Mechanical Properties of Composite Waste Material Based Styrofoam, Bagasse and Eggshell Powder for Application of Drone Frames

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Abstract: The garbage issue becomes a very serious problem at the moment. Much research has been done to make waste into useful materials. One of the utilization of waste is as the basic material of composite material that can be applied in the field of engineering. Some of the wastes generated are styrofoam, bagasse and eggshell. Styrofoam, bagasse and eggshell can be applied to a composite material. Styrofoam serves as a composite binder material while the bagasse and eggshells serve as a reinforcement. Volume fraction between styrofoam, bagasse and eggshell are 80%:10%:10%, 70%:15%:15%, 60%:20%:20%, and 50%:25%:25%. The aims of research are determine the mechanical properties of composite material based waste materials from styrofoam, bagasse and eggshell. Mechanical properties tested in this study are bending strength and toughness of composite materials. The results showed bending strength of composite for each volume fraction of 80%:10%:10%, 70%:15%:15%, 60%:20%:20%, and 50%:25%:25% are 5.07 MPa, 8.45 MPa, 8.68 MPa, and 11.01 MPa, respectively. Toughness of composite materials for each volume fraction of 80%:10%:10%, 70%:15%:15%, 60%:20%:20%, and 50%:25%:25% are 0.33 J/mm², 0.42 J/mm², 0.75 J/mm², and 0.75 J/mm², respectively. Composite materials based on waste materials from styrofoam, bagasse and eggshell can be used as an alternative material for drone frames.

Keywords: Styrofoam, bagasse, eggshell, waste material, bending strength, toughness, drone

1. Introduction
The current waste problem has become a very serious problem for people especially in big cities, not only in Indonesia, but also around the world. Production of waste along increases with population growth, changes in consumption patterns, and people's lifestyles. They have increased the number of waste piles, species, and diversity of garbage characteristics. At the present time many studies concentrate on using waste as a usage or known as waste recycling. Utilization of waste in the field of engineering has not been much applied.

Some of the garbage that can be utilized are styrofoam, bagasse and eggshell. The garbage if processed can be used as material used in field of engineering. One of them is an environmentally friendly hybrid composite material.

Bagasse fiber has been widely used as a basic material of environmentally friendly composites. Research has been done, mechanical properties and properties of the fiber-based composite bagasse [1]. But research that focuses on bagasse with micro size (bagasse powder) is still not widely investigated. To improve the better mechanical properties of sugarcane-based composite can be done by converting the bagasse fiber into the bagasse powder. This is caused by the increasing number of bonds between powder of bagasse with matrix will cause the bonding power between bagasse also higher. it will have an effect on increasing the mechanical
properties of composite. Bagasse size modification has also been done, bagasse powder usage will increase the strength of the composite compared to bagasse fiber [2].

Eggshell is a waste material that is available quite a lot and at this time has not been utilized. The eggshells are containing calcium carbonate (CaCO3) compounds of about 94% [3]. Therefore, the abundant use of eggshells as raw materials for composite materials is a fairly relevant undertaking, in order to improve mechanical properties of composite. Where calcium carbonate has a lightweight, strong and rigid properties that can be used as hybrid composites linked with a powder of bagasse to replace calcium carbonate derived from limestone. The use of hybrid composites based of bagasse and eggshell powder can also indirectly reduce the environmental burden.

Matrix material for binder of environmentally friendly composite can be utilized from waste of styrofoam. Generally, styrofoam is used for packing of food. Styrofoam is made from expanded polystyrene (EPS). According to data from the Central Bureau of Statistics, the import of styrofoam in 2006 reached 3,472,667 tonnes with a value of US $ 7,938,106. As a result, the waste is increasing. Type of plastic packaging of polystyrene often creates environmental problems because it is difficult to decompose biologically. The use of styrofoam as a binder on composites has been investigated. The use of styrofoam for binder on sandwich composites based on sisal fibers and banana stems makes the rise of rigidity of the composite material [4]. Other studies also explain that the use of styrofoam as the core matrix of natural fiber based sandwich composite (sisal fiber) provides a fluctuating sound damping effect but can be applied to soundproofing materials [5].

