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# Bamboo Fiber Commodity in Bali - Reinforced-Composite for Sokasi Craft to Increase The Tourism Products

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## Abstract

This study aims at improving community's prosperity and developing economy in rural community area especially of thosewith low income. The purposes of the study are elaborated as follows: (1) to identify the natural potential fiber which has not been used to substitute glass fiber and (2) to create environment friendly fiber to substituteglass fiber. The research suggested in this study is to engineer material from bamboo fiber to increase commodity of tourism products in Bali by producing a craft productwhich is this case is *sokasi* (Balinese traditional basket). Methodology used in the product development (natural fiber) was *prototyping*. Need analysis and data collection were conducted through interview, documents, field observations, and literature review. The result of the study and the implementation conducted by the research team had createdsokasi (Balinese traditional market)which was made of bamboo fiber material. Bamboo fiber-reinforced-polymer composite at reinforcement volume fractionof2.5% has characteristic value which is very close to the ideal value with tensile strength 38.57 MPa, elasticity modulus 1326.92 MPa, and density 1.203 gram/ml.

***Keywords***: Potential natural fiber;  Glass fiber; Tourism products; *Prototyping*

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## 1. Introduction

Society's need has been increasing along with the development of the world.Therefore, society should be able to make use of nature to support their economy improvement. One of the ways is to create new materials which come from nature. This is because the need of materials tends to increase every year and qualified and cheaper new materials are needed.

In human culture, people use natural fibers as one of the life supporting materials, such as ijuk (fibers made of sugar palm tree) as material for building construction. Balinese society knows ijuk (fibers made of sugar palm tree)as one of the materials for building construction especially for Balinese traditional roof and other natural fibers which function as material for clothes. Natural fibers can be used to support daily life. Along with the development of material technology, the role of natural fibers gradually is being replaced by fibersmade of synthetic material such as glass fiber or carbon fiber. With some innovations conducted in material field, now natural fibers are being noticed to be made as composite reinforcement material. Being elastic, abundant, environmental friendly, and cheaper in term of production cost are the benefits of natural fibers (Indran *et al.*, 2014; Jawaid *et al.*, 2005; Abilash *et al.*, 2013).

Indonesia as a country with rich biologicaldiversity has big opportunity to explore the use of natural fiber as composite reinforcement material. Because natural fiber's strength varies, the ability, starting from composite material for light use which does not need highstrength to composite material which needs high strength, varies too.

Bamboos are plants which are easily found in all regions in Indonesia where the climate is good to grow easily. Bamboosare mostly used in Indonesia such as for home construction, food (bamboo sprouts), and crafts. Researches on composites have been done. Grain size and the volume fraction of the composite material filler affect the mechanical properties of the material composite (Nicole *et al.*, 2003).

The research is about engineeringacomposite material which is reinforced by bamboo fiber to make sokasi craft in order to increase tourism products commodity in Bali. Generally, the study is aimed to know the effect of implementation of sokasi made of bamboo fiber-reinforced-composite to trigger sustainability of sokasi craft in Pengelipuran, Bangli, Bali.

Pangelipuran Village which is located in Kubu Sub District in Bangli District is one of the best and the most producers of bamboo in Bali. The topography of the village is in certain ways where the main area of the village is higher than the rest and it gets lower to the downstream area. In the village, there are Penataran and Puseh Temples which are said to be unique and specific area of the village where the street there is only for pedestrians and at both sides of the road are full of village structural attributes such as penyengker (high wall/fence which surrounds every house in Bali), angkul-angkul (village gate/entrance) and uniformed telajakan(piece of part of or a highway or village street in front of side yard). The uniformity of the village is caused by the consistency of shape and also the soil material for penyengker, angkul-angkul,and roofmade of bamboos for all of the buildings in the village. The use of bamboo for roof, wall, or other parts of the house is automatically a must because the village is surrounded by bamboo forests which are still in Penglipuran territory. The forests later can be used as one of the main source of the raw material for natural fiber in order to develop environment friendly local tourism products.

*Sokasi* (bamboo weaving basket) is a kind of craft product which is usually used to place fruit and other food. Sokasi is usually made from bamboo which is weaved manually by craft-makers in Pengelipuran, Kubu sub district, Bangli District (Figure 1).

