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Drop-Weight Impact Test on Laminated Composite Plate of Flax (Linum Usitatissimum) Using Rice Husk Ash from Paddy (Oryza Sativa) as a Natural Binder

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ABSTRACT

Composite structures and materials are used in aerospace, marine and automotive applications due to their light weight characteristics. By using rice husk ash (RHA) as natural binder to replace epoxy resin, it improves the characteristic of the composite laminated structure. Rice husk has become an important ingredient in silica, silicon carbide, and silicon nitride because of its high a silicon content. This paper evaluates the performance of laminated composite plate in a drop-weight impact testing. Two plates are attached to the test rig in the particular desired impact orientation. The main advantages of this process are the plates provide more realistic drop-weight impact and data. Data from the impact test was collected and analysed to evaluate the material properties of epoxy resin and RHA. Results show RHA's energy absorption is better and it has more deformation to prevent structure failures compared with epoxy resin. This paper aims to evaluate the application of RHA as a geopolymer binder and flax fibre as an alternative material to glass fibre in the composites industry.

Keywords: Laminated Composite Plate, Geopolymer Binder, Drop-Weight Impact Test, Rice Husk Ash (RHA), Flax Fibre, Fibre Glass

INTRODUCTION

In recent years, there has been mounting interest in environmental friendly materials among scientists and manufacturers as a result of greater environmental awareness and an increasing demand for biodegradable materials. Environmental friendly materials make optimal use of resources, produce minimum waste and are safe for the environment; new environmental laws and

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regulations are in place to check pollution levels and thus environmental friendly materials are being promoted to achieve this. An intensive research and development over the last decade has been carried out in order to develop composites using natural fibres which offer good bio-degradability and sustainability. End-of-life after service life was a big issue involving composites structure. Compared with glass fibres, biodegradable materials undergo biodegradation at a slow pace by surrounding microorganisms, bacteria and exposure to the elements (Jinchun Zhu, 2013). In order to overcome this problem, fibres from woods, animal, grasses and other natural sources are used as reinforcement in composite materials, replacing glass fibres. These natural fibres have a potential to be utilised in the composite industry but that requires an advanced knowledge in manufacturing techniques. Compared with glass fibres, these natural fibre-reinforced biodegradable polymer d composites show equivalent performances as well as a higher fibre content. Lighter than synthetic polymer matrix, natural fibre composites contribute to increased fuel efficiency in aerospace and automotive applications. Table 1 shows the advantage and disadvantages of using natural fibre and synthetic fibres to reinforce polymers. Holbery and Houston (2004) and Avella (2009) have reviewed natural fibre composites with their classifications, properties and potential applications.

Table 1
Natural fibre and Synthetic fibre comparison

Fibre	Advantages	Disadvantages
Natural fibre	Biodegradable	non- homogeneous quality
	Low density/price	Dimensional instability
Synthetic fibre	Moisture resistant	Difficult to recycle
	Good mechanical properties	Relatively high price

Note. From Thermophysical properties of natural fibre-reinforced polyester composites by Idicula, M.; Boudenne, A.; Umadevi, L.; Ibos, L.; Candau, Y.; Thomas, S, 2006, Compo. Sci. Technol, 66, 2719–2725.

Rice husk ash

According to FAO's Liaison Office for North America (2008), 20% of the 649.7 million tonnes of rice were residue of rice husk. Utilising partially burnt rice husk from the milling plants as a supplementary cementing material safeguards the environment (Chandrasekhar, 2006). This is because the husk produces ashes when it is used as a fuel contributing to pollution. The composition of chemical in rice husk is different in each sample depending on the type of paddy, climate and geographical condition and also its crop year (Idicula, 2006). Burning the husk under controlled temperature below 800 °C can produce ash with silica mainly in amorphous form *Burning* the *husk under controlled temperature below 800°C can produce ash with silica mainly in amorphous form.* Nair (2008) conducted an investigation on the *pozzolanic activity* of *RHA* by *using various techniques* in *order to verify* the *effect* of *incineration temperature* and *burning duration.* To produce high reactivity with no significant amount of crystalline material, the RHA was burnt at 500 or 700 °C for more than 12 hours producing ashes. Because the duration of burning was short which was less than 360 minutes, it will produce RHA with high carbon content. Mehta (1992) had reported on the physical and chemical properties of RHA, the effect of incineration conditions on the pozzolanic characteristics of the ash, and a summary of the research findings from several countries on the use of RHA as a supplementary cementing pozzolanic material.