This study was conducted to find alternative composite materials to replace the construction of unmanned drones. The composites for this existing drone matrix mostly use composites made of resin and fiberglass or carbon fiber mixtures, in essence these composites include composites that are not environmentally friendly, since these composites if they are no longer used and are discharged to nature Will the process of decomposition for very long even hundreds of years of course things like this very pollute the environment.

The use of environmentally friendly hybrid composites based on styrofoam as binders and reinforcement from powdered bagasse and eggshell powder will be able to reduce the environmental burden. Environmental problems can be resolved and this composite material can be applied for engineering material, especially material for the frame/body of drones.

The purpose of this research is to know mechanical properties (bending strength and impact toughness) of environmentally friendly composite material based on waste material from Styrofoam, bagasse and eggshell so that can be applied as environmentally friendly materials in the field of engineering later, especially for drone’s frame.

2. Literature Review

The composite is a combination of two or more materials into a material consisting of a reinforcement and a binder (matrix) to obtain a better character than the constituent material. Composite materials can be divided into three types when viewed from the type of matrix used. The three types of composites are (1) metal matrix composites, (2) polymer matrix composite and (3) ceramic matrix composite.

The polymer composite-based natural fiber are superior in their mechanical and physical properties [6]. Natural fibers generally have low density (low density), low cost fiber, high specific properties and most importantly have biodegradable properties [7, 8].

In the last decade, researchers have done a lot of research on composite materials that can decompose in nature quickly. One of his researches is the utilization of natural fibers for composite materials. Composite natural fiber or natural fiber composite is widely developed in the automotive field as a substitute of fiberglass composite fiber [6, 9].

Recent research explains that people have turned to micro-sized or nano-sized materials, so are on the composite material. Shear strength and friction resistance of micro-carbon composites and nano-carbon composite are higher than that of macro-sized carbon fiber composites [10]. The use of macro fiber has been replaced with the
use of micro-sized fibers. It also includes the use of natural fibers for composite materials. Natural fibers have been widely transformed into micro size or also called powder/natural fiber particles. The purpose of changing the size of the macro-sized fibers into micro-sized fibers is to obtain a better bonding power so that it will impact on better mechanical properties [2, 11, 12, 13].

3. Method

In this study, materials used were styrofoam, bagasse and eggshell. Styrofoam serves as binder material for composite while the bagasse and eggshells serve as a reinforcement. The styrofoam used was unused styrofoam. Styrofoam is dissolved in an acetone solution to make styrofoam turn into a liquid. After that added additive/compatibilizer on fluid styrofoam. This additive serves to make the styrofoam liquid more homogeneous. In making this binder, the compatibilizer used is acetate anhydride. Due to the brittle nature of styrofoam, it is necessary to add a Diocyl Phthalate (DPO) stabilizer that serves to bend [14]. Bagasses were taken in lawang, West Sumatera. Eggshells were taken in Payakumbuh, West Sumatera. Bagasse and eggshells which still contain impurities cleaned using clean water. After cleaned, then bagasse and eggshell were drained and dried without direct sunlight. After bagasse and eggshells was dried, then the process of blending up bagasse and eggshells into powder with size 74 microns.

Prepare a square-shaped mold with dimensions of 170 mm x 170 mm x 5 mm (bending and impact test) and which have been waxed throughout the surface. The wax is intended to keep the composite from sticking if removed from the mold. Combine styrofoam that has been diluted with the powder of bagasse and eggshell powder, then stirred using mixer for 10 minutes until mixed evenly. Mixing (mixing) is done at room temperature. Pour mixture of styrofoam, powder of bagasse and eggshell into mold. The volume fraction between hybrid fiber and styrofoam matrix is 80:20, 70:30, 60:40 and 50:50. Volume fraction between binder and reinforment 80%-20% (80% styrofoam, 10% bagasse powder and 10% eggshell powder), Volume fraction between binder and reinforment 70%-30% (70% styrofoam, 15% bagasse powder and 15% eggshell powder), Volume fraction between binder and reinforment 60%-40% (60% styrofoam matrix, 20% bagasse powder and 20% eggshell powder), and Volume fraction between binder and reinforment 50%-50% (50% styrofoam matrix, 25% bagasse powder and 25% eggshell powder).

