International Journal of Advances in Engineering and Management (IJAEM)
Volume 6, Issue 10 Oct. 2024, pp: 46-50 www.ijaem.net ISSN: 2395-5252

Investigation on Hygroscopic Properties of Laminated Composite Bamboo

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Date of Submission: 01-10-2024 Date of Acceptance: 10-10-2024

ABSTRACT: The purpose of this study was to investigate the water absorption of laminated compositebamboo. Bamboo fibers as reinforcements for laminate composites came from apus bamboo ((Gigantochloaapus/GA) and wulung bamboo (Gigantochloaatroviolacea/GV). The hygroscopic properties of bamboo in the base, middle, and edge sections were compared and analyzed using the dynamic vapor absorption (DVS) method. The results were analyzed using the parallel exponential kinetics (PEK) model. The results showed that the hygroscopic properties of the fibers between the base, middle, and edge. The percentage of water absorption of apus bamboo laminate composites is higher than that of wulung bamboo laminate composites.The percentage of water absorption of the apus bamboo laminate composite (GA) is the largest at 3.64%, the wulung bamboo laminate composite (GV) is the largest at 3.01, each under the condition of square root of time 700 sec. Bamboo fibre belongs to cellulose fibre. Its water absorption properties are higher than fibreglass. High water absorption is a major drawback of cellulose fibres, as the main cause of degradation in the mechanical performance of the composite. Cellulose fibres absorb moisture due to their hydrophilic nature caused by the presence of multiple H-bonds (-OH groups) between the cell wall macromolecules in the fibre.

KEYWORDS: Laminated composite,Gigantochloaapus, Gigantochloaatroviolacea, Hygroscopic properties.

I. INTRODUCTION

Laminated composite material technology has been applied in the field of interior building structures in the form of parquet flooring. Parquet flooring or commonly called parquet, laminate flooring made from sawdust, or quality wood pieces that are then ground into powder. The requirements for laminate flooring are strong and durable, corrosion resistant, low hygroscopic properties and have high aesthetic value.

Indonesia has abundant natural resources in the form of bamboo plants. More than 100 species of bamboo are found on the Indonesian mainland, so that bamboo production in the world ranks second after China. Bamboo has great potential to be used as a raw material for the interior construction industry because of its high mechanical properties. Bamboo that is commonly cultivated by residents in the North Lombok Regency, West Nusa Tenggara Province, Indonesia is: apus bamboo (Gigantochloaapus/GA), wulung bamboo (Gigantochloaatroviolacea/GV) and kutu bamboo (Bambusamaculat/BM), Bamboo Temen (GigantochloaAtter), Bamboo Kuning (Bambusa vulgaris schard var. Vitata), Bamboo Gombong (Gigantochloapseudoarundinacea), and Bamboo Hitam (Gigantochloaverticillata). Based on the results of the study[1] bamboo temen, bamboo apus has the first and second highest strength compared to the tensile strength of other bamboos. The tensile strength of temen bamboo and apus bamboo, respectively: 195, 179 MPa.

.Bamboo natural resources have the potential to be used in structural engineering design, and sustainable construction. The study[2] studied simple and multiple linear regression analysis to predict the axial compressive load capacity and strength of bamboo culms, as useful information for quality control of building construction. The conclusion is that linear mass, culm wall thickness, outer diameter, water content, and density, statistically significantly affect the compressive load capacity and compressive strength of bamboo. The maximum compressive strength is well related to the density of bamboo.

The work[3] investigated the influence of various parameters on deformation during forming of double curved sheets with bamboo fabric reinforced Poly lactic acid (PLA) composites. The influence of unbalanced weave on the thermoform ability of the composite laminates was studied. Grid Strain Analysis (GSA) technique was used to investigate the surface and thickness strains in the material. Bamboo fabric reinforced PLA composites showed less wrinkling and bending under low forming rates. The domes formed using hot tooling conditions were significantly better in quality than the samples formed using cold tooling conditions.

