Mechanical Properties of Recycled High-Density Polyethylene, Rice Husk Ash, and Fly Ash Composite Mixture

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***Received:** 15 November 2021; **Accepted:** 16 June 2022; **Published:** 25 July 2022*

Abstract In today's world, plastic has become a global environmental issue that needs to be addressed properly. Most of the plastic waste stems from two sources: low-density and high-density polyethylene (HDPE). HDPE has higher mechanical properties in terms of strength, rigidity, and melting point compared to LDPE. As for rice husk ash, it become abundant as a waste material in all rice producing countries. Rice husks ash (RHA) when burnt, releases particulates which are nanometers in size and can decrease air quality but more importantly can cause breathing and eye problems for humans and animals alike. Thus, the increasing interest from researchers using fillers in polymer composites has explored the potential usage of such materials. The objective of the research is to determine the mechanical properties of composite material made from high-density polyethylene (HDPE), rice husk ash (RHA) and fly ash (FA) at different composition ratio. The HDPE, RHA and FA granule is mixed according to different ratio using 3D rotary mixer and then place onto hot press machine to obtain desired shape for the mechanical testing. Four (4) types of composite were tested in this study which were: (i) 100% HDPE, 0% RHA, 0% FA (ii) 90% HDPE, 5% RHA, 5% FA, (iii) 80% HDPE, 10% RHA, 10% FA, and (iv) 70% HDPE, 15% RHA, 15% FA. The results showed that for sample 1, 2, 3 and 4; the maximum stress of 10.506 kN, 8.569 kN, 7.578 kN and 7.485 kN were observed.

Keywords : Plastic Waste, HDPE, Fly ash, Rice husk ash, Composites.

1. Introduction

High-density polyethylene (HDPE) is one of the world's most used and most vital commercial plastics. HDPE has applications in products such as automobiles, packaging, appliances, and even aeronautics. Even though HDPE has mechanical properties such as high chemical stability, high toughness at low temperature, high resistance to heat, and excellent dielectric properties, HDPE has terrible weatherability (Zebarjad, 2006). In industrial and commercial applications, to improve the disadvantages of HDPE, filler materials such as carbon black, sawdust, talc, and silica are commonly used (Aigbodion, Hassan, & Agunsoye, 2012).

Agricultural and industrial byproducts from burning coal and waste residue from rice husks are available in abundant with no real solution in sight to properly manage and dispose of these byproducts. Such waste poses serious environmental problems to the land, water, and air with chemicals such as chromium, lead, arsenic, and dioxins just to name a few (RTI, 2007). The improper disposal of such byproducts will leak life-threatening chemicals into the land and water while spreading particulates into the air. Studies have shown that the incorporation of byproducts into plastic composite materials did not only enhance the mechanical properties of such materials but also become a manageable method of properly disposing of byproducts (Hopewell et al., 2009). Study shows that, the addition of RHA can be used as reinforcing filler when fabricating HDPE, which increased the tensile strength from 22MPa to 27MPa and Young's Modulus from 13MPa to 19MPa (Ayswarya et al., 2012). Thus, the implementation and incorporation of agricultural and industrial byproducts that are fine in size introduced a possible solution for the management of such waste material. The goal of this study is to determine the mechanical properties in term of tensile strength and hardness of composite made from HDPE, RHA and FA.

2. Methodology

Materials

The RHA and FA are obtained via online commerce platforms with size vary from 5 to 10 mm. The rice husks and the fly ash are cleaned with distilled water to remove dirt and grit. Then, the rice husks and fly ash are placed inside an oven to dry for two hours under 100°C. The high-density polyethylene (HDPE) was obtained from recycled center. The HDPE is feed into shredding machine to shred in particulate size 5 to 15 mm.

Specimen Fabrication

The shredded HDPE, RHA and FA was put into a jar and mixed by the 3D Rotary Mixer. The main component of the composite is the HDPE with the maximum combined RHA and FA components of different percentage weightage according to Table 1.

