JURNAL SAINS MATERI INDONESIA (JUSAMI)
ISSN: 1411-1098 (print), 2614-087X (online)
VOL. 26, ISSUE 1 2024
DOI: https://doi.org/10.55981/jsmi.2024.4568

ORIGINAL ARTICLE

Effect of Basalt Size and Composition on Mechanical Properties of Wood Powder Polymer Biocomposite Material and Basalt as Reinforcement Using Polyester Resin

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ABSTRACT – Utilization of waste for raw materials for new materials is very potential for research. Wood waste from door and window craftsmen is widely available as the property business develops. Wood waste mixed with polyester resin is modified by adding basalt to produce a biocomposite material with better mechanical properties. Research on the effect of the addition of basalt composition and size on wood-polyester biocomposite material was studied to see changes in hardness value according to ASTM E384 standard, compressive strength according to ASTM D695 standard, and its effect on density according to ASTM D1622 standard. The results showed that the higher the composition and the smaller the basalt hardness value, the compressive strength and density increased. The highest values of hardness, compressive strength, and density were 36.6 HV0.5, 151.14 MPa, and 0.1420 kg/m3, an increase compared to that without the addition of basalt 26.7 HV0.5, 95.97 MPa, and 0.1288 kg/m3. Changes in the properties of hardness, compressive strength, and density are taken into consideration in the formulation of basalt to obtain new materials according to the desired specifications by utilizing wood waste.

ARTICLE HISTORY
Received: 04 Apr 2024
Revised: 18 Jul 2024
Accepted: 22 Jul 2024

KEYWORDS
Biocomposite
Wood powder
Basalt powder

INTRODUCTION

Population growth is increasing rapidly so the need for housing also increases. Doors and windows are one of the important parts of housing. The basic material of doors and windows is generally wood because it is easily available and cheap. The process of making doors and windows certainly produces residual wood waste that cannot be used, and the amount is quite large in Indonesia, which reaches 2.6 million m^3, and the waste is as much as 1.4 million m^3 per year. Waste from wood is generally in the form of wood chips, logs, veneer waste, and sawdust [1]. Generally, the waste produced by the sawmill industry ranges from 48%, and as much as 10% consists of sawdust [2]. This wood waste can be utilized as an alternative reinforcement for composite materials. Composites reinforced with natural materials have advantages over synthetic materials. Currently, nature-based composites are widely used in various engineering fields to replace synthetic-based composites due to their abundant availability, low cost, environmental friendliness, and sustainability [3]–[6].

Natural fibers consist of two, namely, in the form of natural fibers and the form of powder. Wood powder-reinforced composites have shortcomings when receiving compressive loads due to plastic micro-buckling mechanisms due to fiber misalignment. To overcome this, one can be done by adding filler fillers, which are then called hybrid composites. Hybrid composites are composites that combine two or more reinforcements and have been widely researched to improve their mechanical properties [3], [7]. One of the alternative reinforcement alloys is derived from natural rock, namely basalt. Basalt is one of the basic igneous rocks formed from the process of freezing magma on the earth's surface, which is characterized by a good grain size, is massive and hard, has an aphanitic texture, consists of volcanic glass minerals, namely plagioclase, pyroxene, amphibole, and black minerals [8]. Basalt is famous for its thermal properties of strength and durability. It is environmentally friendly because it can be recycled. Products made from basalt do not have toxic reactions with air or water, are not flammable, are resistant to explosions, and, when in contact with other chemicals, do not produce chemical reactions that can damage health or the environment [9]. In Lampung Province, basalt is found around the west side of Mount Tanggamus, along Semangko Bay to the east side of Mount Rajabasa, Sukadana, East Lampung [10]. There are several studies on the use of basalt as a composite reinforcement, but its utilization has not been maximized [11].

Polyester polymer resins are widely used to manufacture composite materials for the construction, automotive, and aircraft industries [12]–[15]. This resin has the advantage of being cheap, easily available, and has good mechanical properties compared to other thermoset resins [15]. Several studies have been conducted with the addition of basalt powder in polyester resin, which can change the physical and mechanical properties of composite materials [16]–[18].