The chemical, physical, and mechanical properties vary greatly between bamboo species[4] Chemical properties, the lowest holocellulose and α-cellulose content were found in Yellow Bamboo (B. vulgaris var. vittata). Holocellulose and α-cellulose content caused the lowest density in Yellow Bamboo (B. vulgaris var. vittata). Basic Bamboo (Bambusa vulgaris) has the highest lignin content. These substances affect water content, T/R ratio, and shear strength. Basic Bamboo (Bambusa vulgaris) has the lowest water content, the highest T/R ratio, and the highest shear strength. However, Betung Bamboo (Dendrocalamusasper) has the highest density in this study. The compressive strength of Betung Bamboo (Dendrocalamusasper) has the highest value.

Bamboo is a lignocellulosic material that has attracted much attention from scientists because it is environmentally friendly. Bamboo reinforced composites or bamboo composites are well-known for their use as structural materials. The processing method used to manufacture bamboo composites has a significant effect on their performance. The study[5] emphasized the study of the effect of manufacturing method and species on the important physical and mechanical properties of bamboo composites. In their study, two types of composites, namely laminated bamboo wood and stranded bamboo wood, were made using four bamboo species such as Dendrocalamusbrandisii, Bambusa vulgaris, Bambusabambos, and Guaduaangustifolia. The results showed that physical properties such as water absorption, thickness expansion, and volumetric expansion of laminated bamboo wood were significantly lower compared to stranded bamboo wood composites after 2 and 24 hours of exposure. Mechanical properties such as MOR, Modulus of Elasticity, modulus of resilience and compressive strength parallel to the grain were significantly higher in laminated bamboo wood compared to stranded bamboo wood composites. The results also revealed that fabrication method and species significantly affected the physical and mechanical properties of bamboo composites.

However, the research reported to date on the characteristics of bamboo laminate composites is inadequate. As a contribution to the development process of laminated compositebamboo, this paper investigates the hygroscopic properties of bamboo at the base, middle and edge of each bamboo species used as composite laminate reinforcement. And by considering the nonlinear deformation of the material under stress, one point, provides a reference for laminate flooring or parquet flooring applications.

II. MATERIAL AND METHODS

Bamboo used as bamboo laminate composite specimens consists of apus bamboo (Gigantochloaapus/GA), and wulung bamboo (Gigantochloaatroviolacea/GV) as shown in Figure .... The bamboo is supplied from community plantations in SambikElen Village, Bayan District, North Lombok Regency, West Nusa Tenggara Province, Indonesia. The average age of bamboo is around 2.5 - 3 years. Bamboo laminate composite production procedure: sorting bamboo segments (base, middle, tip), cutting, slicing bamboo for laminate layers, gluing, assembly, and hot pressing. Working environment conditions with a measured humidity ratio of 6.2% and a bulk density of 636 kg/m3. Based on initial experimental investigations, it is seen that the compressive yield strength and ultimate strength parallel to the bamboo fiber/cut are 53 MPa and 84.9 MPa, respectively. Based on the tensile test, the tensile strength for laminated bamboo is 108.6 MPa, with an elastic modulus of 9085.6 MPa, and a Poisson's ratio of 0.32.The specimen design for the hygroscopic/water absorption property test method for bamboo laminated composites in this paper is in accordance with the ASTM D570 standard test method.Sheet material types such aslaminates composite, samples must be in the form of rectangular bars/blocks with a length of 76.2 mm (3 in) and a width of 25.4 mm (1 in), the thickness must be specified, but the thickness is 3.2 mm (1/8 in).Permissible variations in thickness shall be 0.20 mm (60.008 in.) except for materials which have greater standard commercial tolerance

The conditioned specimens shall be placed in a container of distilled water maintained at a temperature of 23 ± 1°C (73.4 ± 1.8°F), and shall rest on edge and be entirely immersed. At the end of 24, +1⁄2, 0 h, the specimens shall be removed from the water one at a time, all surface water wiped off with a dry cloth, and weighed to the nearest 0.001 g immediately

