Mechanical characteristics of marble powder composite materials reinforced Kenaf Fiber against static load

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Abstract. Kenaf fibre is one of the strongest natural fibres in the world today. For that purpose, the purpose of this study is to create a new composite of Kenaf fibres combined with marble waste powder. The incorporation of marble powders and Kenaf fibres using a matrix of a polyester resin type has never been done. Thus, this study aims to create and test various composite material composites (mixture of matrix, marble powder and Kenaf fibre) which will produce different mechanical properties and obtain good tensile strength in test specimens with several composition variations. Preparation of test specimens was carried out with 4 (four) compositions of matrix mix and marble powder that is 50:50, 60:40, 70:30 and 80:20 with the weight of Kenaf fibre fixed 2 gram. The largest tensile test value is 63,407 MPa, obtained from 80:20 composition with the largest E value 3.03 GPa. The largest compression test value is 33.49, obtained from the composition of 60:40 with the largest E value of 2.35 GPa. The largest bending test value is 19.80 MPa, obtained from the composition of 80:20 with the largest E value of 36.55 GPa. From the research results of the tensile test, compression test, and bending test which possess good value is between composition ratio 60:40 and 70:30.

1. Introduction
The Kenaf plant (Hibiscus cannabinus L.) is a short-lived herbaceous plant-producing fibers such as hemp, Roselle, and jute. The Kenaf fibers are produced from the bark of the stem. In Indonesia, Kenaf planting spread in Lampung, West Java, East Java, and South Kalimantan with an average productivity of 0.9-1.2 tons/ha of dry fiber [1]. Low productivity leads to high competition at the farm level in obtaining the Kenaf plant [2].

Kenaf fibers have been widely used in various daily life products such as for sacking raw materials, pulp materials, paper, polypropylene composites in the polymer industry and car dashboards. In addition to environmentally friendly, Kenaf fiber is also strong. The mechanical properties of Kenaf pulps derived from Kenaf leather with 6% sodium hydroxide (NaOH) usage have met the NUKP slurry specifications as specified in SNI 6106-1999, ie 4.24 mm long fiber, freeness 760 mL CSF, tensile index 66, 54 Nm / g, crack index 5.72 kPam2 / g and tear index 18.09 mNm2 / g [3].

Various study regarding mechanical properties of Kenaf fiber reinforced-composite have been carried out. Shinji Och (2010), studied the tensile properties of Kenaf fiber extracted from several
Kenaf plants with different characteristics. The study determined how stem diameter and length affect the mechanical characteristics of fibers. It was observed that mechanical characteristics of Kenaf fiber is not ultimately affected by stem diameter and length, however, it is increased as Kenaf increase in height. Additionally, M.R.Ishak, et al., (2010) conducted a comparative study of mechanical properties of short Kenaf bast and core fibre reinforced unsaturated polyester composites with varying fibre weight fraction. The result showed that the Kenaf bast fiber reinforced-composites have higher mechanical properties than Kenaf core fiber composites. The composite with optimum fibre content, 20%, provided the highest tensile strength for both bast and core fibre composites. Moh. Yuazri, et al., (2011) studied the mechanical properties of Kenaf/polyester composites processed through vacuum infusion method. The using of vacuum infusion process in the Kenaf-polyester composite manufactured resulted in a higher strength, low cost alternatives, and environmentally friendly. Furthermore, KotreshSardar, et al., (2014) characterized and investigated the tensile strength of 10%, 20%, 30% and 40% KFRPC material used as Bio-material for tissue implant. According to the results, it is shown Bio-material with 40% of KFRPC material have good tensile strength and might be suitable for tissue implant application, such as for Tendon replacement. Later, A.E. Ismail and M.A. Che Abdul Aziz (2015) studied the effect of fiber orientations and number of layers on the tensile strength of woven yarn Kenaf fiber reinforced polyester composite. The experiment results showed that fiber orientations significantly affected the tensile strength. Nevertheless, it is not affected by the modulus of elasticity for number of layers. In 2016, X.H. Loh et al., investigated the mechanical properties of Kenaf/polypropylene composite with the variations of fiber weight and length. The result showed a higher fiber length improved the impact properties of the composite. Based on these related studies, it can be seen that Kenaf fibre is feasible to be used with various filler combination for biocomposite material development [10].

On the other hand, South Aceh district is well known for Marble stone production. The Marble stone has been widely produced for various home interior need, home appliances, and as a material for carving art. The activity of processing of raw stone into a valuable product produces marble waste that leads to an environmental problem. Thus, this marble waste should be reused to obtain new products that have economic value. For that purpose, this study is conducted to create a new composite of Kenaf fibres combined with marble waste powder.

2. Method

2.1. Method of Manufacture

Before making specimens, special treatment of Kenaf fibers is first soaked in 1% alkaline solution (NaOH) which serves to remove some contents such as lignin, oil, and protein that can cause decay in the fiber. The composition of the specimen was determined as shown in Table 1. The composition differences focused on the resin and marble powder of 20%, 30%, 40% and 50%, while the use of the Kenaf fiber was with a fixed composition of 2%.

Table 1. The composition of test specimens

| No | Specimens type | Polyester Resin % | Marble dust % | Kenaf Fiber % |
|----|----------------|-------------------|---------------|---------------|
| 1  | Specimen A     | 80                | 20            | 2             |
| 2  | Specimen B     | 70                | 30            | 2             |
| 3  | Specimen C     | 60                | 40            | 2             |
| 4  | Specimen D     | 50                | 50            | 2             |
2.2. Measurement Methods
   After the specimens are made with the dimensions as in ASTM standard, some tests are performed as follows:
   1. Tension test according to ASTM D 638-03 standard [11].
   2. Compression test according to ASTM D 695-02a standard [12].
   3. Bending test according to ASTM D790-02 standard [13].
   The test equipment used in a servo Pulser test equipment located at Laboratory of Impact Research Center.