Bio-composite Material

Derived from renewable resources, bio-composite materials are cost effective due to their large scale usage. Replacing glass fibres with bio-composite materials will have a huge impact in the composites industry. To make use of this environmental friendly material, a new way of producing bio-composite materials should be proposed. Natural composite materials, also known as green composites, are a combination of plant fibre and resin. Kenaf and flax fibres are low cost bio materials, light weighted and suitable as environmental friendly alternatives to synthetic fibres (Begum, 2013).

Flax fibre

In fibre-reinforced polymer composites, Flax fibres are considered environmental friendly along with other natural fibres and have the potential to replace synthetic fibres. A feature of natural fibres is that they have a much higher variability of mechanical properties. To produce composites from natural fibres, usually these fibres are made into some sort of a mat for easier application. Other fibre composites have been studied such as kenaf, hemp, sisal, coir and jute but the focus has been on flax fibres.

In some areas, flax fibres are competitive to glass fibres, and hence are reasonably acceptable as replacement. Except for the specific properties of flax fibres as shown in Table 2, three other reasons make the application of flax fibre more attractive: (1) cheaper than glass fibres; (2) less toxic; (3) high strength to weight ratio. Normally, flax fibres have a relatively low price compared with glass fibres. Additionally, glass fibres are suspected of causing lung cancer, but there is no such problem with regards to natural fibres (Bos, 2004). Thermal recycling of flax fibres (burning of flax fibres with few slags left) has a great advantage over glass fibres.

Table 2
Tensile properties of glass and flax fibres

Property	**E-glass**	**Flax fibres**
Specific E-modulus (Gpa/g•cm−3)	0.5–1	0.4–1.1
E-modulus (GPa)	76	50–70
Specific tensile strength (GPa/g•cm−3)	30	36–50
Tensile strength (GPa)	1.4–2.5	0.5–1.5
Density (g/cm3)	2.56	1.4
Diameter (μm)	8–14	10–80

Note. From The Potential of Flax Fiber as Reinforcement for Composite Materials. Ph.D. Thesis, Eindhoven University, Eindhoven, The Netherlands, Bos, H.L (2004).

METHODOLOGY

Specimen preparation

The tested specimens were epoxy resin and rice husk ash of flax material. In order to mix it with other chemicals, the rice husk must be fine (blending it in a blender to make it fine and smooth) so that it can dissolve into the mixture.

There are two process involved:

i. Flax Fibre with natural binder specimen
ii. Flax Fibre with epoxy specimen

Flax Fibre with natural binder specimen. First, all the apparatus and materials are prepared. Next, the materials are cut with 30cm X 30cm dimension for 3 set plate specimen. The mixer will allow the mixture to mix more evenly. It is then poured over the material. Finally, the mixture goes through the compress plate mould process.

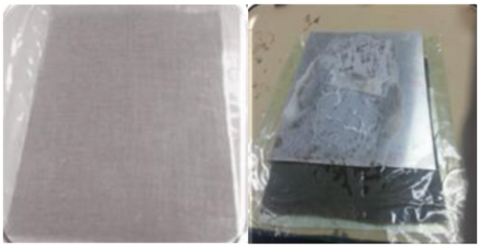

Figure 1. Specimen preparation for RHA.

Flax Fibre with epoxy. Figure 2 shows the process for plate specimen with epoxy mixture. The process is the same with the previous one but the mixture preparation and ratio are different. First, all the apparatus and the materials are prepared. Then, the materials are cut with 30X30cm dimension for 3 set plate specimen. The mixture is then over the material. The mixture then goes through the pressing process.

Figure 2. Specimen preparation for epoxy mixture.

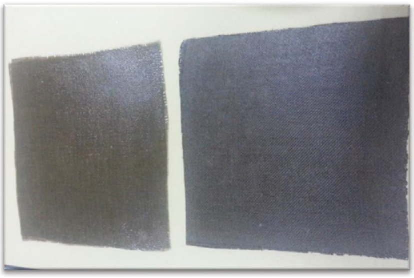

Figure 3. The specimens that will be compared.

Low velocity impact testing

The instrument used the impact test was provided by IMATEK manufacturer as seen in Figure 5. The IM1-C impact test systems consists of a manually operated, low to medium energy, impact tester primarily designed for standard test methods such as plaque penetration, compression, Charpy and Izod impact testing on polymers and advanced composite materials provide an understanding of the mechanism by which the test specimen absorbs energy or fails at rates of strain.

