Special Issue for International Conference of Advanced Materials Engineering and Technology (ICAMET 2013), 28-29 November 2013, Bandung Indonesia

Advances in Environmental Biology, 7(12) October Special Issue 2013, Pages: 3596-3600

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Batu Reput Filled Recycled Polypropylene Eco-polymer Composites

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ARTICLE INFO

Article history:
Received 11 September 2013
Received in revised form 21 November 2013
Accepted 25 November 2013
Available online 5 December 2013

Key words:
Batu reput, dolomite, recycled polypropylene, polymer composites

ABSTRACT

The effect of Batu Reput, which scientifically called as Dolomite mineral filler on the mechanical properties of recycled polypropylene (rPP) mixed using Z-blade mixer was examined. This research has been done to investigate the mechanical properties of rPP/Batu Reput composites such as tensile properties and impact strength. The interfacial adhesion between the Batu Reput filler and rPP was investigated by examining the tensile fracture surface using scanning electron microscope (SEM). The water absorption of the composites was also determined for up to 14 days. In this study, tensile strength results exhibit 300µm with 10% filler content shows significant increase of mechanical strength compared to the neat rPP and other filler percentage composites. This is due to the good interfacial adhesion, better compatibility and good stress transfer during tensile test. While for water absorption testing, the result indicates that the smaller the particle size, the higher the water absorption percentage since there is large surface area of dolomite to be in contact with water. During SEM testing, it can be seen that the effect of dolomite properties on the rPP matrix has led to the good interfacial adhesion with a good compatibility between filler and matrix material. According to this research, the 10% dolomite of 300 µm obtained good tensile strength result compared to the others. While for impact strength testing, the result illustrates similar trend to other testing that lower filler ratio shows higher toughness.

To Cite This Article: Sharifah Shahnaz Syed Bakar, Nurul Shahida Zakaria, Juyana A Wahab, M.A.A.M. Salleh., Batu Reput Filled Recycled Polypropylene Eco-polymer Composites.***Adv. Environ. Biol., 7(12),*** *3596-3600, 2013*

INTRODUCTION

Plastics have become common materials of our daily life due to their high performance and easy used. However, plastic applications also donated to the growing area of landfill, as plastic products are often used only once before disposal. Plastic waste also becomes a risk to environment and other wildlife. Thus, due to the public concern nowadays that required safer environment and eco-friendly polymer, eco-polymer was developed by increasing the progress of recycled polymer especially for polypropylene waste product that also shows high percentage in the landfill [1]. As recycled polymers are affected by the processing and thermal histories, their performances are prone to be demoted. Therefore, some modification should be done by adding recycled polymer with natural resources like as natural fibre, glass fibre, and mineral filler to enhance and increase their value-added properties. When a polymer product contains eco-polymer material and natural resources, it is called as eco-polymer composites. Eco-polymer composite or eco-composites literally means the combination of two materials that led to environmental friendly and easy to disposal [2].

Sreenivasan et.al stated that, in this recent year, because of their versatility, the currently per capita generation in Peninsular Malaysia is nearly 1.2 kg of municipal waste (MSW) amounting to 19,000 tonnes of waste per day and it is set to rise to 30,000 tons daily by year 2020 [3]. Based on that phenomenon, polypropylene (PP) waste becomes seconds of the largest plastic wastes in Malaysia among the other plastic such as Polyvinylchloride (PVC), Polyethylene (PE) and Polystyrene (PS). Polypropylene is a versatile polymer with the chemical structure $(C_3H_6)_n$ which has relatively high melting point of 160°C and has a lot of benefit in all application such as in food containers, toys, automobile part, carpeting, and technology. The most important thing is, it can be recycled since it does not cross linked and will be soft when heated. Due to those traits,

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recycling is the best method to reduce the waste of this plastic as well as can reduce the environmental risk into air, land and water pollution.

Rothon has identified the examples of mineral filler that are commonly used as filler in composites in variety application nowadays are natural calcium carbonate, talc, magnesium hydroxide and dolomite [4]. Kamarudin et.al mentioned that Batu Reput also known as dolomite in their scientific names that given by French Mineralogist Deodat de Dolomieu, consist of $CaMg(CO_3)_2$ composition [5]. Gence et.al reported that dolomite is a type of salt mineral that are naturally hydrophilic and their solubility is greater than oxide and silicates, but less than salts. It gets slightly dissolved and gives ions of Ca, Mg and hydrolysis products in aqueous dispersion [6]. Batu reput usage become important in food and pharmaceutical industries, production of fertilizer, glass, building material and even the kinescopes that used for colour television [7].

