

# The Tensile Strength Evaluation of Untreated Agel Leaf/Jute/Glass Fiber-Reinforced Hybrid Composite

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**Abstract.** The aim of this study is to obtain and compare the tensile strength of untreated agel leaf/jute/glass fiber-reinforced hybrid composites. Six types of composite specimens are fabricated using hand-layup followed by vacuum bagging method. Unsaturated polyester is used as matrix and fibers are not chemically treated. Each type of specimens is reinforced using 7 plies of fibers with different stacking sequences. Pure untreated agel leaf fiber-reinforced composite is used as control variable. All specimens are tensile tested under ASTM D638 condition. The results show that pure untreated agel leaf fiber-reinforced composite has the lowest value of tensile strength. Agel leaf/jute fiber-reinforced composite has bigger tensile strength than pure agel leaf fiber-reinforced composite. Incorporating glass fiber can enhance the value of tensile strength significantly and this value is proportional to the quantity of glass fiber its self.

## 1. Introduction

Composite is a material consists of two or more constituents, matrix and reinforcement, which are combined at macroscopic scale and not soluble in each other [1]. Composite can be used for various applications and has high opportunity to support new properties in material by controlling its constituents. Reinforcements play significant role in determining the properties of composite, especially its mechanical properties. In general, synthetic fibers are commonly used as composite reinforcement. Glass fibers are frequently used due to their low cost (cheaper than aramid or carbon) and relatively better mechanical properties [2]. Nonetheless, the waste of composite made of synthetic fiber (such as glass) brings negative impact to the environment<sup>2</sup>. So that, alternative reinforcement must be applied to reduce this effect.

The use of natural fibers for composite reinforcement is increasing to replace the current synthetic fibers. Natural fibers are biodegradable, low cost, and renewable [3]. Also, many scientists and engineers are attracted to develop this composite for application in low-cost household devices and automotive interior<sup>1</sup>, so that it can enhance the economic value of natural fibers [4]. Some natural fiber commonly used to reinforce composites have been studied, such as banana [5-7], coir [8,9], bamboo [10-12], etc. Study on jute fiber (*Corchorus olitorius*) also has been consideration cause of its abundance<sup>4</sup>. Study on mechanical properties of untreated jute-reinforced composite has been done [13]. It concludes that jute has potential to be used as composite reinforcement, since it is not better than any synthetic fiber, such as fiber glass reinforcement. Nevertheless, jute is eco-friendly, harmless effect on environment, and low-cost [13].



Another natural fiber potentially used as composite reinforcement is agel leaf fiber. This fiber can be obtained from gebang trees (*Corypha gebanga*) which grow in Kulon Progo regency, Indonesia. The use of this fiber for composite purpose is not optimally explored yet and still limited. A study on agel leaf fiber for composite material has been done [14]. The results indicate that agel leaf fiber competitively can be used to reinforce composites.

Nowadays, many researchers are actively investigating hybrid composites which incorporating synthetic and natural fiber as the reinforcement. Synthetic/natural fiber-reinforced hybrid composites show intermediate characteristic between natural and synthetic fiber-reinforced composites [15,16]. Also, improvement in tensile properties of natural fiber-based composites is able to be obtained by hybridizing them with glass fiber [17-22].

This study will focus on the tensile properties evaluation of untreated agel leaf/jute/glass fiber-reinforced composites.

## 2. Methods

### 2.1. Materials

Natural fibers, agel leaf and jute, are bought from local handicraft center in the form of woven. Synthetic fiber (woven roven glass fiber) is bought from Justus Kimia Raya Ltd. The weight of agel leaf, jute, and glass fibers are 120, 160, and 200 gsm, respectively. Unsaturated polyester resin (YUKALAC 157 BTQN-EX, Justus Kimia Raya Ltd.) is used as matrix and Methyl ethyl ketone peroxide type A (MEPOXE, Justus Kimia Raya Ltd.) is used as curing agent.

### 2.2. Composite fabrication

A combination of hand lay-up and vacuum bagging method has been used to prepare the composites. For easy removal of specimens, the working surface is treated with mold release wax. The matrix is prepared by mixing unsaturated polyester resin with Methyl ethyl ketone peroxide, the curing agent, in a weight ratio of 100:1. Every specimen is composed of 7 layers of fiber with 6 different conditions of stacking sequence (Table 1). ALF, JF, and GF stand for agel leaf fiber, jute fiber, and glass fiber, respectively.