Table 1. HDPE-RHA-FA composite according to %weightage

The concentration of components (%wt)		
HDPE	**RHA**	**FA**
100	0	0
90	5	5
80	10	10
70	15	15

Then, the mixed granules were fed into the hot press machine (model TISB 50T). This forming process was done to melt and mix the matrix with the filler well and fabricate the specimen in the shape of square with 1 mm thickness for mechanical testing afterwards. The standard temperature required to melt HDPE is between 150-170°C and it has been set to 170°C so that it mixes and melts well with the composites.

Mechanical Testing

The specimen was cut using saw and undergoes tensile test according to ASTM D1822L as shown in the Figure 1. Total 15 specimens for each composition ratio undergoes tensile test to determine the energy it takes to fragment a specimen under a load which is applied at tension.

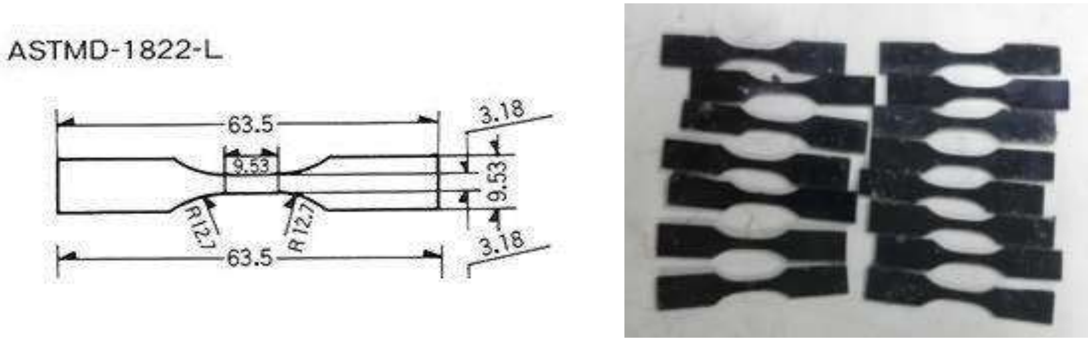

Figure 1. ASTM D1822L test specimen size

The composite specimen hardness was also measured using Shore D durometer hardness testing equipment according to ASTMD2240. The specimen is placed on a hard flat uniform surface. Then, the indenter of the durometer is pressed onto specimen surface and value of hardness is obtained. The specimen with the highest maximum stress is selected to for microstructural analysis using Scanning Electron Microscopy (SEM) equipped with Energy Dispersive X-Ray Analysis (EDX). The specimen is placed into the chamber and high vacuum is applied to hinder the distraction of air which affects the observation of the specimen. An electron gun bombards the specimen. An electron detector then detects it when it reflects back to produce an image.

3. Results and Discussion

Figure 2 shows graph of the weight percentage of HDPE against the maximum stress. It can be observed that there was a decrease of maximum stress from 100 to 70 in the weight percentage of HDPE. This is due to increasing filling and mixing of filler materials; namely fly ash and rice husk ash. Without the addition of any filler material, i.e for HPDE 100%, the maximum stress rate was observed to be 10.51 kN. When a 10% reinforced filler mix made of 5% RHA and 5% FA is combined with the HDPE, the average maximum stress of the HDPE 90% decreased to 8.57 kN. Thereafter, the quantity of the reinforced filler material mix was raised to be of 20% where it consisted of 10% RHA and an equal percentage of FA, the average maximum stress measured for the HDPE 80% composite was now at 7.39 kN. Lastly, reinforced filler of 30%, which is FA and RHA in total (15+15), had been used and average maximum stress for HDPE 70% was recorded at 7.48 kN. It was seen that the higher filler loading levels of RHA had a negative impact on the tensile strength of the composite, which occurs due to the interfacial bonding decreasing between filler which is hydrophilic and matrix polymer being hydrophobic. The material became brittle as the filler loading increased since fraction of polymer decreased (Bisht et al., 2020).

