Study on Mechanical Properties of Composite Polymeric Foams Reinforced by Bagasse Fibers

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Abstract. The use of the bagasse was applied as a fiber for the manufacture of polymeric foam composite materials. This waste treatment is beneficial to increase the economic value of waste materials, as well as provide solutions to handle waste products. Investigation of mechanical properties is needed to produce new materials with better strength. The bagasse has mixed with resins, polymeric foam agents and catalysts to provide a new polymeric foam composite material reinforced by bagasse fibers as well as strength. The tensile and compressive tests were performed by the quasi-static machine to determine the stress, and strain strength and specimens used the D-638 standard and D-1021. The variations of the composition applied to the specimen test based on the weight of each composition, and 40 Mesh. From the test results obtained tensile stress strength and strain of the material composite polymeric foam reinforced by bagasse waste fiber, respectively are 15.69MPa, and 16.41. Moreover, from the test results obtained compressive stress strength and strain of the material composite polymeric foam reinforced by bagasse waste fiber, respectively are 15.68 N and 2.02.

1. Introduction
Advances in science and technology have to increase in the use of composite materials according to their functions[1][2]. Composites are engineering materials consisting of two or more ingredients [3], in which the properties of each element differ from each other in both chemical and physical properties [4]. The mixing process is done macroscopically and produces new material where the original properties of the material remain real [5]. Composites consist of two phases, namely the fiber phase and the matrix phase[6]. Fiber is the discontinuous phase used to carry loads, and the matrix is a continuous phase that is used to bind and send loads to the fiber.

The advantage of using fiber in composite materials is due to isotropic fibers. Fiber has very high specific strength[7], and unique rigidity can be achieved [8]. Composite materials usually used because the elasticity and ease of shape are superior to metals[9]. Fiber is as a reinforced polymer is a composite material consisting of the polymer matrix and high strength fiber[10].

The process of manufacturing of composites can be done by varying the type of fiber, matrix and fiber orientation. This technique aims to be able to produce properties that are better than final composite
products, reduce mass weight, design flexibility and low fabrication costs [11], and are easily produced in large quantities [12].

Fiber-reinforced polymer composite materials are commonly used engineering materials[7] because their elasticity and ease of shape are superior to metals[13]. Fiber is as the reinforced polymer is a composite material consisting of the polymer matrix and high strength fiber. Generally, the matrix in polymer materials can classify into two classes, thermoplastic and thermoset [10].

Polymer foam consumption according to 2013 reached around 19.1 million tons. Moreover, its use is expected to increase to 25.1 million tons by 2019. Most of these polymer foams used in construction applications, due to their excellent thermal and mechanical properties. Solid polyurethane foam (PU) is used primarily as a thermal insulator, packaging, construction, automotive, and other applications[5].

Composites can be mix with foam into polymeric foam material. Polymer foam is preferred because it is cheap, lightweight and easily produced in large quantities [12]. Polymer foam can also use as a core material for composite sandwich material structures [14]. The mechanical properties of foam materials depend on several factors, such as cell structure, foam density, a method of manufacture and temperature [15]. Polymer foam materials could be mix with natural fibers.

The application of polymeric foam composites uses widely in construction, due to its excellent heat resistance and mechanical properties [16]. The fiber used can be derived from synthetic materials and natural fibers. Natural fibers are organic fibers such as fiber derived from animals, plants, etcetera. The use of natural fibers in addition to easy to obtain, cheap, and easy to do, is also an effort to exploit waste is wasted [17]. Sugarcane production throughout Indonesia based on statistical data in 2013 is 2.5 million tons [18]. In the process of making sugar, harvested sugar cane squeezed with a squeeze machine (press machine). From the process of making sugarcane will producing 5% sugar, 90% bagasse waste and the rest in the form of drops (molasses) and water[19]. From this percentage, it would produce a lot of bagasse waste which is still widely used as organic fertilizer or just thrown away or burned. So, to increase the high economic value, bagasse waste is even open the possibility to be engineered to produce new material products. Surely this bagasse waste is processed into fibers which are then combined with other products (resins) to provide composite products that are strong and competitive, cheap and easy to manufacture. The composition of this foamed polymer composite material is based on the weight fraction of the constituent material of each support material by variation of resin, blowing agent, bagasse fibers and catalyst. The variety is to form of a polymeric foam material which has better strength and can decrease the final weight of the resulting product.

This study aims to obtain stress strength and strain of composite polymeric foam material reinforced by bagasse fiber and to obtain compressive stress strength and strain of composite polymeric foam material reinforced by bagasse.

