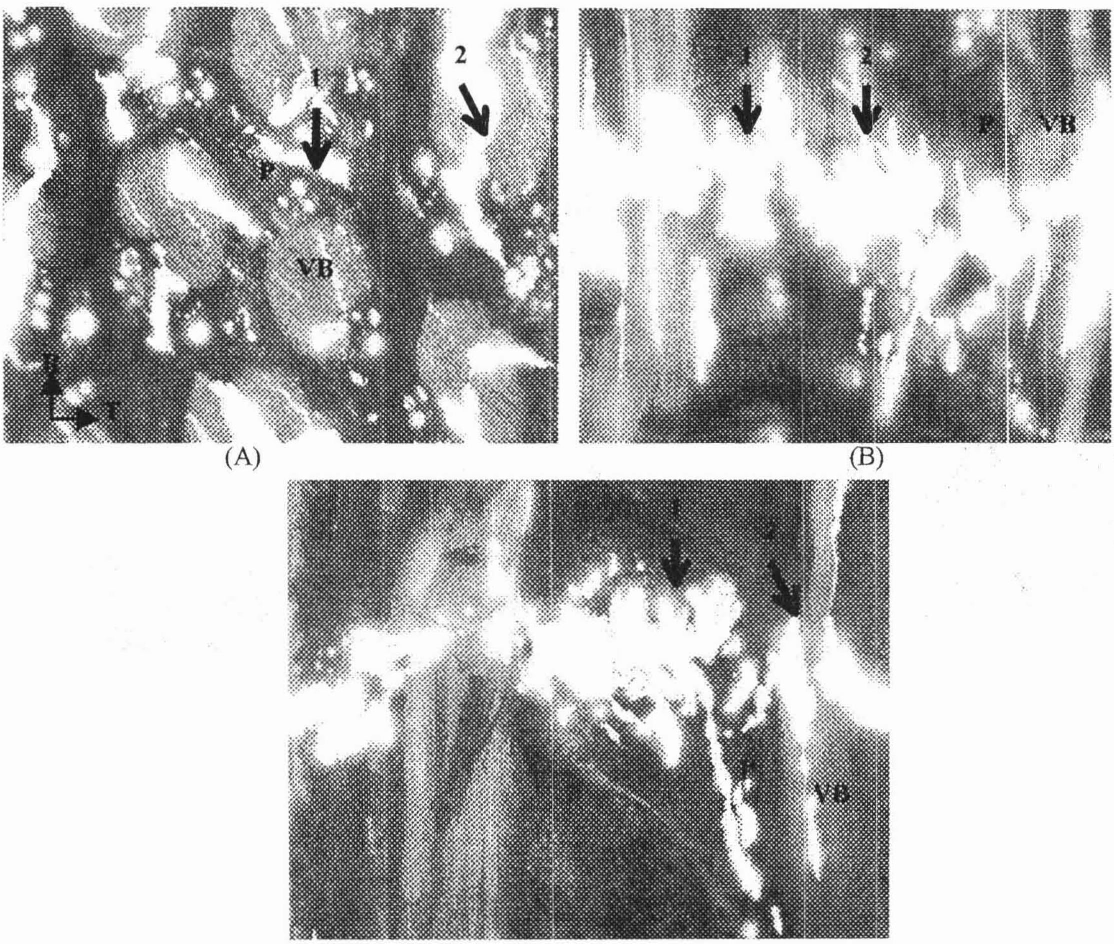


(A) (B)



(C) (D)

Figure 1: Microscopic failure for specimen of *D. asper* at internode: (A) cross-section view (failure at radial direction), (B) cross-section view (failure at tangential direction), (C) tangential view and (D) radial view (Note: 1 = parenchyma failure, 2 = vascular bundles failure, P = parenchyma, VB = vascular bundle, R = radial direction and T = tangential direction)



(A) (B)

(C)

Figure 2: Microscopic failure for specimen of *D. asper* at node: (A) cross-section view, (B) tangential view and (C) radial view (Note: 1 = parenchyma failure, 2 = vascular bundles failure, P = parenchyma, VB = vascular bundle, R = radial direction and T = tangential direction)

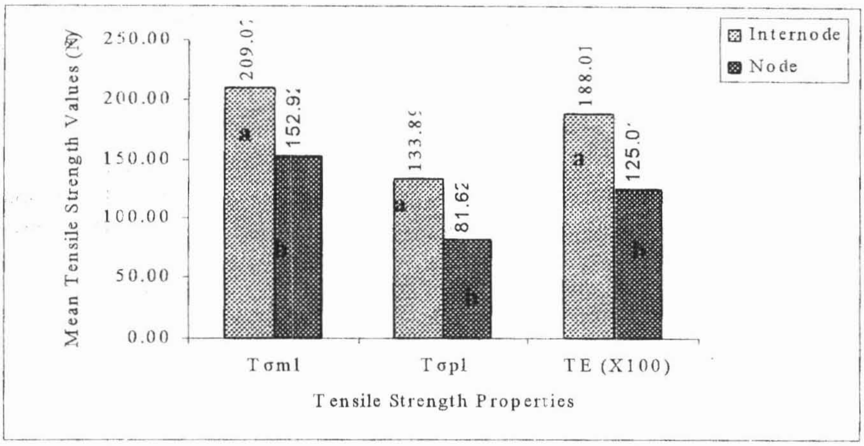


Figure 3: Mean $T\sigma_{ml}$, $T\sigma_{pl}$ and TE values between internode and node for *D. asper* (Note: Means with the same letter are not significantly different at $\alpha<0.01$)

Figure 4 shows the mean $T\sigma_{ml}$ $T\sigma_{pl}$ and TE value from bottom to top portion of *D. asper* culm. The values increased for the respective portions even they posses the same microscopic failure. This is associated with higher concentration of vascular bundles [2, 7, 9], fiber amount [3] and density [2] at top compared to bottom and middle portion.

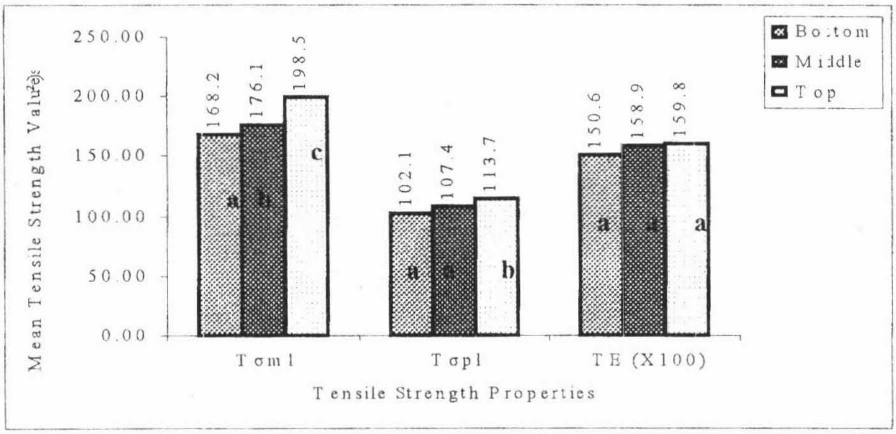


Figure 4: Mean $T\sigma_{ml}$, $T\sigma_{pl}$ and TE values at bottom, middle and top portion for *D. asper* (Note: Means with the same letter are not significantly different at $\alpha<0.01$)

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