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The characteristics of a material are highly dependent on its composition. For this reason, this study was conducted to see the effect of the addition of basalt powder on unsaturated polyester-wood powder (UPWP) biocomposite material by varying the size and composition of basalt powder.

EXPERIMENTAL METHOD

The main material in this research is basalt rock. Basalt rock from East Lampung was crushed with a ball mill machine; basalt powder was then sieved using ASTM mesh 100, 200, and 325 to vary the size. Mixed wood sawdust obtained from the sawmill industry of PT Berkah Jaya was sieved using ASTM mesh 80. Polyester resin (Yukalac 123 B-EX (IV) purchased from PT Justus Sakti Kimia Raya, Indonesia, was used as the matrix with 3% catalyst. The parameters of the hybrid composite specimens used are shown in Table 1. The mixing process of all materials was done manually and then molded using a mold according to ASTM D 695 in the form of a cylinder with a diameter of 12.7 mm and a height of 25.4 mm. The samples were tested for hardness with ASTM E384 standard using Micro Hardness Emco-Test DuraScan 50G5, compressive strength with ASTM D695 method using Universal Testing Machine (UTM) HT-2402 and ASTM D1622 density with density balance. The cross-section of the sample was viewed using an Optical Microscope Nikon Eclipse MA 100.

Table 1. Composite Sample

Sample	Wood	Polyester	Basalt	
	(%)	(%)	(Mesh)	(%)
A	2.5	97,5	-	-
B (1)	2.5	92,5	100	5
B (2)	2.5	87,5	100	10
B (3)	2.5	82,5	100	15
C (1)	2.5	92,5	200	5
C (2)	2.5	87,5	200	10
C (3)	2.5	82,5	200	15
D (1)	2.5	92,5	325	5
D (2)	2.5	87,5	325	10
D (3)	2.5	82,5	325	15

RESULT AND DISCUSSION

In this study, the hardness, compressive strength, and density properties of unsaturated polyester-wood powder (UPWP) materials with the addition of basalt varying in composition and basalt size are obtained in Table 2, and the appearance of the sample surface in Figure 1.

Table 2. Hardness, compressive strength, and density test results

Sample	Wood (%)	Polyester (%)	Basalt		Hardness ($HV_{0.5}$)	Compressive Strength (MPa)	Density (kg/m^3)
			(Mesh)	(%)			
A	2.5	97,5	-	-	26.8 ± 0.2	95.97 ± 13.18	0.1287 ± 0.0004
B (1)	2.5	92,5	100	5	29.3 ± 0.3	137.75 ± 11.34	0.1330 ± 0.0002
B (2)	2.5	87,5	100	10	30.9 ± 0.3	139.17 ± 3.80	0.1352 ± 0.0023
B (3)	2.5	82,5	100	15	31.8 ± 0.4	145.43 ± 5.77	0.1420 ± 0.0016
C (1)	2.5	92,5	200	5	32.1 ± 0.4	142.70 ± 9.91	0.1346 ± 0.0007
C (2)	2.5	87,5	200	10	33.9 ± 0.5	141.60 ± 5.12	0.1380 ± 0.0005
C (3)	2.5	82,5	200	15	35.0 ± 0.5	151.46 ± 8.15	0.1421 ± 0.0006
D (1)	2.5	92,5	325	5	32.6 ± 0.4	142.24 ± 8.58	0.1335 ± 0.0090
D (2)	2.5	87,5	325	10	34.2 ± 0.4	142.11 ± 4.00	0.1376 ± 0.0006
D (3)	2.5	82,5	325	15	36.6 ± 0.6	151.14 ± 6.88	0.1419 ± 0.0007