Gigantochloaapus

Gigantochloaatroviolacea

Bamboo Varieties Used For Composite Laminate

III. RESULT AND DISCUSSIONS

Water absorption test was conducted to investigate the water absorption behavior of bamboo composite laminates according to ASTM D570 test standard. The samples were immersed in distilled water until fully saturated for 24 hours. Before immersion, the initial weight of the specimens was weighed using a digital scale. To evaluate the percentage of water absorption, the composite samples were removed from the distilled water at predetermined intervals. The wet surface of the specimens was cleaned to remove excess water, and the weight of the wet specimens after water absorption was determined. This procedure was repeated until the saturation point was reached. The mass difference between the initial weight and the weight after water absorption at each time interval was needed to identify the percentage of water absorption according to equation (1) referring to [6].

Water absorption(%)= $\frac{M_{t-M_0}}{M_0}$ x100(1)

Here, M_t is the weight of the specimens after water absorption at certain time intervals and M_0 is the weight of the dry.

The rate of water diffusion into the composite laminates was also ascertained by calculating the diffusion coefficient, D, of the water absorption. Equation (2) was utilized to identify the diffusion coefficient of each composite laminate byconsideringthe slope of the water uptake percentage–square root of the time graph.

Diffusion coefficient, D $= \pi\left(\frac{h}{4M_\infty}\right)^2\left(\frac{M_2 - M_1}{\sqrt{t_2} - \sqrt{t_1}}\right)$ (2)

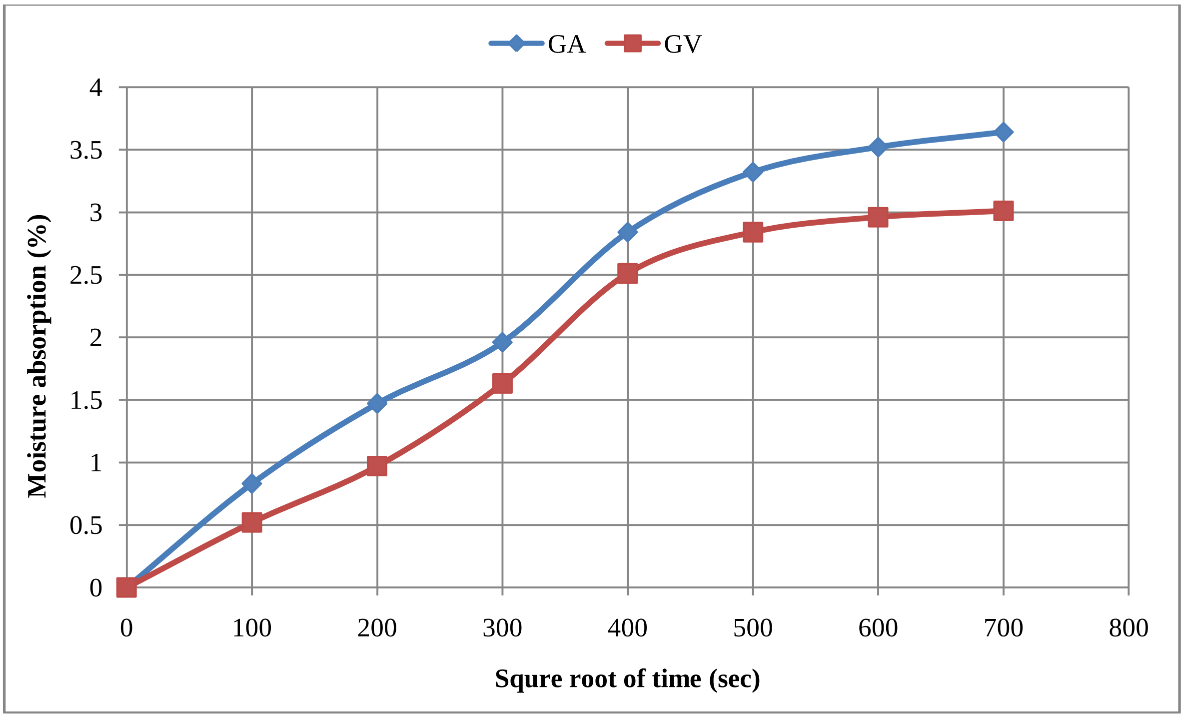
Here, h is the average composite thickness, M∞ is the water absorption percentage at the saturation point, M2 − M1 is the difference between the water absorption percentage at the linear region, and √t2 − √ t1 is the difference of the square rootof time atthe linier region.