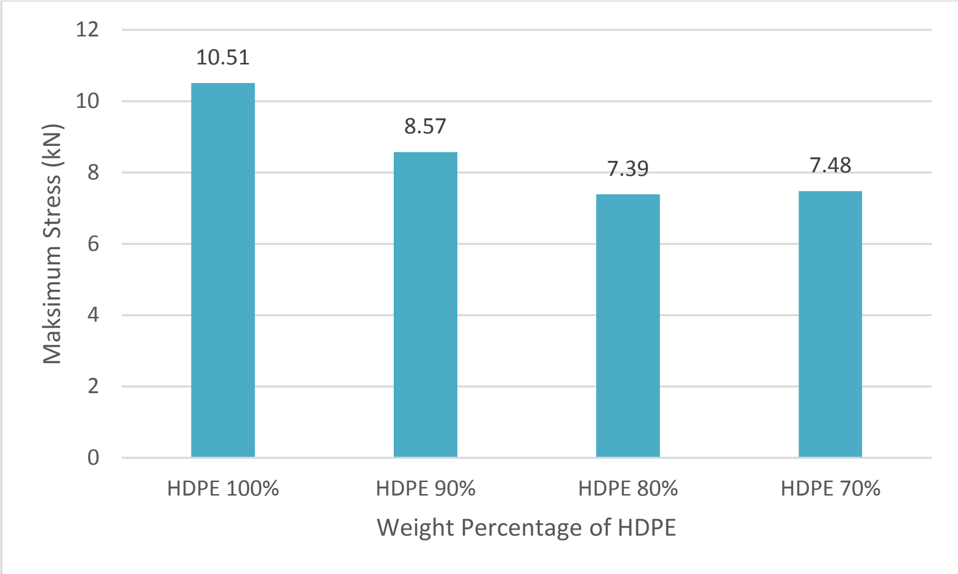

Figure 2. Graph of maximum stress versus weight percentage of HDPE

The hardness of HDPE 100% has the best performance overall and this progressively changes as mixtures of fillers are added as shown in Figure 3. The average hardness value is calculated from 5 different positions. These average hardness values are carried through the experiment. The average hardness 100% HDPE has been at 44.02 N/mm^2. Thereafter, the value decreases to 36.16 N/mm^2 as 10% filler is added, making it lower than that of the initial 100% HDPE. After adding 20% filler, the average hardness value climbed to 40.3 N/mm^2, making it better than the performance of the 10% filler but all while 100% HDPE remained the best performance. When 30% filler was added, an average hardness value of 33.14 N/mm^2 was obtained which was the lowest among all**.** Previous researcher stated that hardness of a composite depends on the homogeneous dispersion of the particulate into the matrix (Premla et al., 2002; Jamil et al., 2006). Usually, the presence of a more flexible matrix causes the resultant composites to exhibit lower hardness (Jamil et al., 2006).