The unsaturated polyester resin is poured on to fiber surfaces. After that, fibers are stacked according to the stacking sequence configurations. Then hand-rolled to release any entrapped bubbles between layer spaces. After that, specimens are vacuum-bagged for 1 hour then let them cured for 24 hours.

**Table 1.** Stacking sequence condition of specimens.

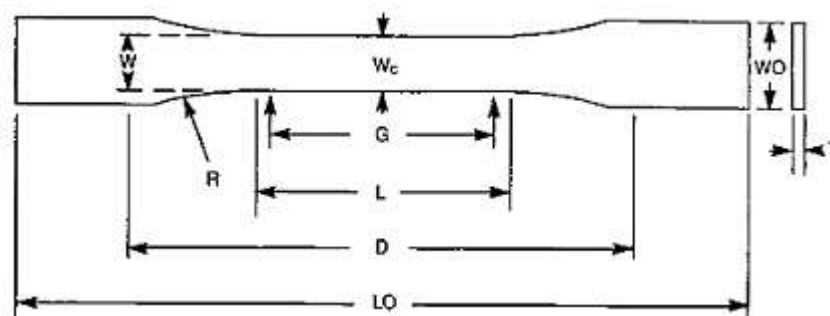
Code of Specimens	Stacking Sequence	Number of Layer		
		Agel Leaf	Jute	Glass
A	ALF- ALF- ALF- ALF- ALF- ALF- ALF	7	0	0
B	JF- JF- JF- JF- JF- JF- JF	0	7	0
C	ALF-JF- ALF-JF- ALF-JF-ALF	4	3	0
D	ALF-JF-ALF-GF-ALF-JF-ALF	4	2	1
E	GF-ALF-JF-ALF-JF-ALF-GF	3	2	2
F	GF-ALF-JF-GF-JF-ALF-GF	2	2	3

### 2.3. Specimens testing

Composites are cut into tensile test specimen based on ASTM D638 standard. This experiment uses Type I with dimension as shown in Table 2 and Figure 1. Every specimen will be tensile tested using Tensilon RTF2410 for three times with 2mm/minute of tensile speed, then results are calculated to obtain the average value. Fracture profile is examined using Dino-Lite Digital Microscope. All testing and observation are done in room temperature.

**Table 2.** Dimension of tensile test specimen according to ASTM D638 [23].

Dimension	Type I (in mm)
	For T-Thickness of specimen $\leq 7$
W-width of reduced section	13
L-Length of reduced section	57
Wo-Width of grip area	19
Lo-Overall length	165
G-Length of gage	50
D-Distance between grips	115
R- Fillet radius	76

**Figure 1.** Tensile test specimen of ASTM D638 [23].

### 3. Results and discussion

#### 3.1. Effect of natural fiber properties on composite

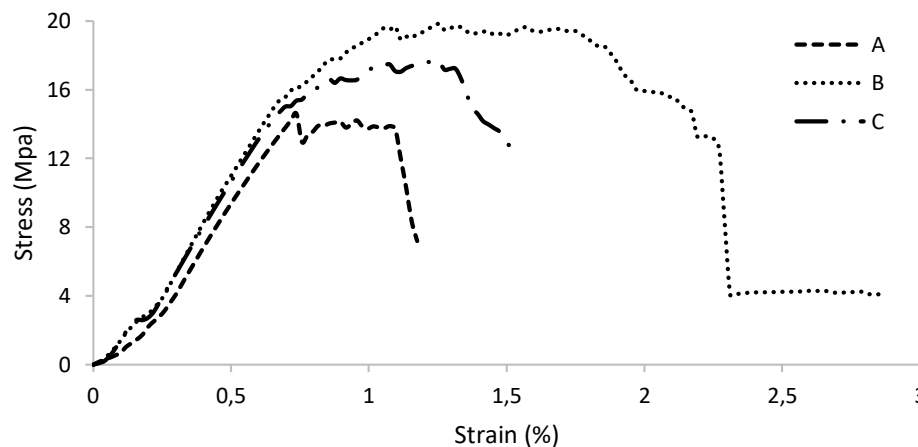
Theoretically speaking, tensile strength of composite is depended on the tensile strength of its reinforcing fibers [24]. Pure jute fiber-reinforced composite shows higher ultimate strength than pure agel fiber-reinforced composite. In this case, we can obtain information that tensile strength of agel leaf fibers is weaker than jute fibers. Mass per meter square of the used jute layer is bigger than agel leaf layer, so the applied load can be absorbed more effectively by jute (until 19,81 MPa) than agel leaf (14,61 MPa).

