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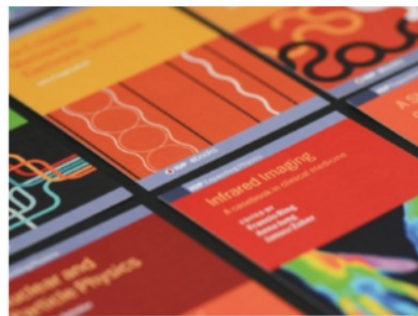
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Mechanical strength of quartz reinforced polyvinyl acetate/leaves-waste composite

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Abstract. A quartz reinforced polyvinyl acetate/leaves-waste composite has been made using simple pressing method. This work was performed as an answer for the solid waste abundance and deforestation activity. Having been wet-milled using ethanol 70% and dried for 4 days, the quartz was added as reinforcement in polyvinyl acetate (PVAc)/leaves waste mixture with varied contents to form PVAc/leaves waste/quartz composite via pressing at 5 metric ton for 20 minutes. The compressive strength test shows the mechanical strength varies from 35.53 to 39.93 MPa as quartz contents, with a sample having quartz sand content 4.60×10^{-3} (w/w) has maximum mechanical strength as 39.93 MPa, and the addition of quartz above the content makes the mechanical strength tends to decrease. The strength values are comparable to some previous works by several authors and some building materials, such Sago pulp composite, polyurethane/solid waste/nanosilica composite, agriculture-waste/silica composite, soil brick, limestone, natural fiber reinforced concrete and Portland cement concrete. This result shows the quartz reinforced polyvinyl acetate/leaves-waste composite has been acceptable to compete the woods as building materials to reduce deforestation.

1. Introduction

In recent years, the building materials and furniture demand for house industries has growth rapidly in developing countries, including Indonesia [1 -2]. Some of the materials widely used to fulfil the demands are woods, plastics, rubbers and composite materials [3-4]. Furthermore, wood utilization to the building and furniture materials grows up as the demand growth of both, and it ultimately supports to the deforestation [5]. Meanwhile, the solid waste handling is urgent problem relating to the environmental issue, where the reutilization and reusing process is too smaller than to that of waste production [6-7].

Paying attention to the leaves waste abundance in several cities in Indonesia, such as Semarang, Bandung, Surabaya and Malang, it is a promise contribution in waste problem solving by utilizing the solid waste as functional materials, and one of the promising methods is composite engineering [8-9]. Particularly, composite engineering is current technology widely used for several material industries, such as packaging, automotive, aerospace and furniture [10]. In composite engineering, it always requires the involving of binder or polymer, filler and reinforcement as the main compilers [11].

Some research relating to solid waste composite have been done, such as agricultural waste/polyethylene glycol composite [12], plastic-reusing composite [13], and palm leaves/plastic waste



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composite [14], with the results are very interesting and prospective to be enlarged in another wastes and methods. In this work, we have made the leaves waste composite using polyvinyl acetate as binder reinforced by quartz as enlargement of previous research. Polyvinyl acetate (PVAc) was chosen since its strength in binding to other materials, such as such as in wood bonding [15], polyester/PVAc composite [16] and as adhesive in bookbinding [17], meanwhile, quartz-sand with its abundance in this country was chosen as its predominant contents is silica having high mechanical properties in strengthening composite as reinforcement for several composites [18], such as concrete/PET composite [19], polyurethane/solid waste composite [20] and sugar palm fiber/polyester composite [21].

The aim of this work is to obtain a PVAc/leaves waste/quartz composite having good mechanical properties to compete several building materials, especially the woods, to reduce the high deforestation number as rapid house industry growth.

2. Materials and Methods

The quartz-sand was obtained from Tasikmalaya, Indonesia, while technical polyvinyl acetate (PVAc) was obtained from FOX glue, and the leaves waste used is Mango (*Mangifera indica* L.) leaves. The ethanol (70%) was purchased from Indrasari chemical store, Semarang, Indonesia.

