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The Effect of Variable Lateral Stress of Laminated Bamboo with Artificially Dent Surface on Mechanical Properties

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***Abstract*— Since many years ago bamboo has been used, in addition to wood, for structural components in rural areas due to easily growth and its short harvest time. The properties of laminated bamboo depend on many aspects, among others: quality of glue, lateral stresses during manufacture and roughness of bamboo lamina. This research used Bambusa Dendrocalamus Asper (local name: Bambu Petung) and aimed to determine the effect of artificial dented surface of the laminas on mechanical properties with variable lateral stresses. The dimensions and the types of the specimen were based on ISO 2004 standard. The age of bamboo specimens was 6 years and the lateral stresses were varied from 0 MPa to 2.5 MPa with 0.5 MPa interval. Physical properties of the specimen such as water content (humidity), specific gravity, were performed prior to the mechanical tests (tensile, compression, shear and flexural tests). Analysis of results was performed by statistical method, in addition to scanning electron microscopy for further inspection of microscopic deterioration.**

***Keywords*— Bamboo Lamina, Lateral Stress, Statistical Method, SEM**

I. Background

At this time the timber with good quality has been difficult to obtain, so the wood is increasingly rare for building construction. However, the wood will be needed because it has several advantages over the baton and steel. The advantages of wood of which have good mechanical properties, wherein the weight ratio of the power compared to a higher kind than concrete and steel in addition to approaching the renewable nature and aesthetics.

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Bamboo grows fast, easy to grow and does not require special maintenance. Bamboo with good quality can be harvested at the age ranges (3-5) years [1]. Bamboo with good quality can be harvested at the age ranges (3-4) years [2]. The advantages of laminated bamboo can be formed in a variety of sizes, better mechanical properties than the base material type of bamboo used [1].

Glue line damage to become laminated bamboo beams crack before its power reaches the maximum value. Bamboo blade in laminated bamboo beams are experiencing compression estimated damage to the fiber and therefore contribute to the strength and power of the glueline laminated bamboo beam.

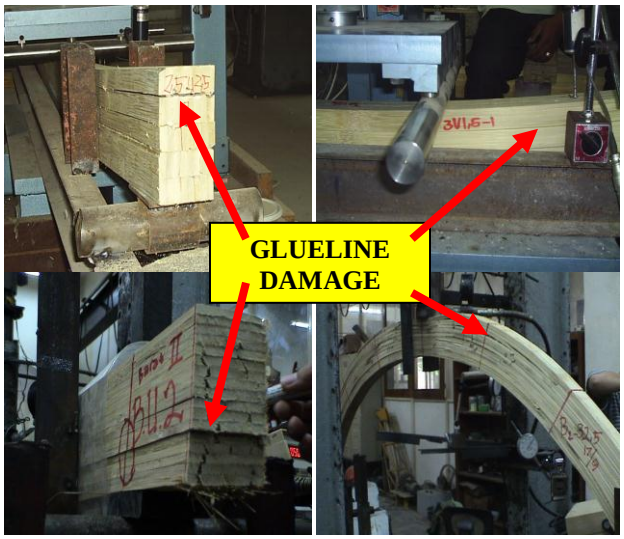

Figure 1. Bamboo Lamination Beam Glueline Damages

The study was conducted to determine the effect of pressure felt on physical and mechanical properties of bamboo. Pressure felts made on bamboo slats with pressure variations Felts 0 MPa, 1.5 MPa, 2 MPa and 2.5 MPa.

II. Literature Review

The influence of lateral stress on the shear strength of the beam clamp horizontally laminated bamboo Petung has been investigated by Oka [3]. Masrizal [4], conducted research on the effect of compression force MoR Petung Bamboo

laminated beams vertically. MOR maximum value obtained in advance of 1.3 MPa compression force s / d 1.6 MPa. Likewise, the influence of pressure on the shear strength of the beam clamp horizontally laminated bamboo Ampel has been investigated by Amirullah [2].

Ochi [5], conducted research the effect of tensile strength of bamboo fiber bamboo laminate applications using biodegradable-plastic resin thereby increasing the tensile strength and bamboo reaches 70% of the tensile strength without resin.

III. Research Method

The raw material is Bambusa Dendrocalamus asper. Making the preliminary test specimen to test the properties of physics and mechanics were based on ISO 2004 Standard and ASTM D143-2008.