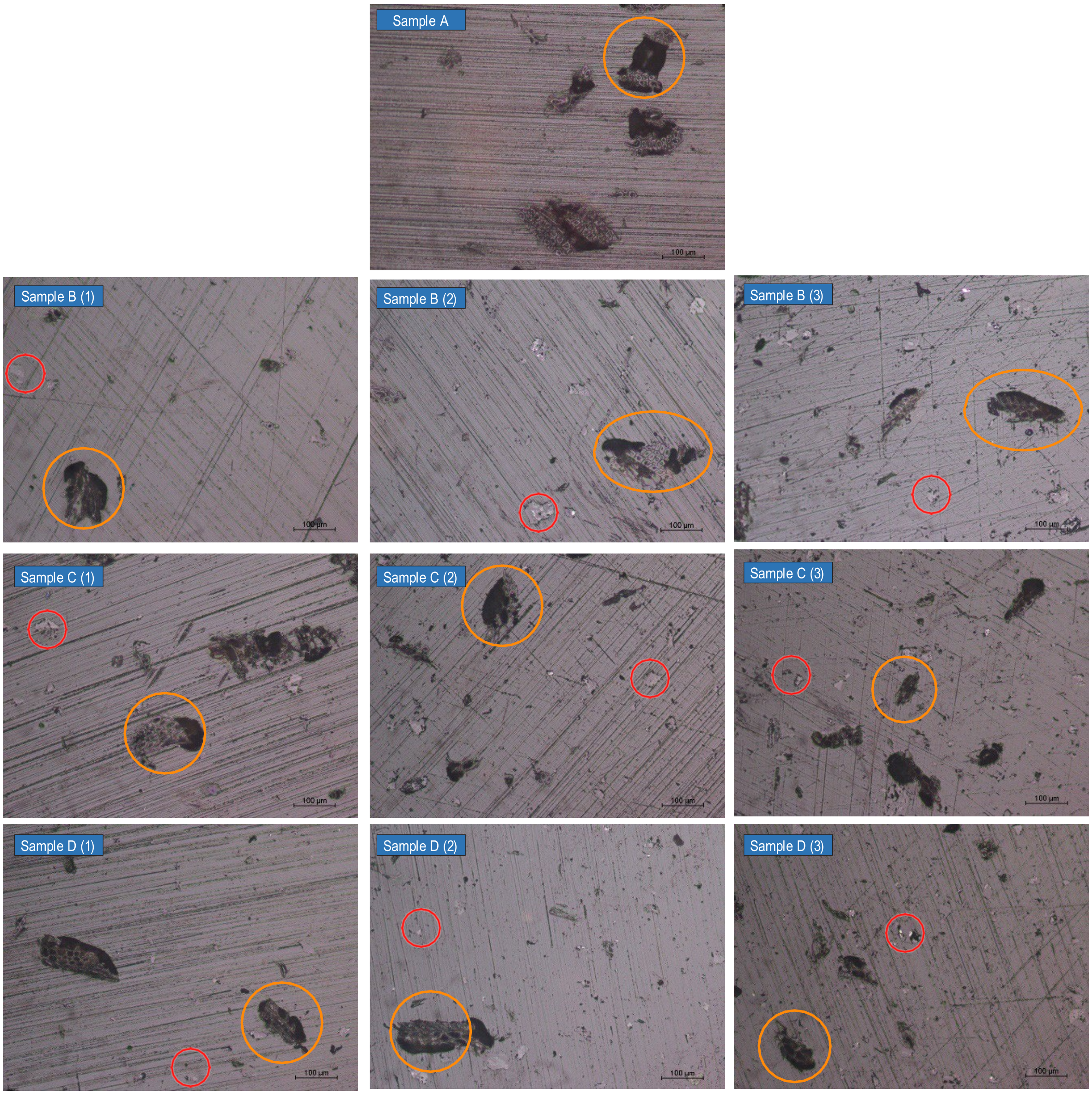

Figure 1. Cross-section view of the sample at 100× magnification (mark: green = wood and orange = basalt)