After the mold is full, there is a compressing molding process on hybrid composite. Then wait for the composite to dry evenly. After this hybrid composite is made (figure 1), then after that will be made bending and impact test specimens. Bending test specimens and impact tests were prepared based on ASTM-D790 and ASTM D5942-96.

![Figure 1. Panel of composite material based on waste material from styrofoam, bagasse and eggshell](image)

The type of bending test to be performed is three points bending using ASTM-D790 standard. Bending test specimen according to ASTM-D790. Testing bending using universal machine testing merk simadzu UH-300 kNI type in Mechanical Engineering Laboratory – Institut Teknologi Padang. On impact test, methods used was charpy flatwise impact (figure 4). The impact specimens were prepared according to ASTM D 5942-96.

4. Result and Discussions

4.1 Bending Strength

Figure 2 shows a graph of bending test results of a hybrid composite. On the graph shows that the highest bending strength is found in the volume fraction between styrofoam, bagasse powder and eggshell powder at 50:25:25 of 11.01 MPa. The lowest bending strength was found in the volume fraction between styrofoam, bagasse powder and eggshell powder at 80:10:10 of 5.07 MPa. This indicates that the increasing composition of bagasse powder and eggshell powder on the composite or the reduction in the amount of the composition of styrofoam makes the hybrid composite bending strength even higher. Bagasse powder and eggshell powder
make composite properties relatively strength, elastic and rigid. While styrofoam tends to make composites become lighter.

![Bending strength of composite based waste material](image)

**Figure 2.** Bending strength of composite based waste material

Bending strength of composite will increase with addition of bagasse powder and eggshell powder. This is due to the increasing composition of bagasse powder and eggshell powder making the bond between styrofoam, bagasse powder and eggshell getting better. Perfect interfacial bonding between binder (styrofoam) and reinforcement (bagasse and eggshell) is indicated by at no more air bubble in the composite. The more air bubble in the composite will cause decrease of composite strength [15].
Figure 3. Fracture surface of bending test specimens. (a) 80:10:10, (b) 70:15:15, (c) 60:20:20, (d) 50:25:25

Figure 3 shows the fracture surface of bending test specimen of the hybrid composite for each volume fraction variation. From the observation of the fracture surface of the composite, shows the fracture surface of the composite with a volume fraction of 80:10:10, the composite having the most bubble (figure 3.a). And on composites with a 50:25:25 volume fraction having the least bubble (Figure 3.d). The more bubble in the composite make composite strength decrease. This is because the air bubble makes no bond (interfacial bonding) between the binder and reinforcement. The results show that with the addition of the composition of the reinforcement (bagasse powder and egg shell powder) and the reduction of the binder composition (styrofoam) makes the composite better in terms of interfacial bonding between the matrix (styrofoam) and the reinforcement (bagasse powder and egg shell) Characterized by the number of air bubble produced on the composite.

Volume fraction of the powder/particles affects the strength of the hybrid composite, wherein the composite with volume fraction 50% of particle (bagasse powder + eggshell powder) provides the highest bending strength compared with the volume fractions of 40% and 30% and 20% of the particles. At volume fraction 50% of particles show a bond between the binder and reinforcement higher. This is caused because the reinforcement has the discretion to fill the empty area between the binders [16]. The bonds between the particles are better and fill the empty space that is not filled by the matrix, so the composite has a high strength and rigid. It’s because the smaller size of the material the more it will bind to the matrix. It is in accordance with the reported [10] that a reinforcement having a particle size (micro-sized) provides better on mechanical properties than fiber-shape.

The results of bending tests was obtained, hybrid composites based on waste materials from styrofoam, bagasse powder and eggshell powder can be applied to the drone body. This is due bending strength of hybrid composite is higher than the maximum bending force for the drones calculated through the Catia software. Where the results of calculations using the Catia software, the bending strength for the drones frame is 3.04 MPa [17]

4.2 Impact Toughness
In Impact tests on hybrid composites styrofoam-based bagasse and eggshell powder was obtained as shown in Figure 4.