The base sits on four adjustable feet used for levelling. The design of the base ensures that the specimen is correctly supported on a rigid structure to prevent loss of impact energy due to movement, flexure or vibration. The specimen area (impact chamber) is enclosed for safety. The front and rear doors are fitted with impact resistant polycarbonate panels, for viewing of the impact event and to accommodate high-speed videoing of the impact event (option).

For this project, the equipment was used to identify the toughness and the energy absorbed for plate specimen with different types of material. The result will be analysed using the equipment system. This test method determines the damage resistance of a multidirectional composite laminated plate subjected to a drop-weight impact event. The test equipment utilised in this experiment meets the requirements of the American Society for Testing and Materials (ASTM D7136 / D7136M, 2005). The plate is subjected to an out-of-plane concentrated impact (perpendicular to the plane of the laminate) using a drop-weight device with a hemispherical striker tip with a diameter of 16 mm and a hardness of 60 HRC. The impact energy corresponds with the potential energy of the drop-weight, defined by the mass (2240 gr) and drop height of the impactor. The damage resistance is quantified in terms of the resulting size and type of damage in the specimen.

The plate is placed in the rigid support fixture, centred relative to the cut-out and secured using the test rig for plate as shown in Figure 4, in order to prevent the plate from rebounding during impact. Figure 5 shows the drop-weight impact-testing device. The device includes a rigid base, a cylindrical drop-weight impactor and a cylindrical guide mechanism. A rebound catcher is used to stop the impactor during its second descent. For the testing of plates that are less than 1 inch (2.42 mm) thick it has optional lightweight crossheads to meet those lower impact energies. To prevent a secondary impact of the falling weight onto the composite plate, anti - rebound device can be employed.

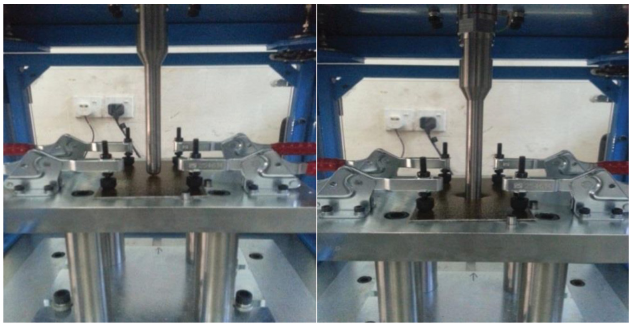

Figure 4. Plate secured in place using the test rig for impact.

Figure 5. Impact Test equipment.

RESULTS AND DISCUSSION

Visual inspections and measurements post impact show specimen failure. Complete with the Data Acquisition System, Visual Impact and a strain gauged tup failure points/modes provide instrumentation that may remain hidden under normal test conditions. The most important information that could not be found without using the instrumentation is the incipient damage point or the first crack.

Table 3
Epoxy specimen results from the impact test

	Peak force (kN)	*Impact energy (J)*	*Peak deformation (mm)*	*Absorbed energy (J)*	*Energy to peak deformation (J)*
Flax+epoxy 1	1.36	23.62	40.98	0.32	-2.22
Flax+epoxy 2	1.07	23.56	40.84	0.18	-5.96
Flax+epoxy 3	0.96	23.68	39.75	0.28	-1.70
Average	1.03	23.62	39.39	0.25	-3.32

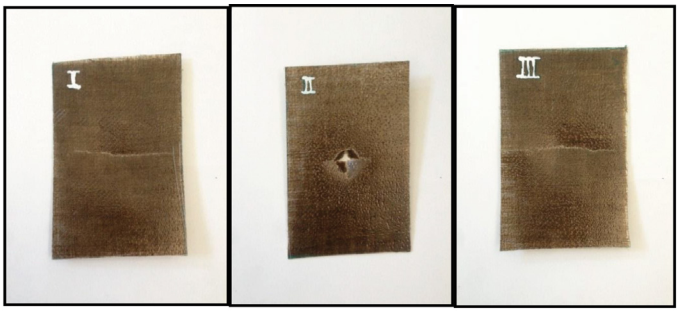

Figure 6. The epoxy specimen after impact

As shown in Figure 6, 3 specimens from epoxy were tested to the drop-weight impact event of the epoxy plate. Data from table 3 was collected and analysed. A visual inspection shows the specimen of epoxy plate could not pass the weight and height of the impactor. All the specimens indicate cracks as the impactor had punched thru the plate. Even though the plate was not impact resistant, the data could still be used to compare with the RHA plate. The energy consumed during peak deformation for the second specimen was higher and this was also the cause of the damage. Average mean of the data were compared with the RHA plate.