In order to create the new innovation of eco-polymer composite, *Batu Reput* (dolomite) was used as filler in recycled polypropylene matrix. This research was conducted in order to investigate the early findings on the mechanical and water absorption properties of this new eco-polymer composite. Through this new discovery of easy decomposed and economical eco-friendly composite, it can be an alternative route of recycling, thus the plastic waste and disposal problems, mainly of polypropylene can be reduced.

Experimental:

Raw materials:

Recycled polypropylene obtained was originated from PP cap only products. It was supplied by Wespack Waste Management Sdn Bhd in black pellet form, density of 0.945 g/cc, tensile strength of 15 MPa and melting point of 171°C. Dolomite was ordered from one of the quarries in Perlis. The dolomite powder supplied was sieved into two sizes: 300μm and 63μm. The dolomite was then dried in the oven at 100°C for 24 hours prior mixing. The mixtures were done according to the filler loading 10%, 20%, 30%, 40% and 50% of weighted composites for both sizes.

Composites preparations:

The composite was compounded using Z-blade mixer. After 5 min pre-heating, the weighted samples were fed into the operating mixer for 15-20 min at 40 rpm speed and 180°C temperature to ensure that the dolomite powder were fully wetted by rPP and homogeneity of the mixture. The compounded samples were then weighted and underwent compression molding to obtain the composites sheets. The samples for tensile test were cut into 120mm × 13mm × 1mm dimension using Wallace de Cutter and cutting mold according to ASTM 638. The analysis on composite tensile strength and % elongation at yield was then carried out with 5kN load cell at crosshead speed of 10mm/min with gauge length of 5mm using Instron Universal Tester. The toughness of the composites was examined by Izod impact test, which was done according to ASTM D256 standard using Izod Impact Tester, with a 4.0 joules pendulum. The sample size is 50mm × 10mm × 2mm. The samples dimension for water absorption test is 20mm × 20mm × 2mm, conducted by ASTM-570. The samples were weighted, immersed in distilled water for prolonged period of time and the weight change of the samples was recorded regularly. During weighing time, samples were removed from the water, pattered dry, blotted with tissue paper to remove excess water and then weighed. The water absorption was calculated based on dried weight by using the following equation:

The dolomite filler distribution and wet ability among rPP matrix were then examined using Scanning Electron Microscopy (SEM). All samples were mounted on aluminium stub and coated with thin gold palladium layer.

$$W_t = \frac{m_1 - m_0}{m_0} \, x \, 100 \,\% \qquad (1)$$

Where:
W_t = water uptake percentages
m_o = weight of dry sample
m_1 = weight of the wet specimen

RESULTS AND DISCUSSION

Tensile properties:

The addition of dolomite filler loading into rPP matrix has enhanced the tensile properties of the composites [Fig. 1(a)]. This improvement was due to their good interfacial adhesion between rPP and dolomite. Although the hydrophilic dolomite and hydrophobic rPP behavior might led to incompatible filler-matrix composites and can cause weak interfacial interaction, but at lower ratio of dolomite the bonding of these two materials are able to resist the load of tensile test. This compatibility seems has given higher tensile strength value as compared to neat rPP. However, the trend has decreased at higher dolomite loading (40% and 50%) as rPP were unable to contain and fully wet dolomite filler. Fig. 1(a) also shows that 300 µm filler's composites have higher tensile strength than smaller 63 µm filler composites. Similar trend also observed for elongation yield, where smaller dolomites results in lower values [Fig. 1 (b)].

The composites elongation yield increased up to 30% of dolomites addition. The ability of these composites to elongate before breaking is due to the ability of the matrix and filler molecular chain refuse to mobile when the force applied on it. Furthermore, although the polypropylene already recycled, their main properties does not change, which contain both crystalline and amorphous structure. Both regions results in difficulty of rPP to break because their molecular chain is strong and bonding are tight while dolomite has assisted in enhancing the elongation at breaks percentages. However, as the filler loading were increased up to 40% and 50%, the molecular chains of the rPP were destructed by the dolomite mineral filler and thus cause the elongation at break of the composites dramatically decreased. When dolomite entered rPP matrix, it filled the space in the matrix and causes the composite become more brittle and stiff. The brittleness of the composites tend to decrease of elongation at break since their molecules are not in ordered due to the chain mobility and thus cannot stand the force applied for a long period.

