Analysis of mechanical strength of woven strip composite at petung bamboo (*Dendrocalamus asper*) epoxy resin tape: tensile strength properties of bamboo strips

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**Abstract.** One of the natural ingredients that have a good prospect to be used as the material of reinforcement of composite material is bamboo. Bamboo in its availability in the territory of Indonesia is quite abundant, as in the area of Tana Toraja South Sulawesi Province. This study aims to see how far the pretreatment can affect the tensile strength of woven bamboo strip composite. The test method used to analyze the tensile strength of bamboo strip composite weaving is based on ASTM D 638-02 standard. The results showed that the duration of immersion affected the tensile strength of the bamboo woven strip composite wherein the treatment of water sulfur immersion the tensile strength was increased with the variation of the duration of immersion time of 1 day, two days, and three days respectively by 89.70 MPa, 125.44 MPa, and 159.01 MPa. While the treatment of soaking water sulfur and continued at seawater immersion treatment with the variation of time immersion time of 1 day, two days, and three days respectively obtained that is 95.92 MPa, 130.69 MPa, and 165.03 MPa. While the tensile strain of bamboo woven strips on immersion of water of sulfur and without immersion of seawater (TPAL) with the variation of immersion time of 1 day, two days, and three days consecutively obtained by 1.58%, 2.00%, and 2.86 %. While the immersion of water sulfur and continued on the immersion of seawater (PAL) with the variation of immersion time of 1 day, two days, and three days respectively obtained by 1.65%, 2.60%, and 3.09%.

**1. Background**

Indonesian people generally do not comprehend about natural fiber; many of them consider it as useless material or garbage. However, by the advancement of engineering technology, composite materials have experienced significant developmental progress, especially in the manufacturing industry. The use of natural materials as composite reinforcing materials becomes the benefits of engineering technology and innovation. Natural materials which have prospects to be used as reinforcement of composite materials are bamboo. Bamboo is the name of woody tree-shaped grass or shrubs collection that is curved, with stems that are usually upright sometimes uphill, wooded and branched, can achieve longevity and often die without flowers. In Indonesia, Bamboo has many types,
and the availability is quite abundant, one of them is petung bamboo in Toraja land of South Sulawesi Province.

Bamboo is an essential biological resource, not only because of its enormous potential but also its utilization rate is higher for example for household appliances, handicrafts, foodstuffs, building materials, etc [1]. In terms of physical and mechanical properties, petung bamboo (Dendrocalamus asper) is a potential structural component for building materials, such as furniture, household needs, and simple houses. Nonetheless, it is still not resistant to wood pests, for example, dry wood powder [2,3]. Bamboo has a great opportunity as an alternative raw material for composite manufacturing production. The growth of bamboo is fast, economical/inexpensive, renewable, and abundant throughout the world. Besides, bamboo has high-grade of physical and mechanical properties and can be compared to other commercial wood species.

The matrix ability in dividing the load on the reinforcing fiber is strongly influenced by the adhesive fibers ability to stick to the matrix. The adhesive ability is significant to guarantee the strength of the composite because the adhesion between fibers with a low matrix results in fiber removal and shifting. As a result, it certainly reduces the strength of the composite. Epoxy resins are used as fiber adhesives which belong to a group that has high strength and resistance to environmental degradation. It is widely used in the aircraft industry, as an epoxy coating resin which has superb adhesion properties and is resistant to water degradation, so is ideal as the body of a boat or ship [4]. This study aims to determine the effect of the soaking time of bamboo woven strips (Dendrocalamus Asper) on the tensile strength properties of sulfur water and seawater with the epoxy resin matrix.

2. Research Method

2.1. The materials

Bamboo (Dendrocalamus Asper) as a reinforcement as well as hot sulfur water used as a soaking medium were obtained from Lembang Tokesan area, Sangalla District, Tana Toraja Regency, South Sulawesi Province. The immersion site in Makula sulfur water bath, Lembang Tokesan, Sangalla District, Tana Toraja, South Sulawesi Province. While the matrix is a type of thermosetting plastic, namely epoxy resin with a resin and hardener ratio of 60:40 which was derived from PT. Justus Kimia Raya, Semarang branch.