Experimental tests performed on specimens with lateral stress variations. Testing the physical properties consist of water content and density, while testing the mechanical properties of bamboo consists of flexural strength, tensile strength, shear strength and compressive strength.

Figure 2. Specimen Manufacturing

Figure 3. Universal Testing Machine

TABLE I. SPECIMEN QUANTITY

No.	Testing Type	Without Lateral Stress	Lateral Stress Variations		
			1.5 MPa	2.0 MPa	2.5 MPa
1	Water Content	30	30	30	30
2	Specific Gravity	30	30	30	30
4	Compression Strengtt	30	30	30	30
5	Tensile Strength	30	30	30	30
6	Shear Strength	30	30	30	30
7	Flexural Strength	30	30	30	30
	Total Quantities	**180**	**180**	**180**	**180**

IV. Result and Discussion

The water content of lateral stress 0 MPa on average 12.95%. At a lateral stress 1.5 MPa the water content is an average of 12.81%. The water content of lateral stress 2 MPa is an average of 12.52%. And the water content of lateral stress 2.5 MPa average water content of 12.43%.

TABLE II. WATER CONTENT AND LATERAL STRESS PARTIAL CORRELATION

Control Variables		1,5 MPa	2 MPa	2,5 MPa	0 MPa
1,5 MPa	Correlation	1	0.624	0.428	0.602
	Significance (2-tailed)	.	0.054	0.217	0.066
	df	0	8	8	8
2 MPa	Correlation	0.624	1	0.157	0.327
	Significance (2-tailed)	0.054	.	0.666	0.357
	df	8	0	8	8
2,5 MPa	Correlation	0.428	0.157	1	0.611
	Significance (2-tailed)	0.217	0.666	.	0.061
	df	8	8	0	8
0 MPa	Correlation	0.602	0.327	0.611	1
	Significance (2-tailed)	0.066	0.357	0.061	.
	df	8	8	8	0

Specific gravity on lateral stress 0 MPa an average of 0.64 g/cm3. At lateral stress 1.5 MPa the value was an average density of 0.73 g/cm3. Density values with lateral stress 2 MPa is an average of 0.75 g/cm3. At lateral stress 2.5 MPa specific gravity value average of 0.78 g/cm3.

TABLE III. SPECIFIC GRAVITY AND LATERAL STRESS PARTIAL CORRELATION

Control Variables		1,5 MPa	2 MPa	2,5 MPa	0 MPa
1,5 MPa	Correlation	1	0.165	-0.193	0.314
	Significance (2-tailed)	.	0.65	0.593	0.376
	df	0	8	8	8
2 MPa	Correlation	0.165	1	0.221	0.378
	Significance (2-tailed)	0.65	.	0.54	0.282
	df	8	0	8	8
2,5 MPa	Correlation	-0.193	0.221	1	0.236
	Significance (2-tailed)	0.593	0.54	.	0.511
	df	8	8	0	8
0 MPa	Correlation	0.314	0.378	0.236	1
	Significance (2-tailed)	0.376	0.282	0.511	.
	df	8	8	8	0

Compressive strength bamboo with 0 MPa Lateral stress were 45.80 MPa. At lateral stress 1.5 MPa had a strong average 70.08. At lateral stress 2 MPa the compressive strength were an average 54.65 MPa. Lateral stress at 2.5 MPa averaged 51.15 MPa.

TABLE IV. COMPRESSION STRENGTH AND LATERAL STRESS PARTIAL CORRELATION

Control Variables		1,5 MPa	2 MPa	2,5 MPa	0 MPa
1,5 MPa	Correlation	1	0.115	0.12	-0.285
	Significance (2-tailed)	.	0.547	0.527	0.127
	df	0	28	28	28
2 MPa	Correlation	0.115	1	0.082	-0.218
	Significance (2-tailed)	0.547	.	0.665	0.248
	df	28	0	28	28
2,5 MPa	Correlation	0.12	0.082	1	0.162
	Significance (2-tailed)	0.527	0.665	.	0.391
	df	28	28	0	28
0 MPa	Correlation	-0.285	-0.218	0.162	1
	Significance (2-tailed)	0.127	0.248	0.391	.
	df	28	28	28	0

The average Flexural strength at lateral stress 0 MPa was 132.54 MPa. Average flexural strength at lateral stress 1.5 Mpa is 146.69 MPa. Flexural strength with forged pressure of 2 MPa is an average of 122.01 MPa. Flexural strength of bamboo with a pressure of 2.5 MPa was forged by an average of 121.52 MPa.