3. Results and Discussion

3.1. Tensile Test
   Tensile strength testing is one effort to know the material characteristics. Tensile tests were performed on 5 specimens per composition so that the average values as shown in Table 2 can be obtained.

| Composition | Max. Stress (MPa) | Break Point Strain (%GL) | Upper Yield Stress (MPa) | Max. Load (N) | E (MPa) | E (GPa) |
|-------------|-------------------|--------------------------|--------------------------|---------------|---------|---------|
| 50:50       | 26.47             | 11.23                    | 26.50                    | 546.16        | 1588.12 | 1.59    |
| 60:40       | 33.71             | 13.42                    | 48.58                    | 513.66        | 2022.82 | 2.02    |
| 70:30       | 33.57             | 14.37                    | 44.20                    | 432.29        | 2014.32 | 2.01    |
| 80:20       | 50.53             | 21.86                    | 42.80                    | 454.62        | 3032.04 | 3.03    |

From the results of the performed test, the maximum tensile stress is 50.53 MPa. This number is to be found from the 80:20 mixture of the polyester resin and marble powder with 2 grams of the Kenaf fiber as shown in Figure 1.

![Figure 1. Maximum stress tensile test](image-url)
polyester resin as a matrix to bind the Kenaf fibers as reinforcement. The average of elastic modulus for this specimen is 3.03 GPa.

3.2. Compression Test

Compression strength test is one effort to know the material characteristics. Compression tests were performed on 5 specimens/composition types so that the average values as shown in Table 3 can be obtained.

| Composition | Maximum point Stress MPa | Maximum point Load N | Breakpoint Strain %GL | Upper yield Stress MPa | Lower yield Stress MPa | Elastic modulus Gpa |
|-------------|--------------------------|----------------------|------------------------|------------------------|------------------------|---------------------|
| 50:50       | 19.03                    | 1141.698             | 3.624                  | 13.070                 | 12.585                 | 1.61                |
| 60:40       | 23.09                    | 1361.352             | 4.586                  | 19.518                 | 18.063                 | 2.35                |
| 70:30       | 24.46                    | 1467.78              | 4.867                  | 21.175                 | 20.069                 | 2.19                |
| 80:20       | 23.88                    | 1432.72              | 6.102                  | 18.403                 | 17.931                 | 1.96                |

From the results of this test, it is obtained the best composition on the mixture of polyester resin is a ratio of 60:40 marble powder with Kenaf fiber as much as 2 grams, as shown in Figure 2. Average of elastic modulus for this specimen is 3.03 Gpa. It is known that the more marble powder will increase the compressive strength. However, it is necessary to further study by bending so that the characteristics of this composite material can be known comprehensively.

![Maximum point Stress](image)

**Figure 2.** Maximum stress of compression test

3.3. Bending Test

From Table 4 it can be seen that there is a difference in value during bending testing.
Table 4. The average yield of bending testing

| Composition | Maximum point Stress (MPa) | Maximum point Load (N) | Break point Strain (%GL) | Upper yield Stress (MPa) | Elastic modulus (Gpa) |
|-------------|---------------------------|------------------------|--------------------------|--------------------------|-----------------------|
| 50:50       | 9.02                      | 180.34                 | -4.93                    | 9.65                     | 49.88                 |
| 60:40       | 11.15                     | 223.02                 | 4.66                     | 9.20                     | 33.52                 |
| 70:30       | 15.91                     | 318.16                 | 12.18                    | 14.80                    | 43.87                 |
| 80:20       | 17.05                     | 341.02                 | 8.00                     | 15.47                    | 36.55                 |

The highest value is obtained from a specimen with a ratio of 50:50 with a stress point of 19.80 MPa. While, the lowest value is yielded by a specimen with a ratio of 70:30 with a stress of 13.54. The average stress of this composition is 17.05 MPa, while, the elastic modulus is 36.55GPa. It is known that the more the marble powder will reduce the properties of polyester resin as the matrix. However, the Kenaf fiber as reinforcement enable to increase the bending strength as shown in Figure 3.

![Figure 3. Maximum stress of bending test](image)

From the research of composite tensile test between the mixture of resin and marble powder, it is observed that the highest value is 80:20 with the Kenaf 2 gram with the highest value reaching 58.91 MPa, while the lowest value is 50:50 with the composition Kenaf fiber as much as 2 grams with value 21.35 MPa. The highest elasticity modulus is also possessed by the 80:20 compositions with a 3.03 GPa elasticity modulus value.

The results of the compressive test show that the highest value co-composition is 60:40 with a value of 33.49 MPa with an elastic modulus of 2.35 GPa, whereas the lowest composition is 50:50 with a value of 16.35 MPa and the modulus of elasticity 1.61 GPa.

The result of bending test shows that the composition which has the highest value is 80:20 with a value of 19.80 MPa while the lowest is composition 50:50 with a value of 6.125 MPa.

From the result of the tensile, compressive, and bending test, a composition having ideal value will be recommended for the manufacture of the product. From the results of this study the composition that has good and ideal value is the composition of the material is 70:30.

4. Conclusion
The conclusions of 3 tests to obtain the mechanical characteristics of the marble composite material are:
1. The largest tensile test value is 63,407 MPa, obtained from 80:20 composition with the largest E value 3.03 GPa. The largest compression test value is 33.49, obtained from the composition of
60:40 with the largest E value of 2.35 GPa. The largest bending test value is 19.80 MPa, obtained from the composition of 80:20 with the largest E value of 36.55 GPa.

2. From the research results of the tensile, compression, and bending test, the composition which possesses good value ranges between a ratio of 60:40 and 70:30.

5. References
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