2.2. The tools

![Figure 1. Go tech universal testing machine](image)

Mold, made of steel size 250 mm x 250 mm, measuring cup 500 ml, syringe 3 ml (to measure catalyst), room thermometer, water thermometer, knife, spoon, scissors, brush and roll, callipers, sandpaper, scales, scale digital and electric ovens. Composite tensile testing equipment (ASTM D 638-02 type I standard) used Go Tech brand Universal Testing Machine, KT-7010A2 model, capacity
1000 Kg, production of Kao Tieh Machinery industrial CO., LTD, 1995. During the tensile test, the speed of the tensile machine was 4 mm/minute.

2.3. Bamboo woven strip testing
The first activity of this research was the manufacture of bamboo into strips with 1 mm thickness and 250 mm length, after a sufficient number of bamboo strips were needed then the bamboo strips were woven in plain shapes with a size of 250 mm x 250 mm. Then, the woven bamboo is weighed to find the water content before being immersed in sulfur water. This woven bamboo undergoes treatment with variations in the immersion time of 1 day, two days, and three days respectively. After the sulfur water immersion, there is the further treatment of seawater immersion with similar time variations as sulfur water [5].

2.4. Printing process
The composite printing process uses a press which makes of 250 mm x 250 mm steel plates. The steps of printing this composite specimen, namely: tools and materials must be prepared in advance, the first step is to pour the resin and hardener according to the ratio that has been determined into a measuring cup. Mix the resin and hardener in a container then stir the mixture evenly, pour the resin and hardener mixture into the mold sufficiently, then flatten until all of the mold areas is filled. After that, insert the bamboo woven strip into the mold and pour the liquid mixture of resin and hardener on it, make it until 3 ply woven bamboo strips. Cover the mold with a lid which was also made of a steel plate then press it with a hydraulic press. The aim is the composite thickness is up to standard, wait for 6-8 hours for the mold to dry/harden. After drying, the composite molds were removed and were still in the form of plates. Then, the slab was affixed with paper which had been drawn by tensile test specimens according to ASTM standards (width, length, and thickness were appropriate) and cut off using a sawing machine to follow the shape of the drawing. Finishing results were done using a file and fine sandpaper so that the outer surface of the test specimen was smoother and flat. Then, the specimen was ready to be tested.

2.5. Composite pulling testing
Tensile test specimens based on ASTM D638-02 type I standard, with dimensions of test specimens Width of narrow section \( W = 13 \pm 0.5 \) mm, Length of narrow section \( L = 57 \pm 0.5 \) mm, width overall, min \( (W_o = 19 \pm 6.4) \) mm, Length overall, min \( (L_o = 165) \) mm, Gage Length \( (G = 50 \pm 0.25) \) mm, Distance Between Grips \( (D = 115 \pm 5) \) mm, Radius of fillet \( (R = 76 \pm 10 \) mm, Thickness \( (T) \) according to the thickness of the test material. The number of tensile test objects was 8 (eight) pieces. It aims to obtain a valid sample.

2.6. Tensile testing steps
Measuring dimensions of specimens include length, width, and thickness. Labeling in the serial number and woven bamboo on each specimen has been measured to avoid the errors of recording data. Turn on Geo-Tech universal engine to do a tensile test; installation of test specimens on the holder (tap) of the tensile testing machine; gently attach the specimen so that it is perpendicular, then tighten the specimen so that it does not slip on the holder. In this case, do not tighten because it can damage the test specimen. Place the elongation pointer on the length of narrow section line then determine the load used in testing and speed. Loading was used at a constant speed of 4 mm/minute with a large loading \( P = 1000 \) kg; after the machine turned on, we observed the load indicator number on the test machine and the indicator elongation, the figure showed the maximum load and the extension of the test specimen when it broke; the machine automatically recorded the stress-strain curve on graph paper; after getting the data the test results continued with the calculation of the characteristics of the tensile strength.
3. Result and discussion

3.1. Tensile strength of woven bamboo-composite strips

The aim of tensile testing of woven bamboo composites determines one of the mechanical properties of bamboo (Dendrocalamus Asper) which the tensile strength of the composite woven bamboo strips is shown as in figure 2.