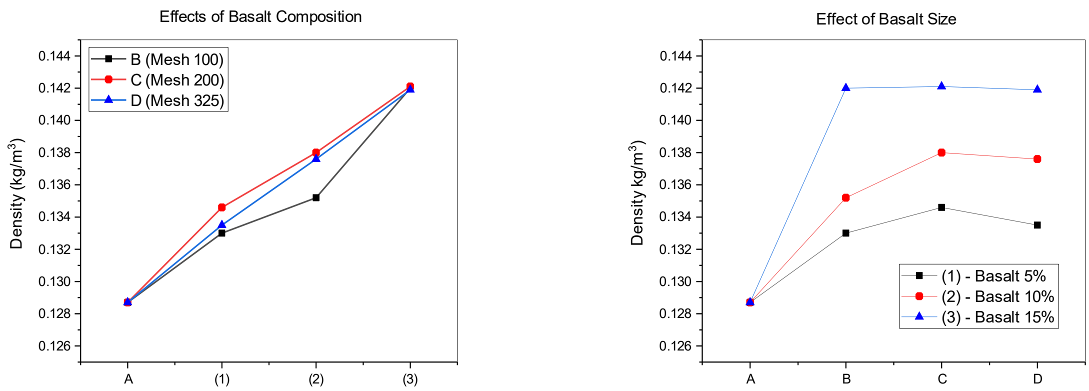

Figure 2. Effects of basalt composition (left) and size (right) on density

From Figure 2, it can be seen that the highest density is obtained with a 15% basalt composition of basalt mesh size 200, which is 0.1421 kg/m^3. It is 10% higher than without the addition of basalt of 0.1287 kg/m^3. The graph shows a significant increase in density with the addition of basalt compared to without basalt. The composition of basalt affects its density; the higher the composition, the more the density will increase. This increase occurs because the density of basalt is higher than resin and sawdust, so the more basalt composition, the density will increase. The density of basalt is 2.9 kg/m^{3,} while resin and wood are below 1 kg/m^3. Basalt size has no significant effect on density because the weight of the basalt composition is the same, so the density is relatively constant. The distribution of basalt that affects density is shown in Figure 1. Basalt powders appear scattered, and the amount depends on the composition of the basalt.

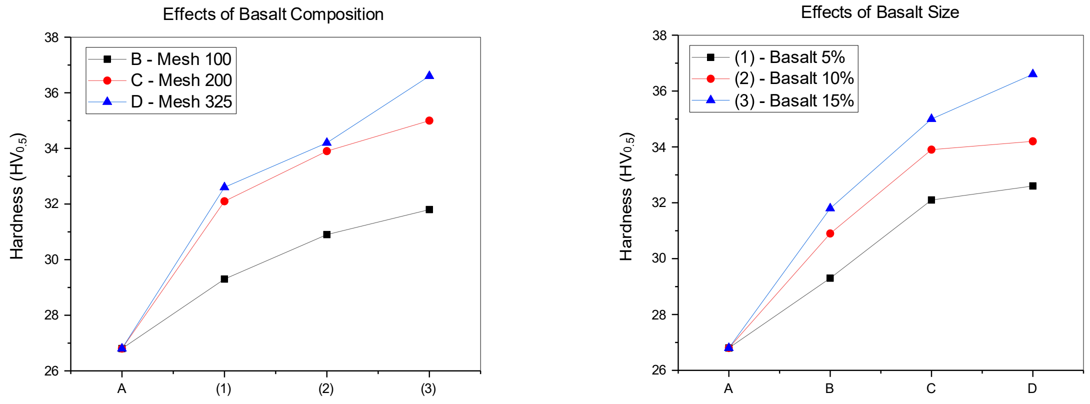

Figure 3. Effects of basalt composition (left) and size (right) on hardness

In Figure 3, it can be seen that the highest hardness value is obtained with 15% basalt composition and with a mesh size of 325, namely 36.6 $HV_{0.5}$, an increase of 37% compared to without the addition of basalt of 26.8 $HV_{0.5}$. The trend shows that the more the composition and the smaller the size of the basalt, the hardness properties will increase. This increase is due to the characteristics of basalt, which is harder than resin and wood, increasing its hardness value. In fact, besides the harder characteristics of basalt, the small particle size of basalt will provide a small empty space and is reduced when the resin as a matrix receives a load during the pressing process, which causes the adhesion distance between the matrix and the particles to be tighter. This increase also aligns with previous research that shows that the amount of basalt affects its hardness properties [16]. The smaller size allows basalt the distance between basalt particles to be closer so that it can be denser than the larger basalt size so that its hardness increases [17].

