Effects of node, internode and height position on the mechanical properties of *gigantochloa atroviolacea* bamboo

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Abstract

The development of the use of bamboo increased as non-wood material. The bamboo *Gigantochloa atroviolacea* is the most popular bamboo used as a construction material in some region of Indonesia. Some weakness bamboo are bamboo non-homogen material, sectional form non-prismatik, the straightness stems not the same, on the culms guiler node and a cross section in hollow. Effects of node, internode and height position on mechanical properties of bamboo were evaluated. In this article, the mechanical properties of *Gigantochloa atroviolacea* bamboo was studied (shear, compression and tensile). In this study, selected of the mechanical properties of bamboo culms, located at different height were investigated with ISO 22157 and ASTM. The mechanical properties of bamboo at node, internode and height position were tested in air dry condition. Base on the test results of all properties strength were increased from bottom to top. Analysis of variance (ANOVA) showed of the effects of node and internode of least significant difference (LSD) except tensile parallel to grain of significant. The effect of height position (bottom, middle and top) was significant except tensile strength perpendicular to grain of least significant difference (LSD). The interaction between node, internode and height position was least significant difference (LSD) except tensile parallel to grain of significant.

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1. Introduction

Currently, bamboo has become the most popular non-wood alternative. Bamboo is easily renewable, fast growth and the age of 3-5 years can be harvested [1]. Uniqueness of bamboo is a cylindrical, usually hollow, light in weight ratio and functionally-graded materials that demonstrates optimal characteristics for the truss elements, which are frequently used in civil construction [2]. To examine the effect of the nodes, samples were checked in such a way that internode and node samples were taken from neighbouring position along the circumference and test ran under the same circumstances. The results were showed that the tensile strength of the node region was only about 30% that the internode. There were also a significant difference in the value of the elastic modulus. Node elastic modulus was about 40% the internode’s [3]. The study of mechanical properties of bamboo indicated that nodes did not impart any negative effects on tensile strength, bending strength and compressive strength parallel or transverse to grain [4]. Many factors were effected of mechanical properties of bamboo such as species and age, green or conditioned, moisture content, form and size of the specimen node or internode, position along the culm, testing speed and short or long-term loading [5].

This study was aimed to determine of mechanical properties of shear, compression, tensile parallel and perpendicular to grain. These properties were assessed in relation to node, internode and height position, so that influence level one known.

2. Introduction

2.1. Field sampling

Bamboo fresh been direct preserved by using borax-acid such 4 borax: 1 acid. Bamboo material retrieved from Yogyakarta region, Indonesia. Twenty four of Gigantochloaatroviolacea bamboo was extracted randomly from selected with diameters 70 to 90 mm. The bamboo length 6.5 m and culms were cut a height of about 50 cm above the ground level. Each culm was to length of 6 m and was later subdivided into three lengths corresponding to the bottom, middle and top portions. For the assessment of the mechanical properties, bamboos were evaluated using samples in the form of full-bamboo and split at 15% moisture content. The full-bamboo was used to a bamboo sample with node and internodia as location of cutting, Fig. 1.

Test samples for determination of moisture content will be prepared immediately before mechanical test. The form will be like a prism with 25 mm wide, 25 mm high and as thick as the wall thickness [6], in Fig. 2. Specimens for mechanical properties is composed of the shear test, the compression test and the tensile test. Samples of shear and compression test were made with same model, which the specimen high was taken equal to the outer diameter and were made from the full-bamboo [6]. Setup tests for specimens of shear and compression were showed in Fig.3. and Fig. 4. Specimens of tensile parallel and perpendicular to grain were made from split bamboo. The form of specimen a tensile parallel of grain is created to follow ISO-22157 standard with node and internode bamboo, while it of specimens a tensile perpendicular of grain is made to follow ASTM standard [7] with all properties mechanical.
on node and internode were then divided into three group on bottom, middle and top. Setup tests for tensile parallel to grain were showed in Fig. 5, while its were showed for tensile perpendicular to grain in Fig. 6.