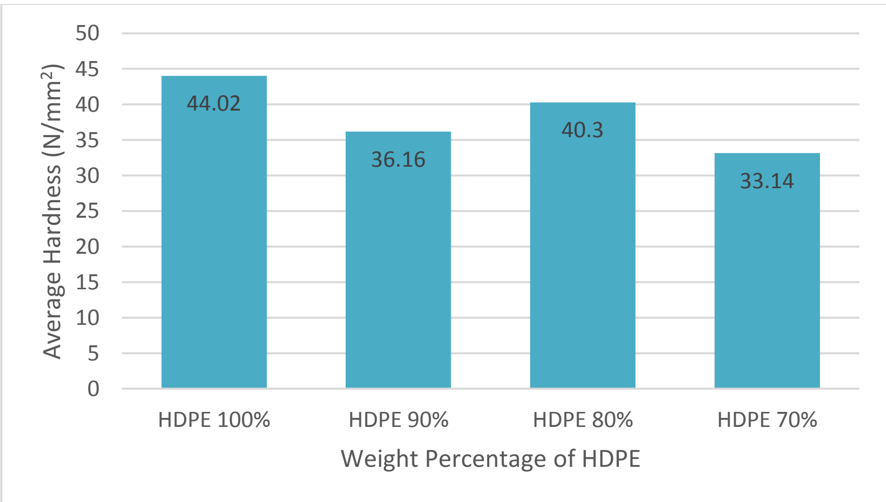

Figure 3. Graph of shore D hardness versus weight percentage of HDPE

Figure 4 shows the SEM results of the 100% HDPE and its 100% wt of carbon content according to EDX analysis. Through observation at a magnification of 200x, it can be seen few voids as shown in the picture with small hole. This is the result of HDPE being properly shredded. Therefore, small holes were not frequent. An indication of the ductility of the 100% HDPE can be determined by how the broken surface part of the 100% HDPE specimens was elongating, and necking before it had broken.

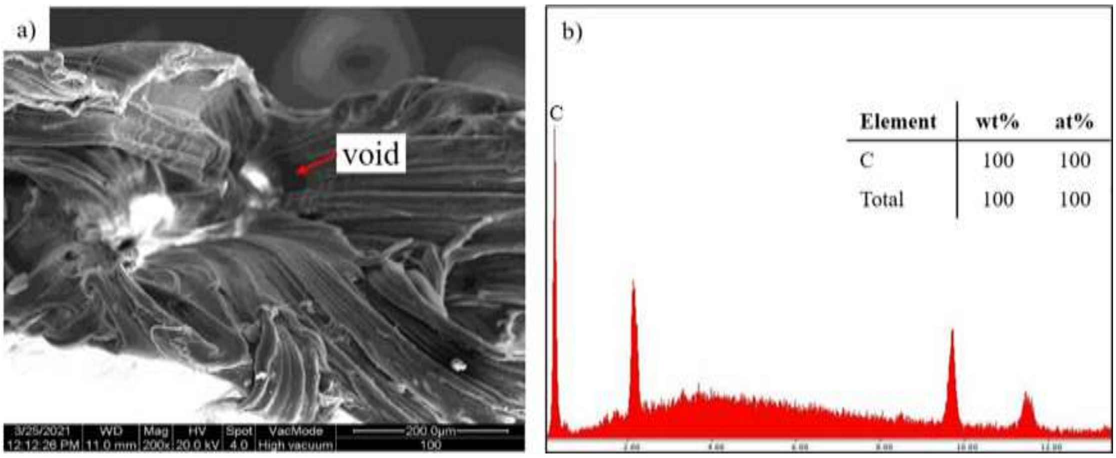

Figure 4. (a) SEM image of 100% HDPE at 200x magnification and its (b) EDX analysis

Figure 5 shows the SEM result of the 90% HDPE and 10% filler materials which were 5% FA, and 5% RHA along with its EDX analysis. At a magnification of 200x, a honeycomb greyscale area being substance-like that indicated RHA. Compared to the 100% HDPE, there were more void in this 90% HDPE specimen. The broken surface part was not elongated nor necking like the 100% HDPE. It can be concluded that the 90% HDPE specimen was brittle compared to 100% HDPE specimen. The composite material was made up of carbon of weight percentage 92.13% and other elements like 5.99% oxygen and 1.62% silicon. Calcium, Iron and Potassium which were present at a weight percentage of 0.04%, 0.09%, and 0.12% respectively indicated the presence of RHA and FA.