TABLE V. FLEXURAL STRENGTH AND LATERAL STRESS PARTIAL CORRELATION

Control Variables		1,5 MPa	2 MPa	2,5 MPa	0 MPa
1,5 MPa	Correlation	1	-0.026	0.019	0.18
	Significance (2-tailed)	.	0.894	0.919	0.34
	df	0	28	28	28
2 MPa	Correlation	-0.026	1	0.011	0.02
	Significance (2-tailed)	0.894	.	0.953	0.915
	df	28	0	28	28
2,5 MPa	Correlation	0.019	0.011	1	0.289
	Significance (2-tailed)	0.919	0.953	.	0.122
	df	28	28	0	28
0 MPa	Correlation	0.18	0.02	0.289	1
	Significance (2-tailed)	0.34	0.915	0.122	.
	df	28	28	28	0

The average of tensile strength with lateral stress 0 MPa is 192.74 MPa. Average tensile strength with lateral stress 1.5 MPa is 216.37 MPa. Tensile strength of bamboo with lateral stress 2 MPa is the average of 164.75 MPa. At lateral stress 2.5 MPa tensile strength of bamboo is average 160.74 MPa.

TABLE VI. TENSILE STRENGTH AND LATERAL STRESS PARTIAL CORRELATION

Control Variables		1,5 MPa	2 MPa	2,5 MPa	0 MPa
1,5 MPa	Correlation	1	-0.149	-0.106	0.003
	Significance (2-tailed)	.	0.432	0.579	0.987
	df	0	28	28	28
2 MPa	Correlation	-0.149	1	0.079	-0.491
	Significance (2-tailed)	0.432	.	0.678	0.006
	df	28	0	28	28
2,5 MPa	Correlation	-0.106	0.079	1	-0.26
	Significance (2-tailed)	0.579	0.678	.	0.166
	df	28	28	0	28
0 MPa	Correlation	0.003	-0.491	-0.26	1
	Significance (2-tailed)	0.987	0.006	0.166	.
	df	28	28	28	0

Shear strength of bamboo with lateral stress 0 MPa pressure is an average of 25.41 MPa. At lateral stress 1.5 MPa an average of 22.05 MPa. Shear strength of bamboo with lateral stress 2 MPa is an average of 17.12 MPa. While the shear strength of bamboo were lateral stress of 2.5 MPa is the average 15.05 MPa.

TABLE VII. SHEAR STRENGTH AND LATERAL STRESS PARTIAL CORRELATION

Control Variables		1,5 MPa	2 MPa	2,5 MPa	0 MPa
1,5 Mpa	Correlation	1	0.004	0.295	-0.115
	Significance (2-tailed)	.	0.985	0.114	0.545
	df	0	28	28	28
2 MPa	Correlation	0.004	1	-0.137	0.088
	Significance (2-tailed)	0.985	.	0.471	0.645
	df	28	0	28	28
2,5 MPa	Correlation	0.295	-0.137	1	0.202
	Significance (2-tailed)	0.114	0.471	.	0.285
	df	28	28	0	28
0 MPa	Correlation	-0.115	0.088	0.202	1
	Significance (2-tailed)	0.545	0.645	0.285	.
	df	28	28	28	0

