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HIGH STRENGTH MANGO LEAF WASTE/POLYURETHANE COMPOSITE REINFORCEMENT USING QUARTZ MATERIAL

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ABSTRACT

Quartz stone contains silica components (SiO2) which have the ability as a reinforcement material for composite materials. Quartz SEM-EDX testing shows that the quartz silica comonent is 69%. Other components contained in quartz are 34% MgO and 2% CaO. Therefore, quartz stone is used as a reinforcing material in mango leaf waste composite materials. Meanwhile, compressive strength testing of composite materials was carried out with variations of Polyurethane (PU) polymers, namely 1, 2, 3, 4, 5, 6 and 7 grams, obtaining the highest maximum pressure at 6 grams polymer mass, which is 38.91 grams. Testing of composite materials that have been given a mixture of quartz stone with a mass of Polyurethane (PU) 6 grams and a quartz stone variation of 0.03; 0,06; 0,09; 0,12; 0,15; and 0.18 grams obtained the maximum power most optimally there is a quartz mass of 0.06 grams of 40.47 grams. The strength of mango leaf composite meets the strength standard for building materials, namely concrete with a value of 20-150 MPa. This shows that quartz stone can be a composite reinforcement comprehenent for mango leaf waste.

Keywords: composite, mango leaf waste, quartz, mechanical strength

INTRODUCTION

Mango (*Mangifera indica* L.) is a type of tropical fruit belonging to the family *Anacardiaceae* which has more than 1000 species around the world. Each part of this plant has a wide variety of nutrients such as minerals, fiber, starch, antioxidants, pleated, etc. Most of the people only use the fruit, the leaves of the mango plant are disposed of like waste [1,2]. A waste is left over material that is not needed and is usually disposed. A waste can be solid, liquid, or gaseous. Waste management through waste sorting has actually been running well, but due to the lack of public awareness and knowledge about organic waste management, waste management is not effective, and there is a buildup of organic waste [3,4].

Organic waste such as leaf waste becomes a fairly complex problem that greatly interferes with the aesthetic appearance of the surroundings. Organic waste is waste that comes from living things, including fallen leaves and food waste. Fallen leaves can be used as a composite material, thereby reducing their availability in the environment [5,6]. Composites have been one of the most widely conducted studies for decades due to their promising advantages such as good thermal conductivity, electrical conductivity, mechanical properties and magnetic properties [6,7]. The use of Polyurethane (PU) and silica sand in composites is used as a binder and reinforcement. PU has a bond that can improve the mechanical properties of the composite Quartz sand is mostly composed of silica so that it can be used as a reinforcement to increase the mechanical strength of the composite. Silica is also widely used as a reinforcement in some other composites [7].

Silica is also widely used as a reinforcement in some composite materials such as: agricultural waste composites and foliage [8-10], composite mortar and concrete [11,12], and also as a filler material in some electrolyte [13-15]. The addition of silica to the composite can improve the interaction between polymer particles, thereby increasing the strength of the composite and can improve its mechanical properties [7,14,15]. The use of PU and quartz sand which has a high silica component is expected to be used as raw material for construction materials such as concrete. The mechanical strength of concrete has a value between 20-150 MPa. Previous research showed that concrete with quartz material has a maximum strength of 38.5 MPa in 7 days and 45.7 MPa in 28 days [16]. Therefore, this study uses composite materials, namely quartz and PU as reinforcement and reference in the manufacture of building materials.

METHOD

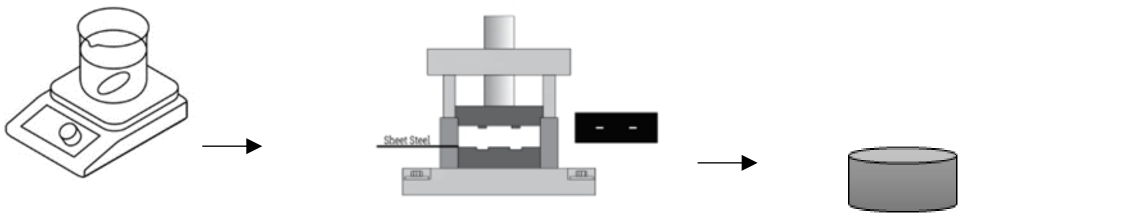
Material

The main material in making composites is mango leaf waste obtained from Sekaran, Semarang, Indonesia, while the quartz stone and polyurethane (pure analytical) polymer were obtained from the Bratachem Chemical Store, Semarang, Indonesia.

