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Physico-Mechanical Properties of Culturally-Preformed *Bayog* (*Bambusa merrilliana* (Elmer) Rojo & Roxas *comb. nov.*)

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Abstract: Culturally preformed *Bayog* (*Bambusa merrilliana* (Elmer) Rojo & Roxas *comb. nov.*) syn. **(***Dendrocalamus merrillianus* (Elm.) Elm.) culms from a plantation in Dumarao, Capiz, Philippines were examined for their mechanical and physical properties. The mechanical properties and the corresponding mean values are as follows: maximum load carried in bending, 1.92 tons; load at proportional limit, 1.16 tons; stress at proportional limit, 84.48 MPa; modulus of elasticity (MOE), 3.94 GPa; and modulus of rupture (MOR), 138.90 MPa. The bends in the upper portion of the culms had significantly higher mechanical property values than the bends in the lower portion. The physical properties of bent *Bayog* culms are as follows: average specific gravity is 0.45 and the mean moisture content is 112.0% at the inner radius and 114.5% at the outer radius of each bend. Shrinkage values also differed depending on the location along the arc of the bent culm wall. The average shrinkage values across the culm wall were 5% and 4.45% for the inner and outer radii, respectively; while the respective volumetric shrinkage values were 9.73% and 8.19%, suggesting that the inner culm wall was more prone to dimensional changes as moisture content changes. Mean longitudinal shrinkage value was 0.23% which was slightly higher than normal culms. Mechanical properties were found to be positively correlated with culm diameter, outer radius and specific gravity but were negatively correlated with length of internodes and moisture content. The findings suggest that cultural preforming of *Bayog* does not adversely affect its mechanical properties and that the resulting preformed poles could meet the strength requirements for load-bearing structural and engineering applications.

Keywords: Bayog (*Bambusa merrilliana*), culm, culturally-preformed, physico-mechanical properties

INTRODUCTION

There are about 62 species and 12 genera of bamboo in the Philippines. Although the numbers suggest wide diversity, there are only nine species that are commercially used (Razal and Palijon, 2009) and *Bayog* (*Bambusa merrilliana* (Elmer) Rojo &

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Roxas *comb. nov.*) syn. (*Dendrocalamus merrillianus* (Elm.) Elm.) is one of the preferred species because of its strength and thick culms. *Bayog* poles are employed in house construction, furniture making, fishpond construction, boat building, basketry and mat making, and as a tying material. The species is also widely used as outriggers for sailboats and motorboats.

Boat builders bend the *Bayog* poles to the desired curved shape through continuous heating and deforming until the targeted shape is attained. Some boat builders make use of preformed *Bayog* direct from bamboo stands as this presumably avoids reduction in the strength of straight culms that are heated to transform them into bent products. Preformed *Bayog* may also be used as furniture and could fetch higher price in the high-end furniture market. The preforming of *Bayog* to produce arches or angled bends or squares and rectangular forms had been tried in bamboo plantations (Piñol *et al*., 1977).

Preformed bamboo culms are made by forcing the growing shoots to pass through metal or wooden forms as the shoot elongates. Forming a square or rectangular culm or curved and angled culms involves proper timing and the correct placement of the forms. The emerging bamboo pole follows the restriction imposed by the form and takes on its shape as the culm matures.

The changes that happen to culms as they mature in a restricted environment are the object of this study. It is designed to determine the effects on the physical and mechanical properties of *Bayog* culms of the imposed restriction on the growing pole.

MATERIALS AND METHODS

Collection and Preparation of Materials

Samples were collected from a plantation in Dumarao, Capiz, Philippines where the Department of Environment and Natural Resources (DENR) conducted bamboo pole preforming experiments. The preformed culms were between 4 to 6 years old at the time of collection. The culms were brought to the Dept. of Forest Products and Paper Science (FPPS) woodworking laboratory of the UPLB College of Forestry and Natural Resources where they were left to air dry for about 6 months before the various tests. The poles were inspected regularly to insure that they were not being attacked by borers and other decay-causing organisms.