Specifically, the purpose of the study is to createsokasi as one of Bali tourism products based on new material which is made of strong composite material, well qualified,and with similar strength with composite made of chemical substance such as glass fiber. The natural substance in this study is bamboo fiber. The finding of the study is to be wide implication in the fields of home industry, crafts, automotive, or other sectors.

## 2. Methods

Reinforcement volume fraction of each fiber is made equally to compare the composites with each other. The reinforcement fraction variations are 2.5; 5; 7.5; 10 and 12.5%. Unreinforced-polymer-composite was made as comparing sample to reinforced sample. Polymer matrix used was BQTN 157 unsaturated resin polyester.The properties of polymer matrix are:

- Density ($\rho$) : 1,2 g/cm$^3$
- Tensile Strength ($\sigma$) :12,07 N/mm$^2$
- Modulus of elasticity (E) :1,18.103 N/mm$^2$
- d. Poisson ratio ($\gamma$) : 0,33

Additionally, the catalyst was added in the form of MEKPO (Methyl Ethyl Ketone Peroxide). It served as a curing agent, shortened curing time, and increased cross linking the polymer. Bamboo was used as filler. Bamboo has a density of 0.72 gr / cm$^3$. Geometry and the dimensions of tensile test specimens were based on ASTM D 638M-93 Type M-I (ASTM, 2000a).

Sokasi which is made from bamboo has gone through some development starting from the size, kind, weaving type, motif and the color. Those changes makesokasi vary nowadays. However, the production process is still complicated and it takes 1 until 2 days to produce a sokasi. This Sokasi press will use hardener to strengthen and to make it more durable than the conventional sokasi. The process of motif and type making can be easier because the press will be made based on consumers' need and request.

## 3. Result and Discussion

The data which derived from tensile test result were then analyzed to get data on tensile strength, elasticity modulus, and composite density. The result is displayed in Table 1 and Table 2.

Tensile strength indicates the ability to receive load or tensionwithout breaking or cutting the composite. This is stated by maximum tensile before cut or known as ultimate tensile strength (UTS). In this study, the tensile strength is around 22.13 MPa-40.82 MPa.

### *3.1 Composite tensile strength of bamboo fiber-reinforced-polyme*r

The result of data analysis showed that at reinforcement volume fraction of 2.5%, composite with the highest ultimate tensile strength was obtained which was 38,57 MPa. The lowest ultimate tensile strength was at reinforcement volume fractionof 12.5% which was 22.67 MPa. Trend of composite tensile strength with bamboo reinforcement volume fluctuated. The composite tensile strength values on each reinforcement volume fractionof 5 %, 7.5%, and 10% were 31.06 MPa, 24.99 MPa and 30.78 MPa (Figure 3).

At the reinforcement volume fraction of 2.4%, composite with the highest elasticity modulus, which was 1326.9 % MPa, was obtained. The lowest elasticity modulus, which was 221.502% MPa, was obtained at reinforcement volume fractionof 12.5%. At composite with reinforcement volume fraction from 0% to 2.5%, there was increase of elasticity modulus before it tended to decrease at the reinforcement volume fraction which was higher than 2.5% even though it increased again at the reinforcement volume fraction of 10%. The elasticity modulus at other reinforcement volume fraction for each reinforcement volume fraction of 5%, 7.5%, and 10% were 660.694% MPa; 408.980%, and 626.134% MPa.

### *3.2 Composite tensile strength of glass fiber-reinforced-polymer*

At reinforcement volume fraction of 2.5%, composite with the highest ultimate tensile strength, which was 40.82 MPa, was obtained. The lowest ultimate tensile strength, which is 22.13 MPa,was obtained at reinforcement volume fractionof 10 %. At Figure 4, generally there is increase trend of composite tensile strength from reinforcement fraction of 0% to 12.5%. However, at reinforcement volume fractionof 2.5% there was increase of composite tensile strength which was higher than reinforcement volume. There was unusual decrease of composite tensile strength at reinforcement volume fraction of 10%. Other composite tensile strength at each reinforcement volume fraction of 5 %, 7.5%, and 12.5% are 32.12 MPa, 24.87 MPa, and 37.08 MPa.