When agel leaf and jute fibers are stacked together, the value of tensile strength of this composite becomes less than jute fiber-reinforced composite and bigger than agel leaf fiber-reinforced composite. By combining agel leaf and jute fibers, composite shows intermediate tensile strength (17,62 MPa). Figure 2 shows the stress-strain diagram comparing tensile test behavior of pure agel leaf, pure jute, and agel leaf/pure fiber-reinforced hybrid composite.

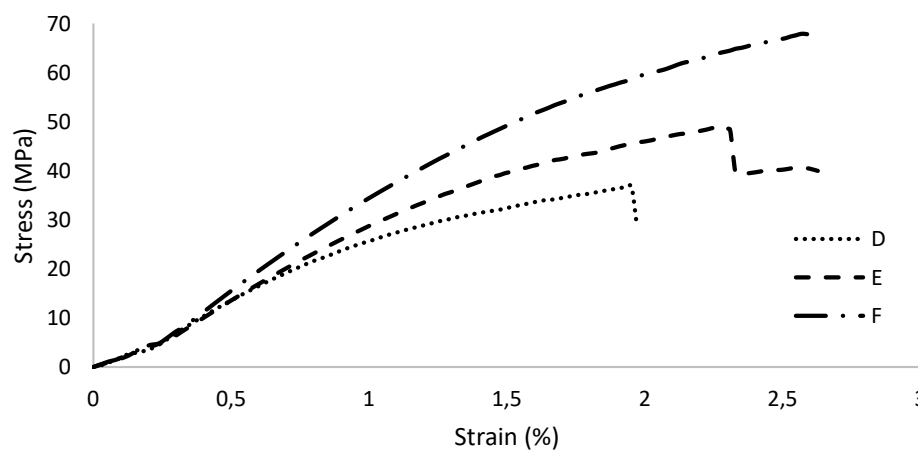
It is shown in Figure 2 that ultimate strength of jute fiber-reinforced composite is higher than pure agel leaf and hybrid agel leaf/jute fiber-reinforced composite. Jute fiber-reinforced composite presents bigger elongation than the other two. This can be indicated from the value of break point strain of specimen B, it is higher than two others. Break point strain of specimen A, B, and C are respectively 1,17; 2,86; and 1,53%.

#### 3.2. Effect of synthetic fiber incorporation on composite

Figure 3 depicts tensile behaviour of specimen D, E, and F using stress-strain diagram. It shows that specimen F has the highest value of tensile strength (67,88 MPa) among the other two. This achievement can be obtained because of specimen F has more glass fibers (3 layers) than specimen D and E (1 and 2 layers, respectively). In this case, the number of incorporated glass fiber in specimen has positive relationship to the value of tensile strength.



**Figure 2.** Stress-strain diagram of specimen A, B, and C.



**Figure 3.** Stress-strain diagram of specimen D, E, and F.

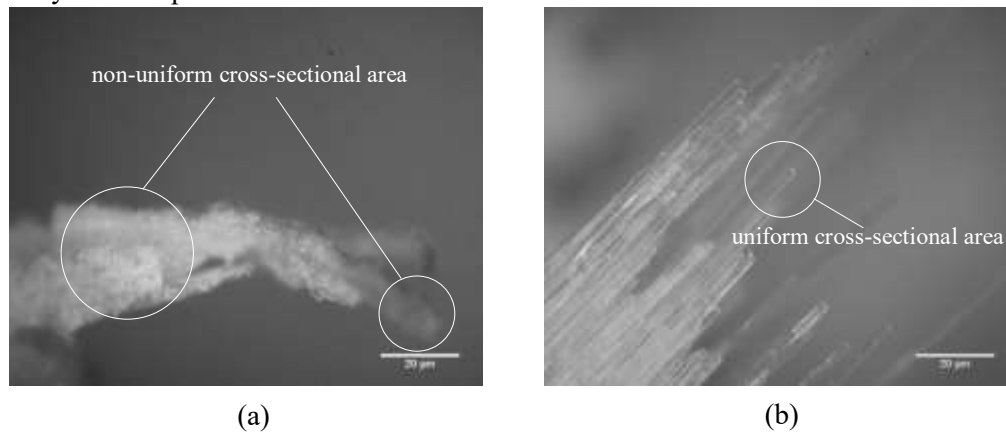
Physically, characteristic of natural fiber is hydrophilic which tends to absorb water. Meanwhile, hydrocarbon based resin, such as unsaturated polyester, is hydrophobic which tends to resist water. This condition leads to poor adhesion between matrices and natural fiber surface which results in poor mechanical properties of composites [25]. Synthetic fibers, such as glass fiber, are not hydrophilic. So, they can contact effectively with resin and make good interfacial bonding. This statement can be confirmed from Figure 3. More glass content in the specimen will result in higher tensile strength. More glass fibers mean more matrices contact with fiber, make an effective load transference from matrices to fiber.