Most of the collected culms had two bends which allowed taking two specimens by cutting at the point of inflection, and the two specimens corresponded to the lower and upper portions of the pole. Out of the seven culms gathered, six had double bends while the only culm with a single bend was designated as a lower bend. All in all, thirteen specimens were prepared for the various tests.

Figure 1. A clump of *Bayog* in the plantation at Dumarao, Capiz, Philippines. For this particular clump, two culms were preformed with the front preformed culm having three arches while the culm at the rear had a single bend. *Note that the internodes are relatively short at the point of inflection of the bends.*

Determination of mechanical and physical properties

The static bending properties of the preformed bamboo specimens were investigated following the methods prescribed in ASTM D 198-97. Modifications in the test procedure were made to suit the specimens because the methods were designed for straight-form, structural-size lumber. The static bending tests (Fig. 2) were performed at the Forest Products Research and Development Institute (FPRDI) Testing Laboratory in Los Baños, Laguna, Philippines. A Shimadzu Universal Testing Machine (UTM), model UH-10A was used, which was connected to a printer that records the load-deflection curve. The load head speed was set at 2.5mm/min while the maximum load was set at 5 tons.

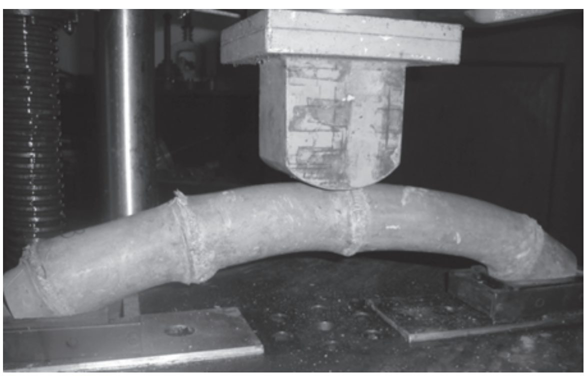

Figure 2. Mechanical test on one of the culturally preformed *Bayog* specimens, using three-point loading due to the short span of the test samples. Grease was applied between the contact points of the support and the ends of the preformed bamboo.

The 13 specimens were prepared by cutting at an angle such that both ends of the specimen would be flat relative to the UTM platform. The specimen length, L, varied depending on the actual dimension of the samples which was in turn dependent on the mold used. The span or base was taken as the mean distance between the inner and outer radii of the bend. Alongside the bending test for each specimen, the following measurements were taken: the radius of curvature, number and length of internodes, diameter of the culm, and culm wall thickness. The distance from the point of loading to the nearest node on the topmost portion of the bend was also measured.

Specific gravity was measured using the procedures in ASTM D 2395. ASTM D 4442 was used for moisture content measurement. The swelling of bamboo exposed to liquid water environment was determined in accordance with ASTM D 4446–84. Samples for the determination of these physical properties were taken from appropriate locations in the test specimens to differentiate the inner radius (under compressive stress) from the outer radius (under tensile stress). One-inch samples were cut for specific gravity and moisture content determination from the specimens after the mechanical tests. For shrinkage measurements, four-inch samples were taken. The physical properties of preformed bamboo were compared with known physical properties of Bayog taken from relevant literature sources.

The maximum load applied was noted for every specimen, which was graphically recorded on real-time. The stress-strain curve showed the maximum load as the highest point of the curve recorded for each test. The stress-strain curve was also utilized to derive the load at proportional limit which corresponded to the highest point in the straight line portion from the base, beyond which deviation from the straight line would occur.

The following formulas were used for the computations (Forest Products Laboratory, 1999):

Stress at proportional limit, $\delta = \dfrac{Mc}{I}$

where M is the maximum load moment, c is the distance to the neutral axis and I is the moment of inertia computed

$$I = \frac{\pi}{4} (r_o^4 - r_i^4)$$

where r_o is the outer radius and r_i, the inner radius.