Composites

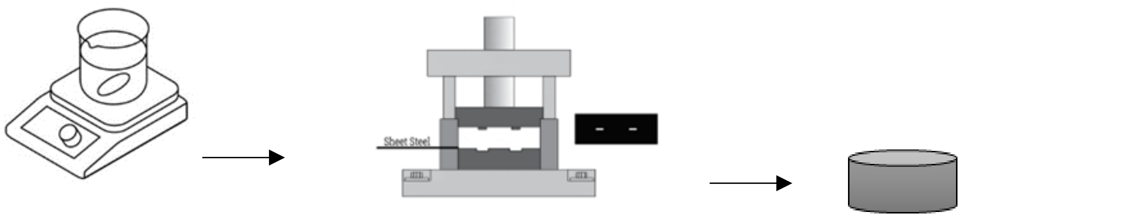
Mango leaf waste that has been crushed using a leaf shredder was filtered using a 200-mesh sieve to obtain an evenly size. The making of composite mixtures is divided into 2 stages, namely composites without quartz mixture and with quartz. The composites without quartz are carried out to obtain composite samples with PU polymer variations having the most optimal compressive strength. PU preparation through polyol polymerization and diisocyanate in a ratio of 1:3 stirred using a 350 rpm-magnetic stirrer for 30 minutes. The variations of PU are PU variation 0.125; 0,250; 0,375; 0,500; 0,625; 0,750; and 0.875 (w/w) to be mixed with 8 grams mango leaf powder. Then, all samples were prepared in the molds to be pressed using a hydraulic press at pressure of 5 metric tons. The sample with the most optimal PU is the composite that has maximum strength. The most optimal PU composition is then used to make composites with a mixture of quartz stone

The quartz powder was obtained by crushing the quartz stone with 98% ethanol medium for 14 hours through a wet-ball milling [17]. The quartz precipitate was then heated using an oven to remove the solvent. After drying, the precipitate is crushed and filtered using a 200 mesh sieve. The quartz powder was mixed with the optimum composition of PU/mango leaf waste sample, i.e. the composite having the maximum strength, with quartz addition variation of 0.03; 0.06; 0.09; 0.12; 0.15; and 0.18 grams. All samples were the prepared in the molds to be pressed using a hydraulic press at pressure of 5 metric tons.



8 (w/w) waste + PU variation | pressed using a hydraulic press with a pressure 5 metric ton | Samples with the most optimum PU

FIGURE 1. Diagram of the scheme of making mango leaf composites and PU variations.



8 (w/w) waste + Optimal PU + quartz | pressed using a hydraulic press with a pressure 5 metric ton | Optimal composite

FIGURE 2. Diagram of the scheme of making mango leaf composites, PU and quartz.

Material Characterization

The compressive strength of all composite samples was tested using the Torsee Tokyo Testing Machine MFG hydraulic press. Ltd. which is equipped with a Load Cell with ASTM C0109M-02 testing standard [18]. Morphological characterization and content investigation of quartz stone have been carried out using Phenom Pro X Scanning Electron Microscopy-Energy Dispersive X-ray (SEM-EDX).

RESULT AND DISCUSSION

Compressive Strength Test

The compressive strength of mango leaf waste composites tends to increase as polyurethane increases. The addition of PU gives rise to van der Waals interactions between mango leaf waste particles and polymer active groups, especially carbonyl group groups as shown in FIGURE 3 [7,19,20]. Further, it is thought the mango leaves generally containing inorganic substances, such as Mg, Ca, Fe and K in complex forms forming several interface interactions with PU carbonyls, even, some of them form chemical bonds to strengthen composites[7,21]. However, it cannot be confirmed exactly since it has not been characterized yet. The composition of PU and mango leaf waste shows stronger bonds that increase the mechanical strength of the composite [22].

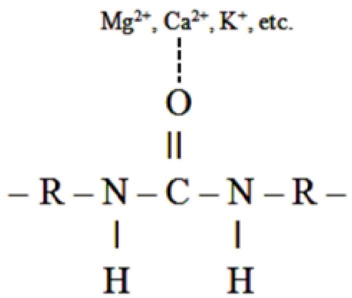


FIGURE 3. Interaction of carbonyl groups with some leaf waste inorganic materials (dotted line) [7].