For first, the quartz-sand was wet-milled by ethanol to obtain the smoothed powder for 40 hours. The quartz powder then was mixed with aquades and PVAc to obtain PVAc/quartz solution with varied composition using magnetic stirrer at 40°C for 20 minutes to ensure the solution homogenization. Meanwhile, having been dried using environmentally drying for 5 days and oven machine at 60°C for 40 minutes, the leaves-waste was crushed using blender machine. Then, the crushed leaves waste was mixed with the polyvinyl acetate/quartz solution. Finally, the PAVc/leaves waste/quartz-sand mixture was pressed at pressure of 5 metric ton for 20 minutes using a holder having radius 3 cm.

SEM-EDX measurement was done using SEM Analytical Scanning Microscope JEOL JS416510 LA to obtain the silica particle size and its compound contents. Further, the compressive test was performed using Torssee Tokyo Testing Machine MFG Ltd. equipped with Load Cell and ASTM C1194-19 to measure mechanical strength of the composite. Using this ASTM, the composite was cut as cubic having all of length, width and height as 2 cm [22].

3. Results and Discussion

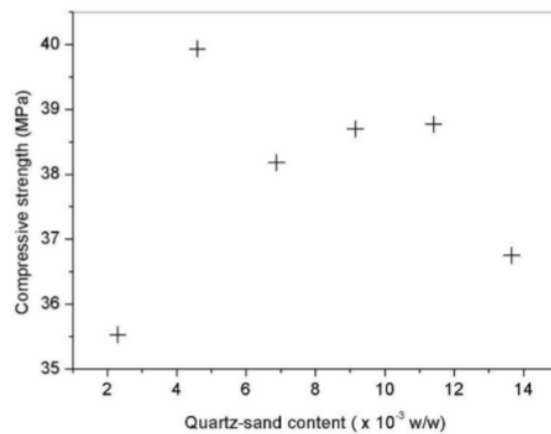


Figure 1. PVAc/leave waste/quartz composite strength as quartz content function. The strength attains at 39.93 MPa for 4.60×10^{-3} (w/w) and tends to decrease as quartz contents addition.

Figure 2(a) shows the SEM-image of quartz particle where using log-normal distribution it was obtained the average particle size is about 0.94 μm . The slightly involvement of the quartz into the composite affects in strength enhancement. It can be understood as smaller quartz particles compared to the rest void size formed between PVAc and leaves-waste, making it enable to fill the void to strengthen the particles interaction. Further, with predominant compound of quartz sand is silica, i.e 32.3% and the others are MgO, C, and CaO are 28.61%, 28.24%, and 10.92% respectively (Figure 2(b)), the mechanical strength of composite rises since silica has high strength, especially if it is added as reinforcement for a composite [18-21].

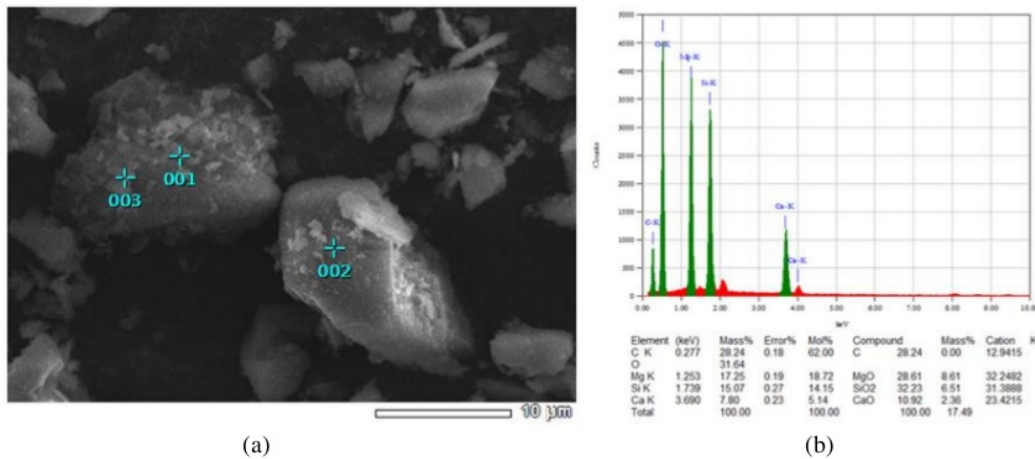


Figure 2. SEM-EDX spectroscopy of quartz powder, with: (a) the average particle size is 0.94 μm (obtained from log-normal distribution calculation), (b) the silica (SiO_2) contains 32.23% (w/w).