At reinforcement volume fraction of 10%, composite with the highest elasticity modulus, which was 916.220% MPa, was obtained. The lowest composite elasticity modulus was obtained at 12.5% ofreinforcement volume fraction which was 267.313% MPa. The trend of composite elasticity modulus with glass fiberreinforcementshould have increase trend. However, the results obtained were unorderly trend. The composite elasticity modulus on each reinforcement volume fraction of 2.5%, 5%, and 7.5% were 809.108%; 457.8%; and 420.632% MPa.

The composite tensile strength of glass fiber-reinforced-polymer must be higher than bamboo fiber-reinforced-polymer composite. This is because bamboo fiber reinforcementis lower than fiberglass reinforcement (Joseph *et al*, 1996). However, the results of reinforcement volume fraction vary. At certain reinforcement volume fraction, the reinforcementis even lower than unreinforced composite or with 0% of reinforcement volume fraction. This is because the void result is bigger which causes fiber-reinforced-polymer composite easy to break during tensile strength test. On two types of composites with 2.5% of reinforcement volume fraction, tensile strength is close to the ideal prediction result. It is because there is increase of fiber reinforcementconcentration around the area of cutting. At 5% of reinforcement volume fraction for each type of composite and glass fiber- reinforced-polymer composite with 10% of reinforcement volume fraction, there is defect which causes the location of cut is not in the gauge area but near clamp base because there is higher concentrationof tensionin the area. Generally, there are some factors which affect tensile strength of fiber-reinforced-polymer composite such as the bond between fiber and the matrix, coulomb style, adhesion, void, fiber's mechanic and matrix characteristic, fiber type, fiber shape, fiber location, catalyst, and reinforcement volume fraction towards the matrix. Due to the resin structure model (including thermoplastic polymers) which is semicrystalline which comprises a polymer chain where its configuration is neatly arranged (lamellar) and is interspersed by parts consisting of unarranged polymer chains. When the specimen is subjected to voltage, it will experience some phenomena (Pothan *et al.*, 2005; Robles *et al.*, 2015; Ramesh *et al.*, 2014) which are interlamellar stretching where the amorph part will be experiencing changes; intracrystalline slip, where the lamellar part experiences change and lamellar plate experiences slip. Next, configuration polymer chains will be directed towards the load pull. If this is continued, the chain will break (Porras *et al.*, 2015).

For elasticity modulus of the two types of composite, the results vary and fluctuate. The accuracy of composite elongation of fiber-reinforced-polymer which isobtained after tensile test also influences the value of composite elasticity modulus. The higher the value of composite elongation, the higher the value of elasticity modulus.At reinforcement volume fractionof 2.5%, polymer composite of bamboo filler with the highest elasticity modulus, which was 1326.9 MPa, wasobtained. The lowest composite elasticity modulus, which was 221.502 MPa, was obtained at reinforcement volume fraction of 12.5%. For glass fiber-reinforced-polymer composite, composite with the highest elasticity modulus, which was 916.220 MPa, was obtained at 10% of reinforcement volume fraction. The lowest composite elasticity modulus, which was 267.313 MPa, was obtained at 12.5% of reinforcement volume fraction. What can be explained from the results is that the modulus elasticity should be in line with the increase of reinforcement volume fraction and the void is also can be considered as one of the causes. Figure 5 shown defected composite.

The bond between the matrix and the filler should be strong (Bismarrack, 2002; Cousins, 1976; Mukhopadhayay & Srikanta, 2008). If the bond is strong enough, then a reinforcement mechanism may occur. On the other hand, when bonding between surfaces particle and matrix is not good, the filler will only function as impurities or impurities within specimen. The result of density test shows that there is decrease trend. The higher the reinforcement volume fraction on bamboo-reinforced-polymer composite, the lower the density of bamboo fiber-reinforced-polymer composite. On the contrary, density of glass fiber-reinforced-polymer composite is in line with the increase of reinforcement volume fraction. This matches the existing theory. The cause is the characteristic of fiber reinforcementand the matrix which forms the composite.

From the results of data analysis in figure 3 and 4 shows the tensile strength between the two types of polymer composites both with bamboo fiber reinforcement and fiberglass reinforcement experienced an up and down trend. There should be an increasing trend in tensile strength for both types of composites to the volume fraction of the amplifier.