2. Methodology

2.1. Materials

The forming material of composite material consists of a resin material as matrix and filler, and catalyst material. Reinforcement/filler material comes from local waste products, bagasse waste. To produce polymer foam forming material uses a blowing agent as Polyurethane. For lubricants used are wax. The process of making polymer foam composite material would be affected by the method of selecting and processing bagasse waste, controlling, and determining the proportion of all the needs of composite material. Also, success factors that are very influential are the process of soaking bagasse, the process of purification and enrichment and the manufacture of material test samples. A fiber as reinforcement comes from waste products, namely bagasse obtained from milling of sugar cane traders around Langsa City. This bagasse could be made as fiber, and it is used to fill composite materials. The bonding material that functions as a matrix is a thermoset resin, which is a BQTN 157 resin. The blowing agent used is a combination of polyols and isocyanates. NaOH added in water is used to soak bagasse to remove lignin. Moreover, catalysts are used to accelerate reactions in the manufacture of composite products.
The variables measured in this study are using a comparison of the composition of the weight of the material. As for the formation of the variable weight of the variable change are resin material and bagasse fiber. While the other supporting parts use are fixed. This study uses three variations compositions, and each variation has three samples. The best results to be analyzed to find out the value of the average. Materials and comparison of material composition could illustrate in Table 1. The label A1, A2, and A3 are a label for every variation compositions of the sample.

| No  | Material Name   | Material Type       | Weight (%) | Sample A1 | Sample A2 | Sample A3 |
|-----|-----------------|---------------------|------------|-----------|-----------|-----------|
| 1   | Polyester Resin | BQTN 157-EX         |            | 83        | 80        | 75        |
| 2   | Bagasse Baggage | fiber               |            | 2         | 5         | 10        |
| 3   | Blowing Agent   | Polyurethane        |            | 15        | 15        | 15        |
|     |                 | amount              |            | 100       | 100       | 100       |
| 4   | Catalist        | MEKPO               |            | 5         | 5         | 5         |
| 5   | Delignin        | NaOH, 1M            |            | -         | -         | -         |
| 6   | Wax             | Wax type            |            | -         | -         | -         |

2.2. The process of making short fiber reinforced of bagasse waste
The procedure of processing bagasse waste is carried out in several stages of the process. The step of processing is 1. Bagasse waste is preparing. 2. Soaking bagasse waste in water containing 1% NaOH solution. 3. Wed bagasse need to dry in the sunrise. 4. Reducing bagasse into small parts (5 to 10 cm). 5. Refining fibers size by using fibers crushing machine. 6. bagasse fibers made in 40 Mesh size. 7. Fibers produced. Figure 1 is the Details processing and making of bagasse waste fibers.

![Figure 1: Stages of the process of making bagasse fibers](image)

2.3. The process of making Test specimens and Preparation
The technique of making polymeric foam composite material in this study begins with the preparation of all research materials. This composite material consists of BQTN of resin, bagasse fibers, blowing agent, and catalyst. Each ingredient is weighed according to the composition of the elements as shown in Table 1. The first step is resin material, and bagasse fibers are mixed into a mixing container and stir until the parts are evenly mixed (about 10 minutes). The second step is to add a catalyst and stir. The catalyst composition is around 5%. The third step is to add a blowing agent to the mixing container and stir for a while. Moreover, the fourth step is pouring ingredients into a pattern by using the casting method. This casting process is carried out to produce foam composite structures with random and non-continuous fiber directions. Hand layups need in this process, where this method use widely in long and continuous fibers. The all step the process in this procedure to produce composite polymeric foam showed in figure 2.

![Process Diagram](image)

**Figure 2.** The process of making bagasse fibers Composite
2.4. Methods of quasi-static Test

The strength of composite polymeric foam reinforced by bagasse fibers need to test under quasi-static loadings. The quasi-static test conducted on the universal testing machine (UTM) according to ASTM D-628. Moreover, D-1021. The number of specimens tested was three each composition. The tensile test is performed to find out the strength of the material specimen and elongation occurred of the composite polymeric foam material reinforced by bagasse fibers. The step of the test tensile test procedure is: (1). Installation of Test Specimens on test machine chucks, (2). Set up the test equipment with a load of 2 kN, (3). Start testing, (4). Record test results. The complete schematic is shown in Figure 4.