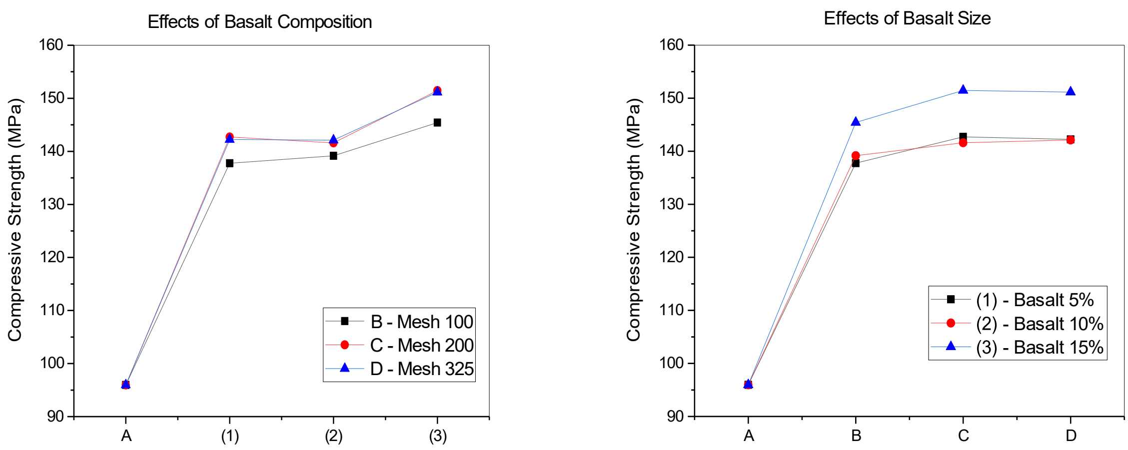

Figure 4. Effects of basalt composition (left) and size (right) on compressive strength

From Figure 4, it can be seen that the highest compressive strength value is obtained with 15% basalt composition and with a mesh size of 200, which is 151.46 MPa, an increase of 58% compared to without the addition of basalt of 95.97 MPa. The trend graph with the addition of basalt shows a significant increase in compressive strength compared to without basalt. The size of basalt has no significant effect on compressive strength, while the more basalt composition, the compressive strength will increase even though it is not significant. This change in value is in line with density and hardness testing, where the denser and harder the material, the higher the compressive strength. The addition of basalt with a small powder size is quite effective in increasing the compressive strength of composite materials because the smaller the size of the constituents of a material, the smaller the cavities that occur between particle bonds will be to minimize the empty space that causes a decrease in strength. The small particle size is able to bind strongly between the particles and the resin, causing higher strength. This research is in line with previous research that basalt can function as a reinforcement, and the more the amount of basalt, the more mechanical properties increase [18].

CONCLUSION

The addition of basalt to the polyester-wood powder composite material can influence the density and increase the mechanical properties of hardness and compressive strength. After adding basalt, the density increased by 10% from 0.1288 kg/m3 to 0.1420 kg/m3, hardness increased by 37% from 26.7 HV0.5 to 36.6 HV0.5, and compressive strength increased by 58% from 95.97 MPa to 151.14 MPa. The effect of composition has a significant influence on these three properties, while size only has a significant influence on hardness. This change can be a basis for consideration in determining the composition and size of basalt to make polyester-wood powder biocomposite materials with the addition of basalt as reinforcement.

ACKNOWLEDGEMENT

The author would like to thank the National Research and Innovation Agency (BRIN), especially the Research Center for Mining Technology and Research Center for Rocket Technology, and the Department of Physics, Faculty of Mathematics and Natural Sciences, University of Lampung, for supporting this research.

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