The deflections of the specimens were also read from the stress-strain curve. The modulus of elasticity (MOE) was computed based on the observed and graphically-derived loads and the physical measurements of the samples. The formula used to compute the MOE is:

$$\mathrm{MOE} = \frac{P'L^3}{48\,I\,\Delta}$$

where P' is the load at proportional limit, L is the base length, I is the moment of inertia of the specimens, and Δ is the deflection at the proportional limit.

The following formula was used to compute the modulus of rupture (MOR) of the specimen is:

$$\mathrm{MOR} = \delta \frac{P_{max}}{P'}$$

where P_{max} is the maximum load carried by the specimens.

The mechanical properties were differentiated between the bends in the lower and upper portion of the culm and correlated with the physical properties of the specimens. Descriptive statistics, comparison among means, as well as correlation and regression analysis were employed. Mechanical properties were evaluated for significance of differences among means, using location of specimens (*i.e.*, upper versus lower bend specimens) as the grouping variable for the *t*-tests. In the regression analysis to determine relationships between mechanical and physical properties, the following regression model was used:

$$Y_{i'} = A_i + B_i X_j$$

where $i = 1, 2, \ldots n$
$j = 1, 2, \ldots n$
Y' = the predicted mechanical property
X = the independent variable (physical property)
A = intercept of the regression line
B = coefficient of the independent variable

RESULTS AND DISCUSSION

Static bending properties

Table 1 summarizes the results of the static bending tests for all specimens. The mean computed MOE for the curved specimens was 3.94 GPa which was lower than the mean MOE of 6 GPa obtained by Espiloy *et al.* (2002) for straight *Bayog* poles. The bending tests showed that curved specimens had high deflection values. The bigger deflection values for the curved specimens, when used as denominator in computing MOE, resulted in lower values. The maximum MOE value for the curved specimens (7.63 GPa) was, however, comparable with the maximum MOE value for straight *Bayog* specimens as reported in the literature (Espiloy *et al.*, *op cit.*).

Table 1. The average maximum load and load at proportional limit carried by the 13 specimens. Stress at proportional limit, modulus of elasticity (MOE), and modulus of rupture (MOR) are also shown.

Statistic	Max Load, Tons	Load at Proportional Limit, Tons	Stress at Proportional Limit, MPa	Modulus of Elasticity, MPa	Modulus of Rupture, MPa
Average	1.92	1.16	84.48	3937.27	138.90
Max.	2.78	1.75	124.95	7631.48	191.07
Min.	1.16	0.65	39.31	2006.12	87.70
sd[1]	0.55	0.36	21.67	1616.55	29.00

[1] sd = standard deviation

With regard to the MOR of preformed *Bayog* specimens, the average was 138.9 MPa, with the highest at 191.07 MPa and the lowest at 87.70 MPa. On the other hand, the average MOR for straight *Bayog* specimens as listed in the Bamboo handbook (Espiloy *et al., ibid*) was 55.2 MPa. The dissipation of the bending force into compressive force at the reaction points could explain the difference. In bending straight specimens, the failure did not occur in the fibers but in the pectinaceous layer in the neutral axis of the stem (Janssen, 1980).

The comparison of strength values between the upper and lower bends is shown in Table 2. Specimens from the upper bend generally had higher mean load values compared to the lower bend. They also had higher mean derived mechanical property values. The *t*-test for significance of the mean difference showed probability values less than 0.05 which indicated that the observed mean differences were significant. These results agree with earlier studies by Bumarlong and Tamolang (1980); Sattar *et al*. (1991); Janssen (1980); Espiloy (1991) and Mohmod *et al.* (1991) that the mechanical properties of bamboo increased from the butt to the top portion.

Table 2. Maximum load and load at proportional limit, and the calculated stress at proportional limit, MOE and MOR classified according to their position in the culm.