Figure 4. Impact toughness of composite based waste material

Figure 4 shows a graph of Impact test results of a hybrid composite. On the graph shows that the highest impact toughness is found in the volume fraction between styrofoam, bagasse powder and eggshell powder at 60:20:20 and 50:25:25 of 0.75 J/mm². The lowest impact toughness was found in the volume fraction between styrofoam, bagasse powder and eggshell powder at 80:10:10 of 0.33 J/mm². This indicates that the increasing composition of bagasse powder and eggshell powder on the composite or the reduction in the amount of the composition of styrofoam makes the hybrid composite impact toughness even higher too. Result of impact test, also similarity with bending test result. Bagasse powder and eggshell powder make composite properties relatively strength, elastic and rigid. While styrofoam tends to make composites become lighter.
Figure 5. Fracture surface of impact test specimens. (a) 80:10:10, (b) 70:15:15, (c) 60:20:20, (d) 50:25:25

Figure 5 shows the fracture surface of impact test specimen of the hybrid composite for each volume fraction variation. Similar with bending test result, from the observation of the fracture surface on impact test specimens, shows the fracture surface of the composite with a volume fraction of 80:10:10, the composite having the most bubble (figure 5.a). And on composites with a 50:25:25 volume fraction having the least bubble (Figure 5.d). The more bubble in the composite make composite impact toughness decrease too. This is because the air bubble makes no bond (interfacial bonding) between the binder and reinforcement. The results show that with the addition of the composition of the reinforcement (bagasse powder and egg shell powder) and the reduction of the binder composition (styrofoam) makes the composite better in terms of interfacial bonding between the matrix (styrofoam) and the reinforcement (bagasse and eggshell powder).

Impact testing of composite based waste material from styrofoam, bagasse powder and eggshell is still below from composite based polyester and rockwool fiber. From impact testing, the highest impact toughness is owned by 4% rockwool composition that is equal to 3.7 J/mm², while the composition of 12% rockwool has impact toughness of 2.4 J/mm², and the composition of 8% rockwool has the lowest impact toughness is 2.2 J/mm² [18].

5. Conclusion
The results showed bending strength of composite for each volume fraction of 80%:10%:10%, 70%:15%:15%, 60%:20%:20%, and 50%:25%:25% are 5.07 MPa, 8.45 MPa, 8.68 MPa, and 11.01 MPa, respectively. Toughness of composite materials for each volume fraction of 80%:10%:10%, 70%:15%:15%, 60%:20%:20%, and 50%:25%:25% are 0.33 J/mm², 0.42 J/mm², 0.75 J/mm², and 0.75 J/mm², respectively. It can be concluded that the highest bending strength and impact toughness of environmentally friendly composite material based on waste material from Styrofoam, bagasse and eggshell bases based on bagasse on volume fraction 50:25:25 was 11.01 MPa and 0.75 J/mm², respectively. Composite materials based on waste materials from styrofoam, bagasse and eggshell can be used as an alternative material for drone frames.
References

[1] Shabiri, Akhmad Nadji, Rizky Salaam Ritonga, and M Hendra S Ginting. 2014. “Pengaruh Rasio Epoksi/Ampas Tebu Dan Perlakuan Alkali Pada Ampas Tebu Terhadap Kekuatan.” Jurnal Teknik Kimia - Universitas Sumatera Utara 3 (3): 28–31

[2] Oladele, Isiake Oluwole. 2014. “Effect of Bagasse Fibre Reinforcement on the Mechanical Properties of Polyester Composites.” The Journal of the Association of Professional Engineers of Trinidad and Tobago 42 (1): 12–15

[3] Yahya, Muhammad, Yelmida Aziz, and Zultiniar. 2016. “Sintesis Hidroksiapatit Dari Precipitated Calcium Carbonate (PCC) Kalit Telur Ayam Melalui Proses Hidrotermal.” Jurnal FTENIK 3 (1): 1–8. doi:10.6052/j.issn.1000-4750.2014.04.S008