## 4. Conclusion

From the analysis, it can be stated that composite determination which is close to the ideal composite mechanic characteristics which are strong, stiff, and light at 2.5% of reinforcement volume fraction for each composite has been found. Bamboo fiber-reinforced-polymer

**Figure 1.** Traditional bamboo sokasi produced with conventional production method

**Table 1.** The result of characteristic of bamboo fiber reinforcement

| Filler fraction (%) | σ (MPa) | E (MPa) | ρ (gr/ml) |
|---|---|---|---|
| 0 | 29.07 | 371.906 | 1.213 |
| 2.5 | 38.57 | 1326.92 | 1.203 |
| 5 | 31.06 | 660.694 | 1.191 |
| 7.5 | 24.99 | 408.980 | 1.187 |
| 10 | 30.87 | 626.134 | 1.178 |
| 12.5 | 22.67 | 221.502 | 1.166 |

**Table 2.** The data result of characteristic of glass fiber reinforcement

| Filler fraction (%) | σ (MPa) | E (MPa) | ρ (gr/ml) |
|---|---|---|---|
| 0 | 29.7 | 371.906 | 1.213 |
| 2.5 | 40.82 | 809.108 | 1.247 |
| 5 | 32.12 | 457.862 | 1.273 |
| 7.5 | 34.87 | 420.632 | 1.310 |
| 10 | 22.13 | 316. 220 | 1.315 |
| 12.5 | 37.08 | 267.313 | 1.321 |

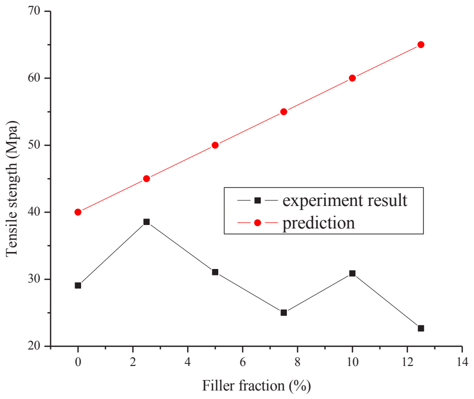

**Figure 3**. Composite tensile strength of bamboo fiber-reinforced-polymer

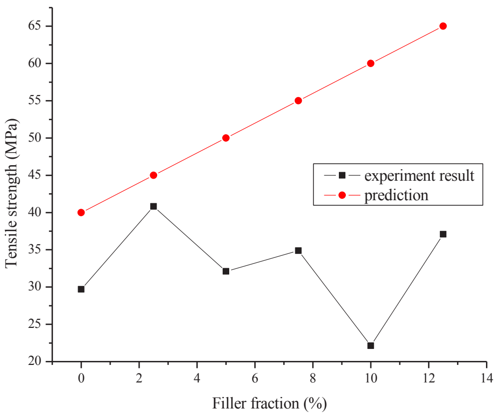

**Figure 4.** Composite tensile strength of glass fiber-reinforced-polymer

**Figure 5**. Defected Composite.

composite at reinforcement volume fraction of 2.5% has characteristic value which is very close to the ideal value with tensile strength 38.57 MPa, elasticity modulus 1326.92 MPa, and density 1.203 g/ml.

From the composite determination, it can be concluded that polymer composite material with bamboo fiber as the reinforcement can be used as alternative to substitute glass fiber as raw material in sokasi craft production. This can be compared with conventional metal like rolan steel in terms of tensile strength. Composite material replaces it as alternative material because rolan steel's tensile strength for kettle raw material which is based on the standard of JIS G3103 is between 35 MPa and 42 MPa. At reinforcement volume fraction of 2.5% and more, bamboo fiber-reinforced-polymer composite density can be lower than rolan steel density. Composite density of rolan steel is around 7.5 gram/ml to 8 gram/ml. This is a benefit of bamboo fiber-reinforced-composite because it is lighter and can be used to substituterolan steel which is heavier.

From the parameters of mechanic characteristics of some materials, it can be concluded that mechanic characteristics of a desired material depend on the process of material selection which is based on the application of certain purpose. Therefore, bamboo fiber is very suitable to be used as raw material for sokasi product in Pengelipuran Village in Bangli District, Bali.

## Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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