The characteristic of single fiber also affects the tensile behavior of specimens. Glass fiber can accommodate load uniformly and be able to avoid any stress concentration. It is because of its cross-sectional area. Meanwhile, natural fiber has relatively non-uniform cross-sectional area. This can lead to stress concentration and fiber will break more easily. Figure 4 shows micro photographs of broken agel leaf and glass fibers.

### 3.3. Comparison between Natural Hybrid and Glass/Natural Hybrid Composites

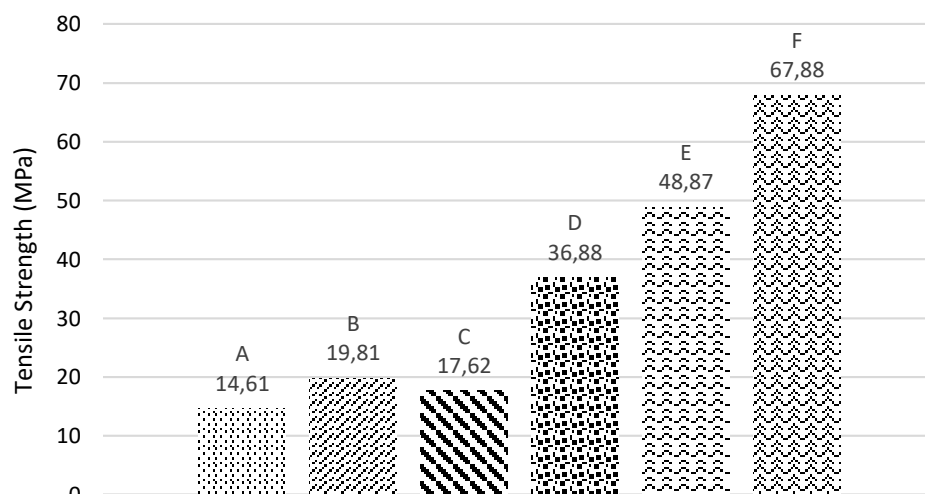
Figure 5 describes the tensile strength value of each specimen. The existence of glass fiber enhances the value of tensile strength significantly. The highest tensile strength of natural fiber only-reinforced hybrid composite is 17,62 MPa (agel leaf/jute fiber-reinforced hybrid composite). This value is progressively increased when incorporated with glass fiber, up to 36,88 MPa for only one layer of glass fiber. In this

study, glass fiber plays important role in improving the value of tensile strength for natural fiber-reinforced hybrid composite.



**Figure 4.** Micro photographs of agel leaf fiber fracture (a) and glass fiber fracture (b).

As shown in Figure 4a, agel leaf fiber is broken at the smallest cross-sectional area which generates high-stress concentration. Whereas, glass fiber, Figure 4b, has uniform cross-sectional area which accommodates uniform load. Minimal stress concentration can be the reason why composite with glass fiber reinforcement exhibits higher tensile strength than pure natural fiber-reinforced composite.



**Figure 5.** The tensile strength value of each specimen.

#### 4. Conclusion

Study on the tensile strength behavior of untreated agel leaf/jute/glass fiber-reinforced hybrid composite has been done. Agel leaf fiber has the lowest value of tensile strength (14,61 MPa) than jute fiber-reinforced composite (19,81 MPa). Hybridizing agel leaf and jute fiber results in intermediate tensile strength value (17,62 MPa). Incorporating glass fiber can progressively enhance the value of tensile strength. The content of glass fiber is positively related to the tensile strength improvement. The highest achievement is obtained in specimen F (67,88 MPa) with three layers of glass fiber, two layers of jute fiber, and two layers of agel leaf fiber.

The characteristic of single fiber affects to the tensile behavior of composites. Agel leaf and jute fiber, which are natural fibers, have hydrophilic characteristic that relatively resist unsaturated polyester resin (hydrophobic). Since glass fiber is not hydrophilic, maximum interfacial bonding between resin and the surface of glass fiber can be formed. This leads in good load transference which results in higher tensile strength.

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