[4] Sinarep, and Agus Dwi Catur. 2012. “Pengaruh Tebal Styrofoam Core Terhadap Berat Jenis Dan Kekuatan Tekan Komposit Sandwich Matrik Poliester Diperkuat Serat Sisal Dan Serat Pohon Pisang.” Jurnal Dinamika Teknik Mesin 2 (1): 1–5

[5] Sinarep, Agus Dwi Catur, and M Hafidzul. 2014. “Redaman Suara Pada Komposit Sandwich Polyester.” Jurnal Dinamika Teknik Mesin 4 (1): 30–37

[6] Sanjay, M R, G R Arpitha, L Laxmana Naik, K Gopalakrishna, and B Yogesh. 2016. “Applications of Natural Fibers and Its Composites : An Overview.” Journal Natural Resources 7: 108–14

[7] Saheb, D Nabi, and J P Jog. 2015. “Natural Fiber Polymer Composites : A Review.” Journal of Advances in Polymer Technology 18 (4): 351–63. doi:10.1002/(SICI)1098-2329(199924)18.

[8] Bongarde, U. S, and V .D Shinde. 2014. “Review on Natural Fiber Reinforcement Polymer Composites.” International Journal of Engineering Science and Innovative Technology (IJESIT) 3 (2): 431–36.

[9] Holbery, J, and D Houston. 2006. “Natural-Fibre-Reinforced Polymer Composites in Automotive Applications.” Jom 58 (11): 80–86.

[10] Liu, Ning, Jianzhang Wang, Jie Yang, Gaofeng Han, and Fengyuan Yan. 2015. “Effects of Nano-Sized and Micro-Sized Carbon Fibers on the Interlaminar Shear Strength and Tribological Properties of High Strength Glass Fabric / Phenolic Laminate in Water Environment.” COMPOSITES PART B 68. Elsevier Ltd: 92–99. doi:10.1016/j.compositesb.2014.08.035

[11] Iniguez, C G, C J J Bernal, M W Ramírez, and N J Villalvazo. 2014. “Recycling Agave Bagasse of the Tequila Industry.” Advances in Chemical Engineering and Science 04 (02): 135–42. doi:10.4236/aces.2014.42016.

[12] Jahjono, Arif T. 2011. “The Influence of Wood Powder Adding on the Porosity of Composite Material,” no. February: 2–3.

[13] Ramli, Ridzuan, Maksudur Rahman Khan, Najmul Kabir Chowdhury, Mohammad Dalour, Rohaya Mohamed, Astimar Abdul Aziz, Zawawi Ibrahim, and Nahrl Hayawin Zainal. 2013. “Development of Cu Nanoparticle Loaded Oil Palm Fibre Reinforced Nanocomposite.” Journal Advances in Nanoparticle 2 (November): 358–65

[14] Nurhajati, Dwi Wahini, and Ilaha Novia Indrajati. 2011. “Kualitas Komposit Serbuk Kelapa Dengan Matrik Sampah.” Jurnal Riset Industri V (2): 143–51

[15] Perdana, Mastariyanto, and Romi Perdana Yulsardi. 2015. “Pengaruh Fraksi Volume Penguat Terhadap Kekuatan Lentur Green Composite Untuk Aplikasi Pada Bodi Kendaraan.” Jurnal Iptek Terapan, Kopertis Wilayah X 3: 71–77.

[16] Siswanto dan Kuncoro, D., 2011. Pengaruh Fraksi Volume dan Ukuran Partikel Komposit Polyester Resin BerpengauatPartikel Genting Terhadap Kekuatan Tarik dan Kekuatan Bending. Jurnal Politeknosains. Vol. X, No. 2, 91 – 99

[17] Sayuti, Syahril, and Muhammad Hakim Soffian. 2016. “Perancangan Dan Pembuatan Rangka Drone Yang Ekonomis Dan Praktis.” In Prosiding Seminar Nasional Aplikasi Sains & Teknologi (SNAST), 485–90

[18] Putra, F., K. 2014. Analisa Pengaruh Variasi Komposisi Terhadap Kekuatan Tarik Statik dan Impak Komposit Berpengauat Serat Rock woll Pada Pesawat Tanpa Awak. Thesis. Universitas Sumatera Utara.