Fig. 2. Specimen moisture content

Fig. 3. Setup test of shear

Fig. 4. Setup test of compression

2.3. Statistical analysis

Analysis of variance (ANOVA) is a method to test the relationship between a dependent variable with one or more an independent variable [8]. In this study, the one dependent variable and two or three an independent variable is called two way ANOVA. The data were analysed using the Statistical Package Social Science version 15 (SPSS 15). Analysis of two way ANOVA was used to determine of the effects of node, internode and height position of mechanical properties of bamboo culms. The significance value in the calculation smaller than probability 5% (sig. < 0.05) is called significant (*), while the significance value in the calculation larger than probability 5% (sig. > 0.05) is called least significant difference (LSD). Effects were reviewed in analysis of two way ANOVA as main and interaction variables. The independent variable of F1 was a variable of node and internode sections while the independent variable of F2 was a variables of height position at bottom, middle and top sections. The main effects
were an independent variables of F1 and F2, while the interaction effect was a combination of the independent variable of F1 and F2 respectively.

3. Results and discussions

From 24 bamboo specimens without node, the moisture content was found that the specimens varied from 12.94% to 16.16% with an average of 14.59%. The requirement as building material was limited at 15% moisture content [9]. Table 1 and Table 2 show the average mechanical properties obtained from 3 repetition research mechanical properties. The average values of shear strength on internode and node of mechanical properties were 7.77 MPa and 7.60 MPa from 24 bamboo specimens with 12 node specimens and 12 internode specimens, in Tabel 1. The shear strength of samples with internode and node was almost similar. The average values of shear strength were observed of the node and internode at bottom, middle and top respectively, in Fig. 3. Results analysis of variance (ANOVA) performed for the data of mechanical properties in relationship of the effects of node and internode at height position were shown in Table 2. The results analysis of variance (ANOVA) of shear strength of F1, F2 and F1*F2 were 0.03, 15.24 and 0.01 respectively, which values significantly were least significant difference (LSD), significant (*) and least significant difference (LSD). Variable of node and internode (F1) was least significant difference (LSD) against shear strength, so in research of shear strength may only view node or internode section. Variable F2 of height position (bottom, middle, top) was significant (*) against shear strength, so in research of shear strength should be reviewed as a complete of variable height position on bottom, middle and top section. Variable of interaction (F1*F2) was least significant difference (LSD) against shear strength, so in research of shear strength may only view of variable node or internode on bottom, middle and top section.

The average values of tensile parallel to grain strengths from 24 bamboo samples with 12 samples internode and 12 samples node were 254.30 and 109.88 MPa, while the tensile strengths perpendicular to grain from 24 bamboo samples with 12 internode samples and 12 node samples were 2.73 and 2.74 MPa respectively. The strengths of samples of tensile parallel to grain with node show significant difference, while its were for tensile perpendicular to grain of almost similar. The differences of the tensile strength parallel and perpendicular to grain on bottom, middle and top section were shown in Fig. 8 and Fig. 9.

Base on analysis of variance (ANOVA) computed F1, F2 and F1*F2 value, the independent variables for tensile strength parallel to grain were 646.094, 19.479 and 5.270 respectively, while the independent variables for tensile strength perpendicular to grain were 0.005, 3.398 and 0.016 respectively. The significantly different of the independent variables of F1, F2 and F1*F2 for tensile strength parallel to grain was all significant (*), whereas the tensile strength perpendicular to grain was all least significant difference (LSD). In other word, on determining of tensile strength parallel to grain should be reviewed as a complete against variable F1 (node and internode), F2
(height position on bottom, middle and top section) and $F_1*F_2$ (node and internode on bottom, middle and top section), while on determining of tensile strength perpendicular to grain may only review against variable $F_1$ (node or internode section), $F_2$ (bottom or middle or top section) and $F_1*F_2$ (node or internode on bottom, middle and top section). In other word, hypothesis of tensile strength parallel to grain same was rejected, but hypothesis of tensile strength to grain difference was accepted. Similarly hypothesis of tensile strength perpendicular to grain same was accepted, but hypothesis of tensile strength perpendicular to grain difference was rejected.