Statistic	Max Load, Tons		Load at Proportional Limit,Tons		Stress at Proportional Limit, MPa		MOE, MPa		MOR, MPa	
	Up[1]	Low[2]	Up	Low	Up	Low	Up	Low	Up	Low
Mean	1.99	1.86	1.22	1.11	99.2	71.9	5333.3	2740.7	160.5	120.4
sd	0.59	0.55	0.35	0.38	17.6	16.8	1319.2	396.0	24.6	17.6
t_{prob}	0.025		0.047		0.018		0.005		0.014	

[1] Up refers to bend at the upper portion of the culm.
[2] Low refers to bend at the lower portion of the culm.

Table 3 shows the different types of failures in the static bending test. Compression indentation, as commonly observed in three-point bending tests, result from the loading head directly compressing the center of the sample. In the present case, this occurred at the point of contact on the outside radius (r_o) of the specimens where the fibers were crushed. Another type of failure was cracking either on the neutral plane or on the side of the inner radius (r_i) of each specimen. The fibers failed in shear and caused the cracks.

Table 3. Type of physical failures observed in the specimens during the mechanical tests.

Sample	Remarks
1	Compression indentation at point of loading & longitudinal crack at the inner radius.
2	Compression indentation at point of loading & multiple longitudinal cracks at near neutral axis.
3	Compression indentation at point of loading & crack at the inner radius.
4	Compression indentation at point of loading & multiple longitudinal cracks at neutral axis & inner radius.
5	Compression indentation at point of loading. No crack visible.
6	Compression indentation at point of loading & longitudinal crack at both the outer and inner radii.
7	Compression indentation at point of loading & longitudinal crack at near neutral axis.
8	Compression indentation at point of loading & longitudinal crack at the inner radius.
9	Compression indentation at point of loading & longitudinal crack at the inner radius.
10	Compression indentation at point of loading & crack at the inner radius.
11	Compression indentation at point of loading.
12	Cracks along the neutral axis and at the inner radius.
13	Compression indentation at point of loading. Crack at the inner radius & neutral side.

Physical properties

Listed in Table 4 are the physical measurements of the bent specimen right before mechanical testing. The mean radius of curvature of the specimens was 33.92 cm, and the mean number of internodes was 3, with the highest number at 5 and the lowest at 3 internodes per sample. The mean internode length was 14.9 cm, while the mean base length was 41.96 cm. The specimens were comparable in base length with

Table 4. Various physical measurements on the bent specimens made prior to the mechanical tests.

Statistic	Radius of curv-ature, cm	No. of inter-nodes	Ave. Length of inter-nodes, cm	Base, cm	Distance of load from the nearest node, cm	Diameter of the culm, mm			Thickness of culm wall, mm			
						$(N_{side})^1$	$(R_o \rightarrow R_i)^2$	Ave	N_{side}	R_o	R_i	Ave
Mean	33.92	3	14.90	41.96	3.23	66.5	65.1	65.8	21.0	21.1	21.0	21.0
Max	50	5	19.00	43.75	8.00	80.8	72.8	76.8	25.4	24.8	24.1	23.9
Min	21	2	9.60	39.75	0.00	55.6	58.6	57.1	15.6	16.6	15.8	16.8
sd	9.34	0.71	2.23	1.24	2.69	6.44	4.01	5.11	2.63	2.44	2.49	2.38
t_{prob}						0.17			0.94			

[1] N_{side} refers to measurements along the neutral plane relative to the bend and load application.
[2] $(R_o \rightarrow R_i)$ refers to measurements along the diameter from the outer radius R_o, to the inner radius, R_i, *i.e.*, along the culm diameter parallel to direction of load.

the shortest at 39.75 cm and the longest at 43.75 cm. The distance of the load head to the nearest node were also recorded since the nodes had been previously observed to be weak points in the culm (Liese and Ding, 1991; Servañez, 2002). The mean distance of load to the nearest node was 3.23 cm. Two specimens had the load head bearing directly on the nodes. The mean diameter and culm wall thickness of the specimens was 65.8 and 21.04 mm, respectively. Although the diameter and thickness of the culms were recorded from different planes of the culm, the resulting differences were not significant.