TABLE 1. Results of sample compression test with mass variation of polyurethane

No	Waste (gr)	PU (gr)	Maximum pressure (gr)	w/w=(1/1+8) $\left(\frac{dissolved\ mass}{dissolved\ mass+\ solvent\ mass}\right)$
1	8	1	25.40	0.11
2	8	2	26.80	0.20
3	8	3	31.36	0.27
4	8	4	26.13	0.33
5	8	5	32.54	0.38
6	8	6	38.91	0.43
7	8	7	23.33	0.48

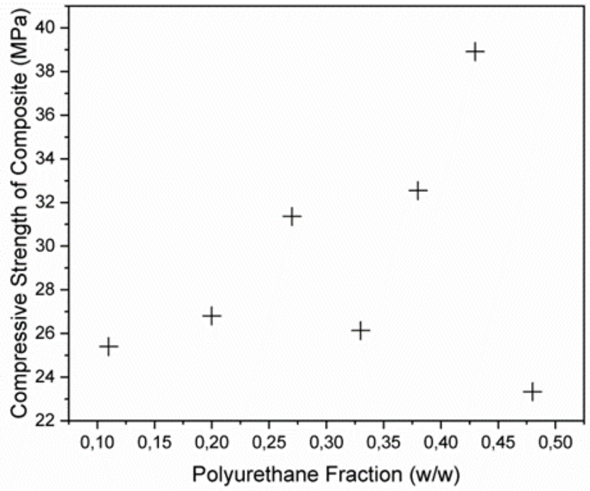


FIGURE 4. Compressive strength of mango leaf waste/PU composite as PU content where the maximum strength of 38.91 MPa is attained at PU content of 0.43 (w/w).

The compressive strength of composite tends to increase as the PU content increases until to a certain PU content of 0.43 (w/w), the compressive strength reaches 38.91 MPa. The addition of PU content above that value tends to decrease the compressive strength (FIGURE 2). At lower PU concentrations, only a small content of leaf waste particles interacts with PU particles, and when PU content is added, the interaction of leaf waste particles with PU will increase [7,22]. This increase will stop when all leaf waste particles interact full with all PU particles, and in this condition the compressive strength has reached its maximum. Thus, the addition of PU above the value will increase non-interaction area of PU, which results in reduced compressive strength [7,23]. Composites with optimal PU content are composites with the maximum compressive strength value (FIGURE 5). This shows that the PU level is effectively used as a composite mixture.

TABLE 2. Sample compression test results with variations in the mass of quartz

No	Waste (gr)	PU (gr)	Quartz (gr)	Maximum pressure (gr)	w/w=(0.03/8+6)x10^{-3} $\left(\frac{dissolved\ mass}{dissolved\ mass + solvent\ mass}\right)$
1	8	6	0.03	38.71	2.14
2	8	6	0.06	40.47	4.29
3	8	6	0.09	36.46	6.43
4	8	6	0.12	38.47	8.57
5	8	6	0.15	38.22	10.71
6	8	6	0.18	37.58	12.86

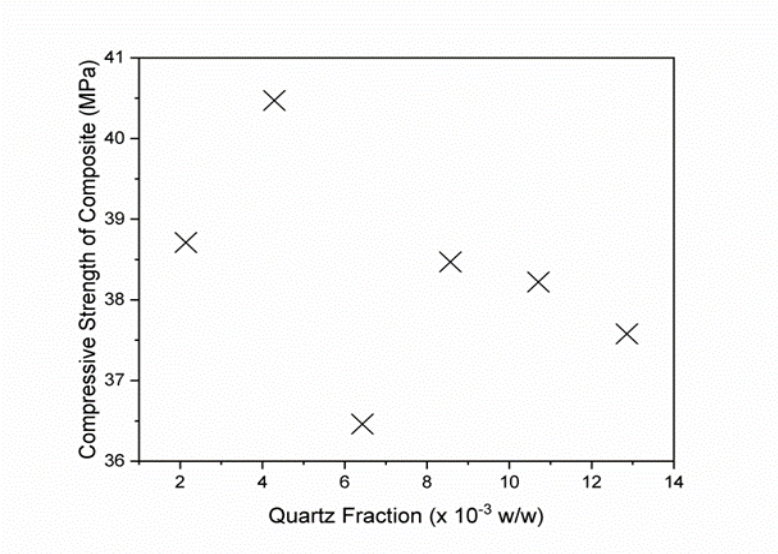
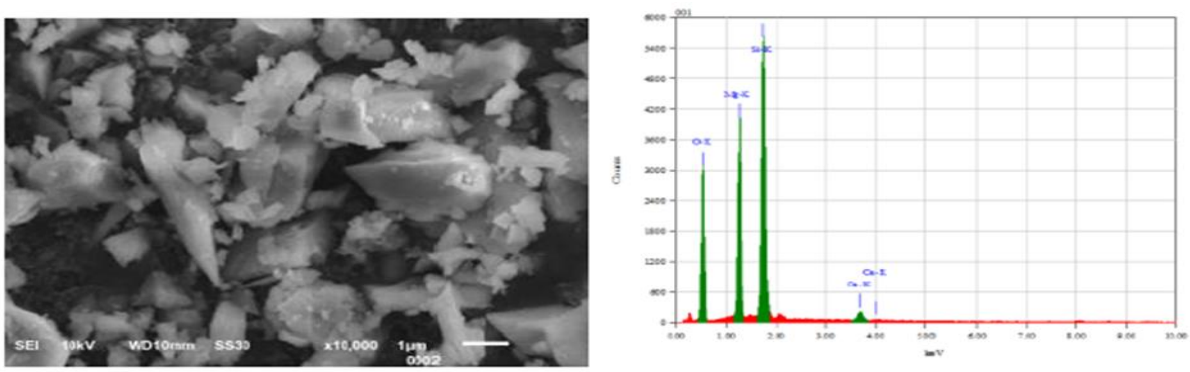