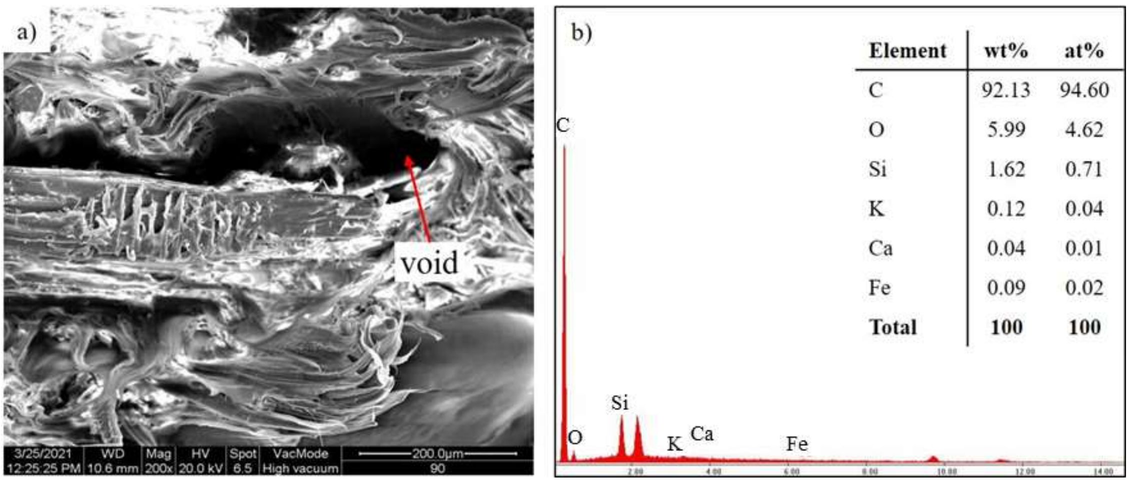

Figure 5. (a) SEM image of 90% HDPE+5% FA+5% RHA at 200x magnification and its (b) EDX analysis.

SEM result of the 80% HDPE and 20% filler materials which were 10% FA, and 10% RHA and its EDX analysis is shown in Figure 6. At a magnification of 200x, a honeycomb like substance indicates RHA. More void could be observed compared to the 100% HDPE specimen and the 90% HDPE specimen. This larger void can affect the results of the specimen during testing by affecting adhesiveness and filler-matrix bond. But this problem can be remediated by using an extrusion machine during the blending process to mix the filler phase materials and the matrix phase material uniformly and better. In this way, the composites material bond tightly and homogenously. Figure 6 (b) also shows that the composite material was made up of 84.49% Carbon, 10.29% Oxygen, 0.14% Magnesium, 0.26% Potassium, 4.74% Silicon, which shows the presence of RHA and Calcium of 0.09% indicates the presence of FA.