Table 5 shows the comparison of culm diameter measurements and culm wall thickness in the upper and lower bends of the culms. Culm diameter and culm wall thickness at the lower bend were significantly higher than the corresponding values at the upper bend. Generally, bamboo poles taper from the base to the top and apparently, this is still the case in preformed specimens.

Table 5. Average diameter and culm wall thickness of the culms classified according to their position in the culm.

Statistic	Ave. diameter of culm, mm		Ave. culm wall thickness, mm	
	Up[1]	Low[1]	Up	Low
Mean	63.61	67.69	19.13	22.69
SD	3.92	5.52	1.92	1.21
t_{prob}	0.014		0.001	

[1] Up and low are as in legend to Table 2.

Table 6 shows the initial moisture content and shrinkage values for the bent specimens. In straight bamboo poles, shrinkage is simply measured along the length and across the culm wall. It was felt that there was a need to specify the location of the sample in bent specimens relative to the curve, because the differences in the nature of the strain

Table 6. Initial moisture content of specimens and shrinkage values classified as to location in the bend.

Statistic	Green moisture Content, %		Shrinkage along circumference of culm, %		Shrinkage along thickness of culm, %		Longitudinal shrinkage, %		Volumetric shrinkage, %	
	Ri	Ro	Ri	Ro	Ri	Ro	Ri	Ro	Ri	Ro
Average	112.0	114.5	5.00	3.91	5.0	4.4	0.23	0.23	9.7	8.2
Max	147.1	179.5	12.94	5.45	11.7	6.0	0.64	0.52	19.7	10.7
Min	81.1	78.7	3.41	0.11	0.00	3.4	0.02	0.05	4.2	5.4
sd	25.5	31.0	2.46	1.33	2.67	0.85	0.18	0.15	4.0	1.5
t_{prob}	0.82		0.17		0.48		1.00		0.20	

[1] R_i refers to measurements of samples taken on the side of the inner radius of the bend.
[2] R_o refers to measurements of samples taken on the side of the outer radius of the bend

in the inner (under compressive stress) and outer radius (under tensile stress) might affect shrinkage outcomes. On average, shrinkage across the culm wall was higher on the outside radius than in samples near the inner radius. However, longitudinal shrinkage, which is still lower than the shrinkage across the wall, is the same regardless of location within the bend. Statistically, the differences in the physical properties of samples from the upper and lower bends of the culms were not significant.

The physical properties of the specimens evaluated after the conduct of the mechanical tests are shown in Table 7. The mean moisture content at the time of test was 26.95%. The samples on the outside radius had higher moisture contents compared to the inner radius. However, the difference was not significant. The mean specific gravity of the samples was 0.45 and did not differ much between the outer and inner radii.

Table 7. Moisture content at the time of mechanical test and specific gravity of culturally preformed *Bayog* classified according to location in the bend.

Statistic	Moisture content, %			Specific gravity		
	(R_i)[1]	(R_o)[1]	Ave	R_i	R_o	Ave
Average	27.11	26.79	26.95	0.46	0.45	0.45
Max	50.00	56.25	53.13	0.53	0.54	0.54
Min	9.52	11.11	12.08	0.35	0.32	0.33
SD	13.62	11.22	11.18	0.06	0.06	0.06
t_{prob}	0.95			0.70		

[1] R_i and R_o are as in legend to Table 6.

The Handbook on Philippine Bamboos (Espiloy *et al*., *ibid.*) also gave specific gravity values for straight specimens of *Bayog*. The mean specific gravity was found to be 0.582; the highest specific gravity was 0.639 at the top of the culm while the lowest was 0.533 at the butt portion (Table 8). The specific gravity of the specimens of

Table 8. Comparison of the physical properties of culturally preformed and naturally growing *Bayog*.