3. Results and Discussions

3.1. Tensile Strength

Tensile strength testing needs to be conducted on the quasi-static method. The samples were carried out on three composition variables with Labels A1; A2; and A3. Test specimen size follows ASTM D-628 Standard. The test resulted can be shown in Figure 5. The ultimate maximum strength value was 15.7 MPa, occurred in A2 sample material. The sample composition was 80% BQTN Resin, 5% bagasse fibers, and 15% blowing agent. Whereas the ultimate minimum strength was 6.71 MPa, occurs in A3 sample. The sample composition was 75% BQTN Resin, 2% bagasse fibers, and 15% blowing agent.
The mechanical properties generated from tensile testing on composite polymeric foam reinforced by bagasse fibers can describe in Table 2. The modulus of elasticity obtained by the results for the composition of bagasse fibers are 2%; 5%; and 10%. The modulus of elasticity value is respectively: 8.24 MPa; 0.41 MPa; 0.36 MPa. Whereas the strains that occurred are respectively are 12; 16.41; and 7.94.

The effect of adding bagasse waste fibers to material composite polymeric foam on mechanical properties can translate into a curve. Figure 6 is a curve that explains the impact of bagasse waste fibers composition on mechanical properties.
3.2. Compressive Strength

Compressive strength testing needs to be conducted on the quasi-static method too. Test specimen size follows ASTM D-1021 Standard. The test resulted value can show in Figure 7. The ultimate strength value maximum is 15.68 MPa, occurred in the label A1 samples material. The Material composition is 83% BQTN Resin, 2% bagasse fibers, and 15% blowing agent. Whereas the ultimate strength value minimum is 7.46 MPa, occurred in the label A3 samples material. The material composition is 75% BQTN Resin, 10% bagasse fibers, and 15% Blowing agent.

![Figure 6. Effect variations of bagasse fiber to mechanical properties](image)

Figure 6. Effect variation of bags fiber to mechanical properties

![Figure 7. Compressive stress-strain diagram for different composition of the composite](image)

Figure 7. Compressive stress-strain diagram for different composition of the composite

The mechanical properties resulted from compressive quasi-static on composite polymeric foam materials reinforced by bagasse fibers can be described in Table 3. For the modulus of elasticity obtained for the composition of bagasse fibers 2%, 5%, and 10%. The modulus elasticity values respectively is 4.26 MPa; 7.76 MPa; 6.51 MPa. Whereas, the strains that occurred respectively are 1.75; 2.02; and 1.84.

| Composition | Compressive Stress (MPa) | Strain (MPa) |
|-------------|--------------------------|--------------|
| 83% RES, 5% BGF, 15% BA | 11.98 | 1.75 |
| 83% RES, 2% BGF, 15% BA | 7.46 | 2.02 |
| 75% RES, 10% BGF, 15% BA | 15.68 | 1.84 |

Table 3. Compressive properties of composite Polymeric foam bagasse fiber
The effect of adding bagasse fibers to the material composite polymeric foam on mechanical properties can be translated into a curve. Figure 8 is a curve that explains the impact of bagasse fibers composition on mechanical properties.

![Figure 8. Variations of bagasse fiber to Compressive Strength](image)

**Table 4. Comparison between compressive and tensile strength**

| Ultimate stress | 75 wt% Resin | 80 wt% Resin | 83 wt% Resin |
|-----------------|--------------|--------------|--------------|
| Bagasse Fiber   | 10 wt%       | 5 wt%        | 2 wt%        |
| Blowing agent   | 15 wt%       | 15 wt%       | 15 wt%       |
| Tensile (MPa)   | 6.71         | 15.69        | 10.20        |
| Compressive (MPa) | 7.46       | 15.68        | 11.98        |
| Ratio of Compressive strength/ Tensile strength | 1.11 | 1.00 | 1.17 |

Comparison of maximum compressive strength and maximum tensile strength described in Table 4. The ration of compressive strength and tensile strength value was about 1.11, for the composition of 10% bagasse fibers. For the sample composition of 5% bagasse fibers, the resulted value was about 1. As for the bagasse fibers of 2% value was about 1.17.

### 4. Conclusions

From the results of this testing study, it can be concluded that the maximum compressive strength and tensile strength of polymer composite reinforced by bagasse fibers occurs in samples with A2 label. The
results obtained in the composition of the sample material is 80% Resin; 5% bagasse fiber; 15% blowing agent.