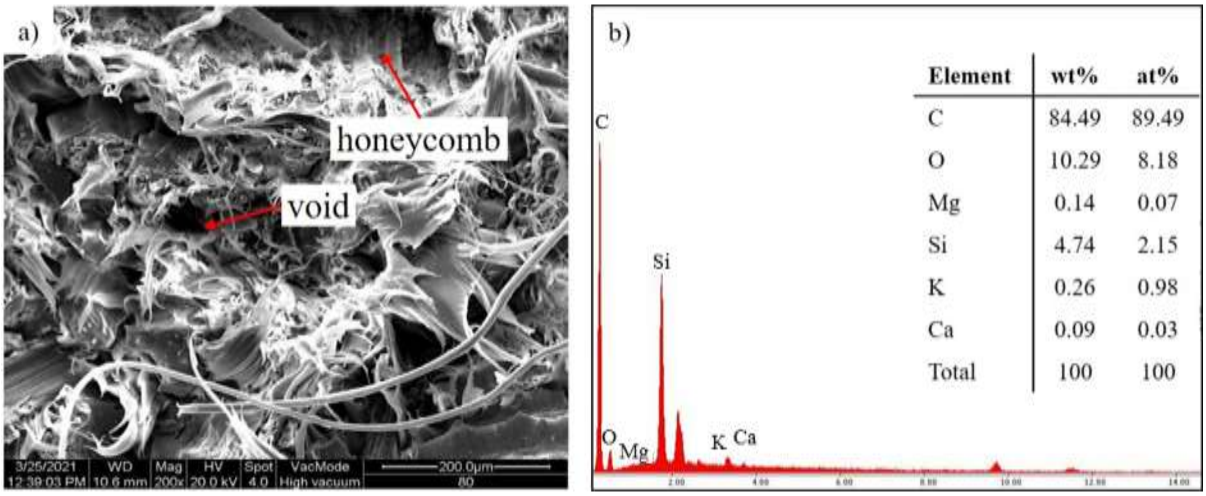

Figure 6. (a) SEM image of 80% HDPE+10% FA+10% RHA at 200x magnification and its (b) EDX analysis.

Figure 7 shows the SEM result of the 70% HDPE and 30% filler materials which consisted of 15% FA, and 15% RHA along with its EDX analysis. At a magnification of 200x, a honeycomb like substance can be observed which indicates RHA. The greatest amount of voids was observed with this 70% HDPE specimen. This is because the composite material did not blend well. To fix this problem, the same solutions that were previously mention can be applied to create a more uniform specimen, yielding better results.

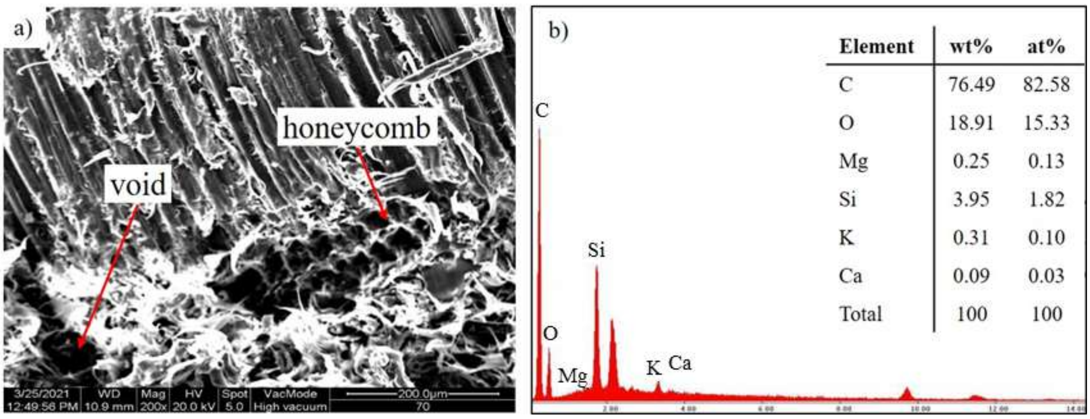

Figure 7. (a) SEM image of 70% HDPE+15% FA+15% RHA at 200x magnification and its (b) EDX analysis

4. Conclusion

In conclusion, highest tensile was found to be 10.51 kN without the inclusion of any filler material followed by 8.57 kN for 90% HDPE, 7.48 kN for 70% HDPE and 7.39 kN for 80% HDPE. It can be inferred that the higher the ratio of filler material combined with HDPE, the lower the composite material's overall stress. The explanation for the substantial reduction in maximum stress after the inclusion of the filler material can be investigated. The inadequacy of the blending process may be one of the key reasons for the decline in maximum tension. This would allow the filler and matrix materials to mix more homogeneously when at a high temperature where each molecule of the materials diffuse with each other resulting in a more integral composite substance. Since FA and RHA is a brittle substance, it is essential to design the filler material ratio that is not more than 10% weightage. Based on the fact that HDPE 100% hardness has the best overall efficiency, and this slowly shifts as filler mixtures are applied. After that, when 10 percent filler is applied, the value declines to 36.16, rendering it smaller than the original 100 percent HDPE value. The overall hardness value increased to 40.3, which was higher than the result of the 10% filler, but 100% HDPE appeared the best performer.

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