Physicalproperties	Culturally-preformed *Bayog*	Naturallygrown *Bayog*			
	Mean	Mean	Butt	Middle	Top
Length of nodes, cm	14.9	25.2	18.2	31.0	26.6
Culm diameter, cm	6.58	5.4	6.4	5.7	4.0
Thickness of culm, cm	2.104	1.9	2.7	1.8	1.1
Specific gravity	0.455	0.582	0.533	0.574	0.639
Green moisture content, %	113.2	106.2	122.1	107.6	89.0
Tangential shrinkage, %**	3.72	8.1	7.2	8.6	8.4
Radial shrinkage, %***	4.06	12.0	10.5	13.3	12.1

* Source: Z. B. Espiloy *et al*., *ibid.* Handbook on Philippine Bamboos.
** Shrinkage values measured along the culm circumference
*** Shrinkage values measured across the culm thickness

culturally preformed *Bayog* was slightly lower than that of their straight counterparts. Although the significance of the mean difference in specific gravity could not be ascertained for lack of additional statistical data, it is worth mentioning that preformed specimens, although they had lower specific gravity values, could carry more load than straight bamboo poles.

Internodes in naturally-grown *Bayog* poles are longer than that of culturally preformed *Bayog* and this difference in internode length is apparent in Figure 1. In preformed bamboo, the internodes were shorter and more frequent, regardless of whether they were along the bent portions or in straight sections of the culm.

The green moisture content of straight specimens of *Bayog* was reported by Espiloy *et al*., (*ibid*.) to be 106.2%. This value was comparable to the value obtained in this study. On average, the butt portion of the straight culms had higher moisture content of 122.1% while the top portion had a lower moisture content of 89%.

In previous tests done on straight specimens, Espiloy *et al.* (*ibid*.) found the mean radial and tangential shrinkage to be 12% and 8.1%, respectively with the highest value recorded in the middle portion of the culm while the lowest was observed in the butt portion. The values obtained by Espiloy and co-workers were considerably higher than the corresponding transverse shrinkage values of culturally preformed *Bayog*. This could be explained in terms of the specific gravity of normally grown specimens which was greater than that of the culturally preformed *Bayog*.

Relationship of mechanical and physical properties

Table 9 shows the significant correlation indices between the physical parameters and mechanical properties of preformed *Bayog* poles. The length of internodes was negatively correlated with maximum load and load at proportional limit. The distance of the node closest to the load head was also negatively correlated with stress at proportional limit and MOE while the culm thickness was negatively correlated with

Table 9. Statistically significant correlation coefficients (Pearson) for interrelationships of selected mechanical properties and physical parameters of *Bayog* bending test specimens.

Property/measurement	Maximum load	Load at proportional limit	Stress at proportional limit	MOE
Length of internodes	-0.633*	-0.607*		
Distance of closest node from load head,			-0.698**	-0.585*
Ave. culm diameter	0.737**	0.631*		
Ave. culm thickness				-0.799**
Outer radius	0.692**	0.571*		

* - Significant at 5% level
**- Significant at 1% level

the MOE. Positive correlations were found between the culm diameter measurements and the maximum load and load at proportional limit, as well as between the outer radius and the maximum load and load at proportional limit. It could be inferred from these relationships that the specimens with shorter internodes and those specimens with loads placed closer to the nodes resulted in higher mechanical property values. This suggests that the nodes were not the points of weakness along the culm. The specimens with bigger culm diameters could also carry higher loads as shown by the significant positive relationship. Moreover, the specimens with thinner culm walls showed higher MOE values. Preformed samples from the upper portion of the culm had higher MOE values compared to the specimens from the lower portion which had thicker culm walls. Thinner walled culms have greater flexibility and are less rigid than the thick-walled portions.

Table 10 shows the significant correlation values between the mechanical and the physical properties of the specimens measured after the test. The moisture content on the outer bend was positively correlated with MOE; and so was the average moisture content. This indicated that the higher the moisture content, the greater would be the MOE. Specific gravity was positively correlated with maximum load and load at proportional limit. This affirmed the general rule that specific gravity largely determines the mechanical strength of wood-based materials. The moisture content was negatively correlated with load at proportional limit, stress at proportional limit, and MOR. The lower the moisture content, the higher would be the mechanical strength of *Bayog*. The shrinkage along the thickness of the culm as well as the volumetric shrinkage values were positively correlated with the derived mechanical property values with the exception of the longitudinal shrinkage which gave a negative

Table 10. Statistically significant correlation coefficients (Pearson) for interrelationships of mechanical properties derived from static bending tests with selected physical properties of preformed *Bayog* poles.