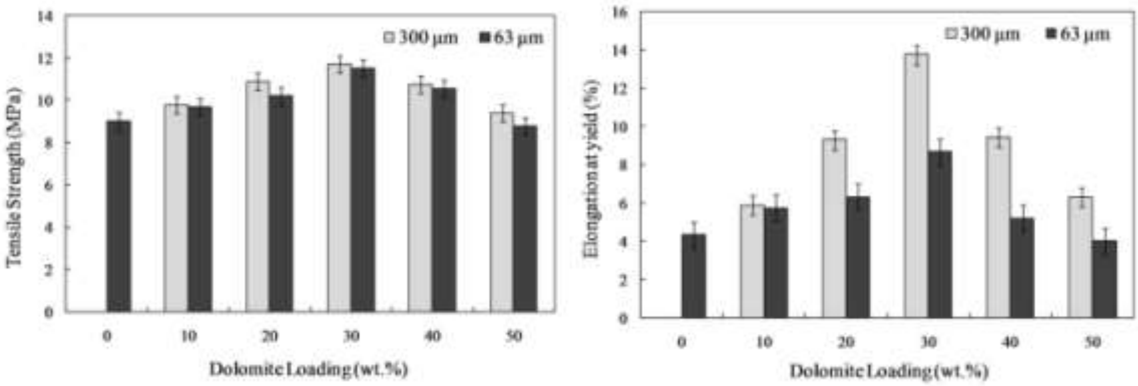

Fig. 1: Effect of dolomite filler loading on (a) tensile properties (MPa) and (b) elongation and yield (%) of eco-polymer rPP/dolomite composites.

Tensile properties of rPP filled dolomite composite are then evaluated by scanning electron microscope. Fig. 2 shows the micrographs of dolomites distributions and their adhesion on rPP matrix. These micrographs were taken on the composite tensile fracture. The fracture analysis was in the agreement with the tensile properties showed, where 10% dolomites filler loading [Fig. 2 (a)] were relatively well distributed as compared 50% filler loading [Fig 2 (b)]. As shown in Fig 2, dolomites were embedded well into rPP matrix, which lead to a good compatibility between the filler and matrix that indicating a good interfacial adhesion between the composites. Although these two materials consist of different polarity, the incorporated rPP with 10% dolomite has increased the tensile properties of the composites. Good filler-matrix compatibility also enhances the crack resistance of the composites.

At 50% filler loading, large amount of dolomites had lead to poor interfacial bonding between rPP matrix and filler. Filler were not distributed well in the matrix since agglomeration occurred at this high filler loading [Fig. 2 (b) and (d)]. This has caused poor stress transfer between dolomite and rPP during tensile loading. Besides that, rPP matrix was not able to fully wet and hold the filler, thus weakened the composite strength. This agglomeration caused the composites had low mechanical properties while cracking propagation easy to occurs and initiated to the presence of micro crack. Similar trend was observed in composite containing smaller size of dolomite, 63 µm at where the agglomeration has occurred after 50% filler loading. Moreover, their poor distributions has lead to low tensile properties [Fig. 2 (c) and (d)].

Water absorption properties:

The results obtained on the water absorption eco-polymer rPP/dolomite composites are displayed in Fig. 3. Water absorption testing has been done at room temperature condition (23°C) for 14 days. The graph illustrates that 100 % rPP hardly absorbs water, which is linear at the beginning, then approaches saturation after prolonged time. This result was expected since rPP has hydrophobic behaviour and high resistance to water absorption. While the increasing filler loading had increased the water uptake and swelling, the maximum percentage of weight gained was obtained by 50 % of 63 µm dolomites filled composites. Based on the trend, we can say that the smaller the filler sizes, the higher the water absorption percentages. This phenomenon can be explained by considering the hydrophilic behaviour of dolomite as the composite that contain 63µm filler size at

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50%, the water absorption percentage increase dramatically compared to 300µm filler size. This occurrence was due to the smaller size of 63 µm filler have larger surface area that can absorb water. According to the Dhakal et.al when the composite is exposed to moisture, the hydrophilic dolomite swells. As a result, micro cracking of the composite may occurred. The high dolomite content in rPP matrix further contributes to more water penetrating into the interface through the micro cracks induced by swelling of filler, thus creating swelling stresses leading to composite failure. As the composite cracks and gets damaged, capillarity and transport via micro cracks become active. The capillarity mechanism involves the flow of water molecules along filler–matrix interfaces and a process of diffusion through the bulk matrix. The water molecules actively attack the interface, resulting in debonding of the filler and the matrix [8].