From 24 bamboo specimens for compression strength show 12 bamboo specimens with node and 12 bamboo specimens without node. The average values of compression strength in Table 1 showed on node and internode of 50.50 MPa and 52.27 MPa, whereby values differences on higt position at bottom, middle and top were showed in Fig. 10. Base on of analysis of variance (ANOVA) computed $F_1$, $F_2$ and $F_1*F_2$ value, the independent variable for compression strength were 1.62, 7.25 and 0.32 respectively. The significantly different of the independent variable of $F_1$, $F_2$ and $F_1*F_2$ for compression strength was least significant difference (LSD) for variable $F_1$, significant (*) for variable $F_2$ and least significant difference (LSD) for variable interaction $F_1*F_2$. Variable $F_1$ of node and internode was least significant difference (LSD) against compression strength, so research of compression strength may only view node or internode section. Variable $F_2$ of height position (bottom, middle, top) was significant (*) against compression strength, so research of compression strength should be reviewed as complete of height position on bottom, middle and top section. Variable interaction $F_1*F_2$ of node and internode on bottom, middle and top
section was least significant different (LSD) against compression strength, so research of compression strength may only view node or internode on bottom, middle and top section.

Fig. 9. The difference of tensile strength perpendicular to grain at bottom, middle and top.

Fig. 10. The difference of compression strength parallel to grain at bottom, middle and top.

Table 1  Mechanical properties of bamboo

| Character                          | Unit | Internode Samples | Internode Samples |
|-----------------------------------|------|-------------------|-------------------|
|                                   |      | Bottom | Middle | Top | Average | Bottom | Middle | Top | Average |
| Shear strength                    | MPa  | 7.20    | 7.52   | 8.58 | 7.77    | 7.12    | 7.53   | 8.14 | 7.60    |
| Tensile strength parallel to grain| Mpa  | 2.48    | 2.70   | 3.00 | 2.73    | 2.48    | 2.75   | 2.99 | 2.74    |
| Tensile strength perpendicular to grain | Mpa  | 2.48    | 2.70   | 3.00 | 2.73    | 2.48    | 2.75   | 2.99 | 2.74    |
| Compression strength              | MPa  | 48.77   | 50.90  | 51.82 | 50.50   | 48.90   | 52.30  | 55.60 | 52.27   |
Table 2  Influence of node, internode and height position of mechanical properties

| Character                      | Main effect | Analysis of ANOVA | Interaction effect |
|-------------------------------|-------------|-------------------|--------------------|
|                               | $F_1$      | Sig. $^{a,b,d}$   | $F_2$             | Sig.             | $F_1 \times F_2$ | Sig. $^{a,b,d}$ |
| Shear strength                | 0.03       | 0.87$^{a,d}$      | 15.24             | 0.00$^{*}$       | 0.01              | 1.00$^{a,d}$     |
| Tensile strength parallel to grain | 646.09    | 0.00$^{*}$        | 19.48             | 0.00$^{*}$       | 5.27              | 0.02$^{*}$       |
| Tensile strength perpendicular to grain | 0.001    | 0.94$^{a,d}$      | 3.40              | 0.06$^{a,d}$     | 0.02              | 0.98$^{a,d}$     |
| Compression strength          | 1.62       | 0.22$^{a,d}$      | 7.25              | 0.01$^{*}$       | 0.32              | 0.73$^{a,d}$     |

4. Conclusion

A study effects of node, internode and height position of Gigantochloaatroviolacea bamboo split and full-bamboo test configuration was evaluated. Mechanical properties of shear, compression, tensile parallel and perpendicular to grain strengths on node and internode increased from bottom to top. The strength on node and internode were almost similar of all mechanical properties, except tensile parallel to grain.

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