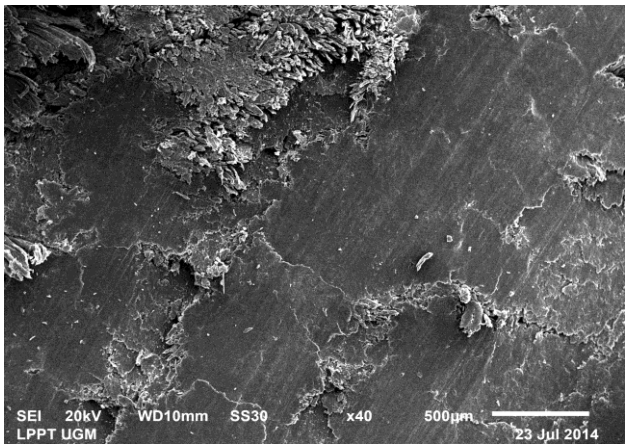

Figure 3. Specimen Without Lateral Stresses

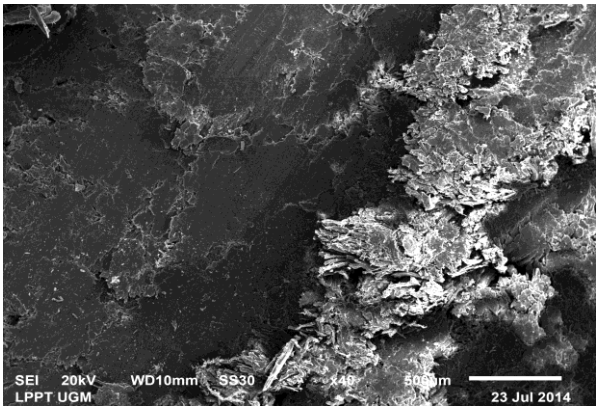

Figure 4. Specimen With Lateral Stresses 1,5 MPa

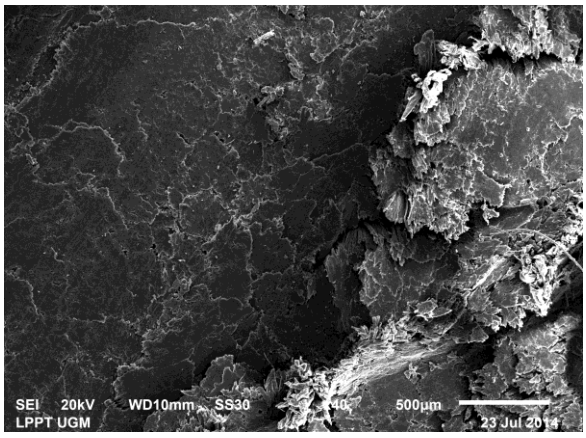

Figure 5. Specimen With Lateral Stresses 2 MPa

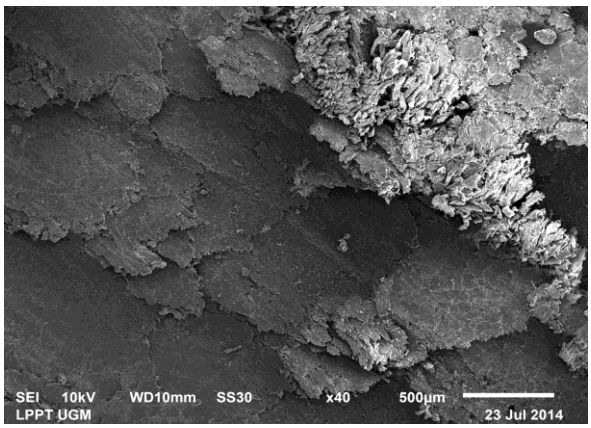

Figure 6. Specimen With Lateral Stresses 2,5 MPa

v. Conclusion

Average of bamboo water content with lateral stress of 0 MPa, 1.5 MPa, 2 MPa and 2.5 MPa were 12.95%, 12.81%, 12.52%, and 12, 43%. The Average of bamboo specific gravity with lateral stress of 0 MPa, 1.5 MPa, 2 MPa and 2.5 MPa were 0.64 g / cm3, 0.73 g / cm3, 0.75 g / cm3 and 0.78 g / cm3. Statistical analysis shows the physical properties of bamboo Petung not significantly with lateral stress.

Average flexural strength of bamboo with lateral stress of 0 MPa, 1.5 MPa, 2 MPa and 2.5 MPa were 132.54 MPa, 146.69 MPa, 122.01 and 121 MPa, 52 MPa. Average shear strength of bamboo with lateral stress of 0 MPa, 1.5 MPa, 2 MPa and 2.5 MPa were 25.41 MPa, 22.05 MPa, 17.12 MPa and 15.05 MPa. Average compressive strength of bamboo with lateral stress of 0 MPa, 1.5 MPa, 2 MPa and 2.5 MPa were 45.79 MPa, 70.08 MPa, 54.65 MPa and 51.15 MPa. Statistical analysis showed that there was significantly related to the lateral stress.

Average tensile strength of bamboo with lateral stress of 0 MPa, 1.5 MPa, 2 MPa and 2.5 MPa were 132.54 MPa, 146.69 MPa, 122.01 and 121.52 MPa. Statistical analysis showed the lateral stress of 2.5 MPa was significantly.

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