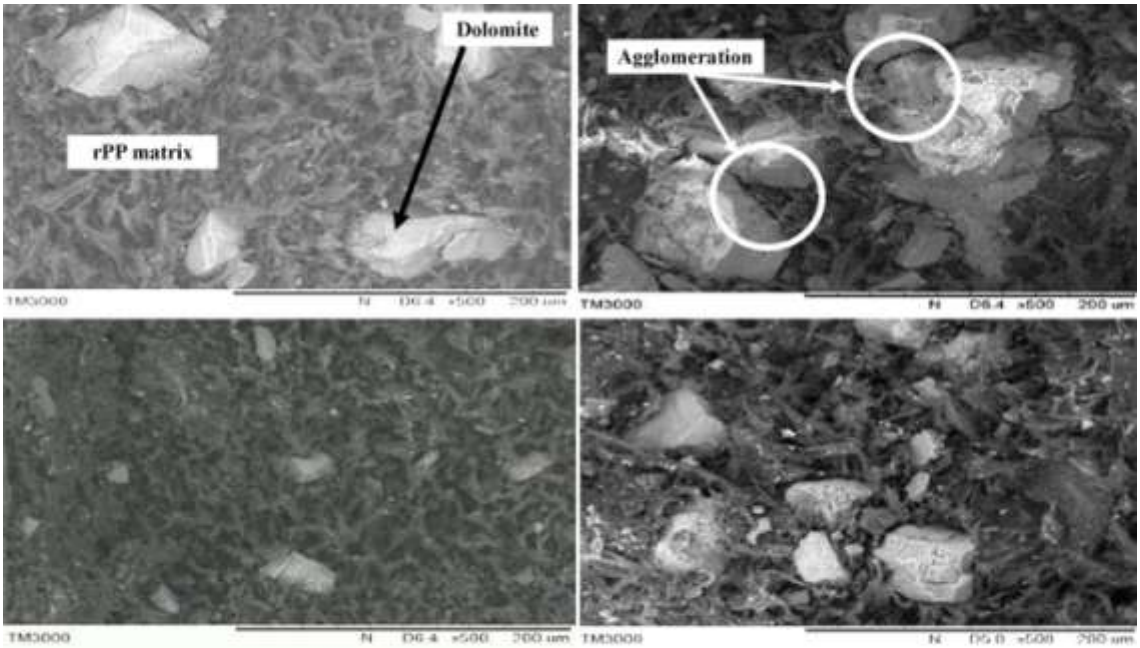

Fig. 2: SEM micrographs of eco-polymer filled (a) 300 µm at 10% dolomite (b) 300 µm at 50% dolomite (c) 63 µm at 10% dolomite and (d) 63 µm at 50 % dolomite.

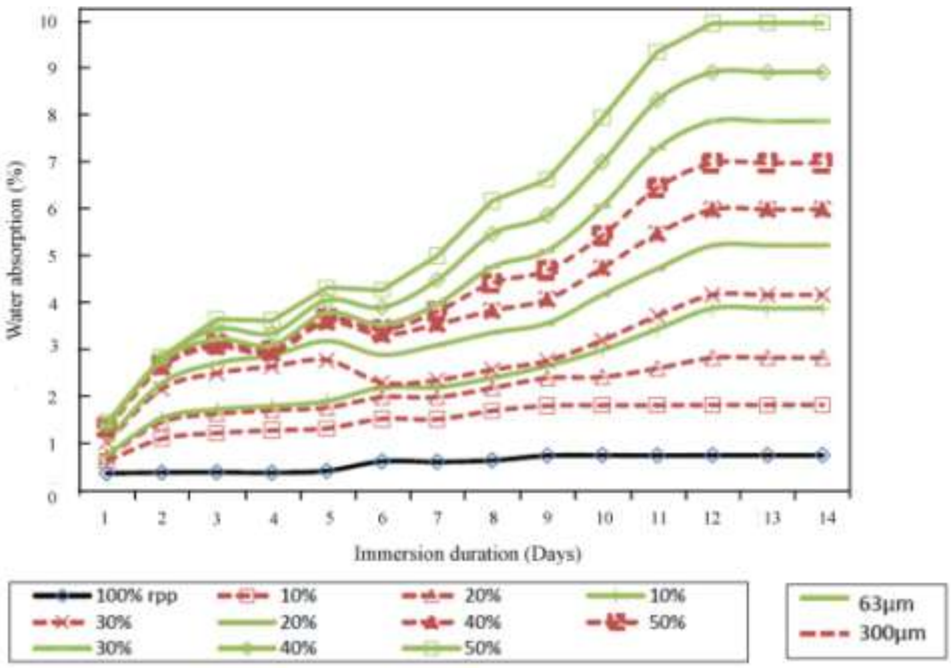

Fig. 3: Effect of dolomite filler loading on water absorption (%) of eco-polymer rPP/dolomite composites.

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Conclusions:

In this study, the effect of mechanical properties on recycled polypropylene filled dolomite composites has been investigated. From the result obtained, the mechanical properties of rPP/dolomite have been summarized. The presence of dolomites has increased the mechanical properties of rPP. Highest tensile strength observed at 30% of 300 µm filler loading, which also showed that bigger size filler given higher strength to the composites. Good mechanical properties are viable via good adhesion between filler and matrix, which resulted in good stress transfer. Smaller dolomites size however leads to higher water absorption.

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