The composite produced has appropriate strength, that its value tends to rise as quartz addition, and it attains to 39.93 MPa for 4.60×10^{-3} (w/w) quartz content. It means that for the maximum strength the interaction among PVAc, leaves waste and quartz has maximum pairs-occupation, that is almost of all the particles have already faced each-others [23]. Therefore, the addition of later silica makes the strength reduction as observed in 3rd, 4th 5th and 6th data, where the more the quartz contents the smaller the compressive strength.

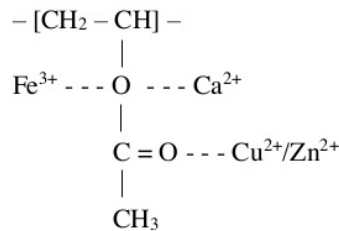


Figure 3. Van der Waals scheme between vinyl group and several minerals contained in Mango leaves, such as Fe^{3+} , Ca^{2+} , Cu^{2+} and Zn^{2+} .

The quartz effect in enhancing the composite strength microscopically is governed by the van der Waals interaction [24]. Without quartz the interaction is truly believed occurs between vinyl group and both of leaves waste particle and silica's quartz. The leave waste extremely contains metal particles as plant minerals at slight contents [25], such as calcium, copper, iron, zinc, etc, interacting to oxygen's vinyl group (Figure 3), as well as they ultimately contribute to the mechanical strength occurrence. Further, as shown in Figure 4 the interaction may occur between hydrogen's vinyl group and oxygen's

quartz to form dipole-dipole van der Waals interaction [26], while a London dispersion interaction may also occur between silicon and oxygen's vinyl group [27]. Even, the interaction may also occur between oxygen's silica and oxygen's vinyl group via hydrogen bridge formed as water containing and or bonded in the composite [28]. However, an investigation about the explanation has not been done yet in this work.

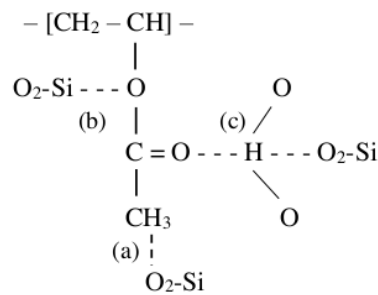


Figure 4. VdW interaction between vinyl group and silica of the quartz: (a) dipole-dipole interaction between oxygen (silica) and hydrogen (vinyl group), (b) London dispersion interaction between silicon (silica) and oxygen (vinyl group), (c) hydrogen bridge connecting oxygen (silica) and oxygen (vinyl group) formed as water contents in the composite.

The composite strength is comparable some composite having been performed in previous works, such as Sago pulp composite [29], polyurethane/solid waste/nanosilica composite [20], and agriculture-waste/silica composite [30] with mechanical strengths values ranges from 0.12 to 160 MPa. It is also compatible to several building materials, such as soil brick, limestone, natural fiber reinforced concrete, and Portland cement concrete having compressive strength from 3.5 to 80.2 MPa [31-36]. As conclusion, the PVAc/leaves waste composite reinforced by quartz containing silica is very adequate to be enlarged as building material competing the woods.

4. Conclusion

The quartz-sand reinforced polyvinyl acetate/leaves-waste composite has been made using a pressing process at 5 metric ton for 20 minutes. The composite has appropriate strength from 35.53 to 39.93 MPa varies as quartz content, with the maximum strength was attained for 4.60×10^{-3} quartz content (w/w). This strength is comparable to previous works performed by several authors and also very compatible to building materials, such as Sago pulp composite, polyurethane/solid waste/nanosilica composite, agriculture-waste/silica composite, soil brick, limestone, natural fiber reinforced concrete and Portland cement concrete. From this result, it shows that the PVAc/leaves waste composite/quartz is acceptable to compete building materials, such as the woods.

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