Physical properties	Maximum load	Load at proportional limit	Stress at proportional limit	MOE	MOR
Moisture content, R_i[1] side				0.730**	
Ave. moisture content				0.621*	
Specific gravity, R_o[1]	0.599*	0.674*			
Ave. specific gravity	0.572*	0.631*			
MC, R_i		-0.575*	-0.579*		-0.665*
Ave. green MC					-0.586*
Shrinkage across the culm thickness, R_i			0.772**		0.694**
Shrinkage across the culm thickness, R_o			0.662*		0.602*
Longitudinal shrinkage, R_o			-0.715**	-0.629*	-0.762**
Volumetric shrinkage, R_i			0.683*		
Volumetric shrinkage, R_o				0.554*	

* - Significant at 5% level; **- Significant at 1% level; [1] – R_i and R_o are as in legend to Table 6.

correlation index. The other variables shown in the correlation table had no significant relationships with the mechanical variables.

SUMMARY AND CONCLUSION

The mechanical properties investigated in this study were maximum load, load at proportional limit, stress at proportional limit, modulus of elasticity and modulus of rupture. Statistical relationships between the mechanical properties and certain physical parameters as well as the physical properties of the preformed *Bayog* poles were also shown. The average maximum load carried by the specimens was 1.92 tons; the load at proportional limit had a mean of 1.16 tons. The stress at proportional limit, MOE and MOR had mean values of 84.48 MPa, 3.93 GPa, and 138.9 MPa, respectively. Significant differences in mechanical property values between the upper bend specimens on one hand, and the lower bend specimens were also found.

Comparisons made with existing data on mechanical properties of *Bayog* showed that the culturally preformed specimens had higher stress at proportional limit and MOR compared with their straight counterpart. However, the preformed specimens had lower mean MOE values than straight poles. From the utilization point of view, the culturally preformed specimens can be used not only for furniture but for structural purposes as well. The bent specimens may be used as arches for windows and doors and can carry the load of the walls of houses or building components. The culturally preformed *Bayog* may also be utilized as arches for building trusses or arches and catenaries for bridges and river crossings as in the constructions of Hidalgo (Adams, 2003); Vahanvati and Vahanvati (2009); Rao (2009); Mishra and Sanyal (1991) and Stamm (2009).

Comparison of the physical parameters of the culturally preformed *Bayog* against those of straight specimens showed that the culturally preformed Bayog had smaller mean internode length, bigger mean culm diameter, higher mean culm thickness, lower mean specific gravity, higher green moisture content, and lower radial and tangential shrinkage. However, the significance of these differences could not be ascertained due to lack of additional statistical data.

Negatively correlated properties of preformed bamboo are as follows: the length of internodes with maximum load and load at proportional limit; distance of load head from closest node with stress at proportional limit and MOE; green moisture content with load at proportional limit, stress at proportional limit and modulus of rupture; culm thickness measurements with MOE; and longitudinal shrinkage with stress at proportional limit, MOE and MOR. Statistically positive correlations were obtained for the following relationships: culm diameter measurements with maximum load and load at proportional limit; the outer radius with maximum load and load at proportional limit; moisture content at time of test with MOE; specific gravity with maximum load and load at proportional limit; transverse shrinkage with stress at proportional limit and MOR; and volumetric shrinkage with stress at proportional limit and MOE.

The physico-mechanical relationships had indicated that even if the specific gravity value of the culturally preformed *Bayog* was lower than those for straight specimens, the mechanical strength of the bent specimens was more than adequate to meet load-bearing requirements in house and furniture construction. Further, it was found that the nodes within preformed bamboo were not points of weakness and that they can be made to directly bear loads applied on the preformed bamboo pole.

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