FIGURE 5. Compressive strength of mango leaf waste/PU/quartz composite as quartz content where the maximum strength of 40.47 MPa is attained at PU content of 0.06 (w/w).

In addition, silica is a high-strength material, so the addition of quartz powder containing mainly silica makes the composite strength larger. The addition of quartz powder to the mango leaf waste composite can increase stiffness and hardness to increase compressive strength. The addition of a small amount of silica can increase the compressive strength until at certain value, i.e. 0.06 (w/w) the compressive strength reaches 40.47 MPa as the maximum value (FIGURE 2(b)). Otherwise, the addition of silica above the value cannot improve the composite strength since the latter silica will interact each other, causing brittleness, as a result of which the strength of the composite decreases [7,21].

Quartz SEM-EDX Measurement

FIGURE 4 shows the results of SEM-EDX testing of quartz found that the main content of quartz is silica (64%), magnesium oxide (34%) and calcium oxide (2%).



(a) (b)

FIGURE 6. (a) SEM images of quartz powder, with the average particle size is 0.94 µm, (b) EDX of quartz powder that shows the dominant compound is silica (64%) and the rest are MgO and CaO

Quartz granules that manually measured have a grain size ranging from 0.5–5 μm. A fitting using log-normal distribution function shows that the average size of quartz granules is 0.94 μm. The grain size is obtained by wet-milling process, where the quartz stone was milled using ethanol as solvents by a milling machine. Based on EDX testing, the quartz components SiO_2, MgO and CaO were obtained with content of 64%, 34% and 2% respectively. The very small size of quartz granules allows them to enter the pores between PU and mango leaf waste. Quartz granules filling the pores result in a smaller distance between particles in the composite, which can increase the strength of the composite. This can happen due to the increased interaction of van der Waals.

The increase in the strength of composite due to the microscopic addition of silica has been regulated by van der Waals about the interaction between silica and the two PU active groups, namely the amine and carbonyl groups [22,23]. The lower silica content in the mixture results in the silica particles spreading into amine and carbonyl groups from PU. Inside the silica or dispersed PU component, O_2 in silica interacts with the hydrogen amine group to form hydrogen interactions that are critical in governing the composite strength [24].

Regarding to the compressive strength, the mango leaf/PU/quartz composite is very adequate to be used as a material competing wood, stone or brick in building applications. Its strength is comparable to clay bricks [25], slate [26], sandstone [27], limestone [28]. Therefore, this composite is very adequate to compete with building materials such as bricks, stone and wood in mortar, concrete or wood applications. As conclusion, the composite produced promises a good chance to be applied in building industries and applications.

CONCLUSION

The mango leaf/polyurethane composite has been produced to obtain the maximum compressive strength of 38.91 MPa for polyurethane content of 0.43 (w/w). The addition of quartz powder as reinforcement to the composite fabrication improves the strength of composite. The maximum strength of mango leaf/polyurethane/quartz attains up to 40.47 MPa for quartz content of 0.06 (w/w). This is in accordance with the strength standards of building materials, namely concrete with compressive strength of 20-150 MPa. The increasing of composite compressive strength due to quartz addition was confirmed by SEM-EDX measurement that obtained the main compounds of the quartz is silica (64%) and the rest are MgO dan CaO. The compressive strength is comparable to several materials widely used in building industries, such as clay bricks, slate, sandstone, and limestone. Therefore, the composite is adequate to be produced as a supporting material in building application.

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