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6. References
[1] M. Rosso, “Ceramic and metal matrix composites: Routes and properties,” J. Mater. Process. Technol., vol. 175, no. 1–3, pp. 364–375, Jun. 2006.
[2] Husaini, Mitsuo, Notomi, K. Kishimoto, and T. Shibuya., “Crack Initiation Behavior Of ABS Resin Under Mode I And Mixed Mode Loading,” Mater. Sci. Res. Int., vol. 3, no. 3, pp. 158–165, 1997.
[3] Y. Yang, M. C. Gupta, K. L. Dudley, and R. W. Lawrence, “Novel Carbon Nanotube–Polystyrene Foam Composites for Electromagnetic Interference Shielding,” Nano Lett., vol. 5, no. 11, pp. 2131–2134, Nov. 2005.
[4] B. D. Agarwal, L. J. Broutman, and K. Chandrashekhara, Analysis and Performance of Fiber Composites. John Wiley & Sons, Incorporated, 2017.
[5] B. Notario, J. Pinto, and M. A. Rodríguez-Pérez, “Towards a new generation of polymeric foams: PMMA nanocellular foams with enhanced physical properties,” Polymer (Guildf.), vol. 63, pp. 116–126, Apr. 2015.
[6] T. A. Adlie, Z. Arif, F. Amir, S. Rizal, N. Ali, and S. Thalib, “The Effect of Fiber Size of Oil Palm Empty Fruit Brunches to the Tensile Strength of the Polymeric Foam Composite,” Int. J. Sci. Res., vol. 7, no. 7, pp. 2319–2064, 2018.
[7] Husaini and K. Kishimoto, “Mixed-mode fracture behavior of PC/ABS blends,” in Proceedings of SPIE - The International Society for Optical Engineering (Proceedings of SPIE), 2001, pp. 4317–18.
[8] Z. Arif et al., “Tensile Loading on Composite Polymeric Foam Reinforced by Empty Fruit Bunch Waste (EFB),” Int. Conf. Sci. Technol. Mod. Soc., vol. 1, no. 1, pp. 168–171, 2017.
[9] M. S. Qatu, R. Warsi, and W. Wang, “Recent research advances on the dynamic analysis of composite shells: 2000 – 2009,” Compos. Struct., vol. 93, no. 1, pp. 14–31, 2010.
[10] E. Omran, P. L. Menezes, and P. K. Rohatgi, “State of the art on tribological behavior of polymer matrix composites reinforced with natural fibers in the green materials world,” Eng. Sci. Technol. an Int. J., vol. 19, no. 2, pp. 717–736, Jun. 2016.
[11] A. G. Mamalis et al., “Crashworthy capability of composite material structures,” Compos. Struct., vol. 37, no. 2, pp. 109–134, Feb. 1997.
[12] U. E. Ozturk and G. Anlas, “Hydrostatic compression of anisotropic low density polymeric foams under multiple loadings and unloadings,” Polym. Test., vol. 30, no. 7, pp. 737–742, Oct. 2011.
[13] B. Syam et al., “Design and production of stopper made of concrete foam composite used for open channel conduit cover and parking bumper,” IOP Conf. Ser. Earth Environ. Sci., vol. 126, no. 1, p. 012053, Mar. 2018.
[14] E. A. F.-J. Q.M. Li, “International Journal of Solids and Structures Indentation into polymeric foams,” Int. J. Solids Struct., vol. 47, pp. 1987–1995, 2010.
[15] K. S. Yen, M. M. Ratnam, and H. M. Akil, “Measurement of flexural modulus of polymeric foam with improved accuracy using moiré method,” Polym. Test., vol. 29, no. 3, pp. 358–368, May 2010.
[16] C. T’Joen, Y. Park, Q. Wang, A. Sommers, X. Han, and A. Jacobi, “A review on polymer heat exchangers for HVAC&R applications,” Int. J. Refrig., vol. 32, no. 5, pp. 763–779, Aug. 2009.
[17] R. A. Eshkoor, A. U. Ude, A. B. Sulong, R. Zulkifli, A. K. Ariffin, and C. H. Azhari, “Energy
absorption and load carrying capability of woven natural silk epoxy–triggered composite tubes,” *Compos. Part B Eng.*, vol. 77, pp. 10–18, Aug. 2015.

[18] Y. A. Muh.Edi Subiyantoro, “Statistik Perkebunan Indonesia,” in *Statistik Perkebunan Indonesia*, Desember., J. D. Perkebunan, Ed. Jakarta: Jakarta, 2014.

[19] A. Pandey, C. Soccol, P. Nigam, V. S.-B. Technology, and U. 2000, “Biotechnological potential of agro-industrial residues. I: sugarcane bagasse,” *Elsevier.*