![Figure 2. Relationship of pull strength of bamboo strip composite to soaking time](image)

Figure 2 shows that the immersion of composite woven bamboo in sulfur water without seawater treatment (TPAL) with variations in time of 1 day, two days and three days were 89.70 MPa, 125.44 MPa, and 159.01 MPa. Then, It continued with seawater immersion (PAL) with a variation of 1 day, two days, and three days respectively were 95.92 MPa, 130.69 MPa, and 165.03 MPa. From the two treatments, it can be concluded that immersion using sulfur water (TPAL) produces less tensile strength compared to subsequent submersion in seawater (PAL). The results of immersion in sulfur water and then continued seawater immersion have an impact on the increased mechanical properties of bamboo woven strips, especially the tensile strength properties as in the picture above.

The results are in line with several studies on bamboo woven strip composites. Including Mechanical reinforced composites properties of the bamboo strip with a polyester matrix with variations in strip arrangement are obtained the highest stress occurs in elongated fiber structures [6]: compressive strength and flexural material of epoxy bamboo fiber composites. The material is bamboo fiber petung, borax, and boric acid and aquadest as a solvent. The result is that preservative chemicals increase the tensile strength of bamboo [7]. The use of bamboo material as an alternative composite material for making boat shells replacing wood material shows that the direction of the radial and tangential slices of bamboo fiber does not significantly influence the strength of the composite material (BRP). Factors that significantly influence the strength of the BRP composite material are bamboo species, and fiber variation (woven, non-woven and random fiber) [8].

3.2. Tensile strength pull of woven bamboo strips

The tensile strain properties of the bamboo woven strips to the soaking time are shown in figure 3.

![Figure 3. Relationship of pull structure of bamboo webbing composite strip to soaking time](image)
Figure 3 shows the relationship between the tensile strain of composite woven bamboo strips on the immersion time. The tensile stretch of woven petung bamboo strips on sulfur water immersion and without seawater immersion (TPAL) with variations of immersion time of 1 day, two days, and three days respectively were obtained at 1.58%, 2.00%, and 2.86 %. Whereas sulfur water immersion and continued with seawater immersion (PAL) with variations in the immersion time of 1 day, two days, and three days were 1.65%, 2.60%, and 3.09 % respectively. If compared to TPAL treatment with PAL in accordance with the immersion time, the increase in tensile strain strength was obtained for 1 day, 2 days and 3 days respectively by 4%, 23% and 7% whereas if it was referred to the smallest tensile strain strength value then it was obtained by 4%, 39%, and 49%.

4. Conclusion
The results of the study conclude that soaking time affected the tensile strength of the petung bamboo composite. Sulfur water immersion treatment obtained increased tensile strength with variations in the immersion time of 1 day, two days, and three days respectively 89.70 MPa, 125.44 MPa, and 159.01 MPa. Whereas sulfur water immersion treatment continued with seawater immersion with variations in 1 day, two days, and three days respectively were 95.92 MPa, 130.69 MPa, and 165.03 MPa. While tensile stretching of petung bamboo in sulfur water immersion and without seawater immersion (TPAL) with variations of time of 1 day, two days, and three days were obtained by 1.58%, 2.00%, and 2.86 %. Whereas sulfur water immersion continued with seawater immersion (PAL) with variations of 1 day, two days, and three days were respectively 1.65%, 2.60%, and 3.09%. Utilization of sulfur water and seawater can function as a medium for increasing mechanical strength, as long as the absorption by petung bamboo-composite has not reached its saturation point.

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