Bamboo fibers as reinforcements for laminate composites came from apus bamboo ((Gigantochloaapus/GA) and wulung bamboo (Gigantochloaatroviolacea/GV). The variation of fibers from different bamboo species affects the water absorption characteristics of bamboo laminate composites. The hygroscopic or water absorption characteristics of bamboo laminate composites are shown in the figure

The percentage of water absorption of apus bamboo laminate composites is higher than that of wulung bamboo laminate composites.The percentage of water absorption of the apus bamboo laminate composite (GA) is the largest at 3.64%, the wulung bamboo laminate composite (GV) is the largest at 3.01, each under the condition of square root of time 700 sec

Bamboo fibre belongs to cellulose fibre. Its water absorption properties are higher than fibreglass. High water absorption is a major drawback of cellulose fibres, as the main cause of degradation in the mechanical performance of the composite. Cellulose fibres absorb moisture due to their hydrophilic nature caused by the presence of multiple H-bonds (-OH groups) between the cell wall macromolecules in the fibre. When the fibre comes into contact with moisture, the H-bonds will be broken and the -OH groups will form new H-bonds with water molecules. Thus, it can be concluded that hydrophilic -OH groups are the main source of water absorption in cellulose fibres. There are more H-bonds (-OH groups) in GA bamboo fibre than in GV bamboo fibre. Therefore, the absorption percentage of GA bamboo fibre is higher than that of GV bamboo fibre at the same square root of time.

According to the study results[7]water absorption is determined by the percentage of fiber content volume fraction. Similarly, [8] also evaluated the water absorption behavior of sisal/urea-formaldehyde composites with different fiber wt. % (10, 20, 30, 40, 50, 60 and 70%). The lowest water absorption for the composite with 30 wt% fiber was only 0.98 wt%, which was attributed to the strong bonding between the fiber and the matrix. Water absorption was found to be directly proportional to the fiber concentration when the water absorption behavior of unidirectional jute/epoxy composites was studied[6] found that unidirectional palm fiber/vinyl ester resin composites showed the lowest water absorption values compared to bidirectional fiber composites. However, all composites showed high water absorption compared to pure vinyl ester, which may be due to the incompatibility between the fiber and the matrix resulting in microbubbles and voids.



Moisture Absorption of Bamboo Varieties Gigantochloaapus And Gigantochloaatroviolacea

IV. CONCLUSION

The percentage of water absorption of apus bamboo laminate composites is higher than that of wulung bamboo laminate composites.The percentage of water absorption of the apus bamboo laminate composite (GA) is the largest at 3.64%, the wulung bamboo laminate composite (GV) is the largest at 3.01, each under the condition of square root of time 700 sec. Bamboo fibre belongs to cellulose fibre. Its water absorption properties are higher than fibreglass. High water absorption is a major drawback of cellulose fibres, as the main cause of degradation in the mechanical performance of the composite. Cellulose fibres absorb moisture due to their hydrophilic nature caused by the presence of multiple H-bonds (-OH groups) between the cell wall macromolecules in the fibre. When the fibre comes into contact with moisture, the H-bonds will be broken and the -OH groups will form new.

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