Table 4
RHA specimen results from the impact test.

	Peak force (kN)	*Impact energy (J)*	*Peak deformation (mm)*	*Absorbed energy (J)*	*Energy to peak deformation (J)*
Flax+RHA 1	0.98	23.58	40.54	0.27	-2.53
Flax+ RHA 2	1.13	23.55	39.99	0.32	-1.80
Flax+ RHA 3	0.95	23.56	42.33	0.27	-1.95
Average	1.01	23.56	40.17	0.29	-2.13

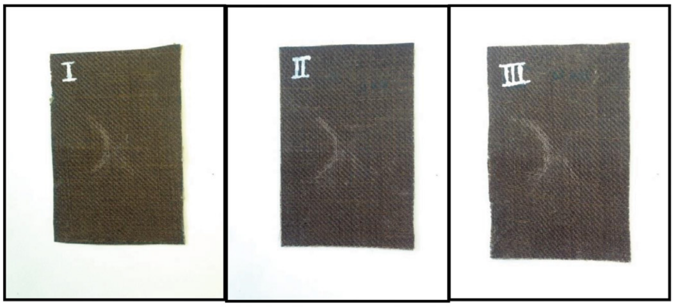

Figure 7. The RHA specimen after impact

Table 4 shows RHA specimen impact test data and the mean of dataset. Figure 7 shows the specimen post impact. A visual inspection shows the RHA plate does have any defect except the dent due to the impact. The average impact energy for this specimen is the same as the third specimen. Even though it is a high energy absorbing material and extensive evidence of deformation because of the impact, it does not crack or damage the plate. The energy absorption during peak deformation for the first specimen was higher but did not cause any damage to it. Average data for RHA specimen was then compared with the epoxy specimen.

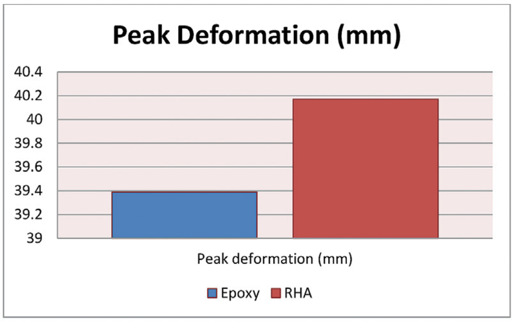

Figure 8. Comparison of Average Peak Deformation (mm) for Epoxy and RHA.

Figure 8 compares the peak deformation for epoxy plate and RHA plate. For epoxy plate, 39.39 mm deformation was measured after impact and 40.17 mm for RHA plate. Thus, RHA plate showed greater deformation compared with epoxy plate, indicating flexibility of the material. The results for the epoxy plate showed the materials are more brittle compared with the RHA plate.

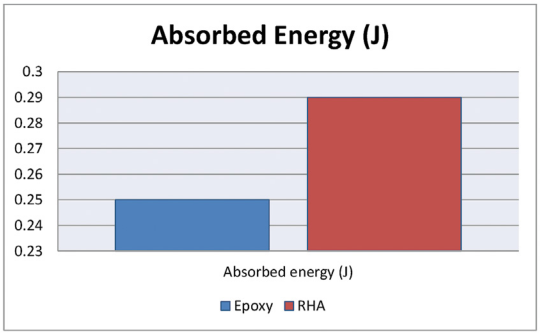

Figure 9. Comparison of Average Absorbed Energy (J) for Epoxy and RHA.

Figure 9 compares energy absorption for epoxy plate and RHA plate whereby the latter shows more deformation and greater energy absorption post impact. It shows the RHA material properties are better than epoxy materials. The energy absorption capability and deformation mechanisms of RHA plate was experimentally studied with the aim of developing a real application and also for impact analysis for future research. It also contributes to developing a comprehensive constitutive law to be implemented for industries.

CONCLUSIONS

Strength analysis under drop-weight impact was conducted for epoxy plate and RHA plate composites, results show acceptable stiffness prediction for RHA plate. The fabrication of flax composites that use natural resin are advantages in terms their recyclability allowing the reutilisation of the materials as the composites are ecologically friendly,100% biodegradable. Since the material is widely available and cheaper, there is a good future of natural fibre composites with high-performance in structure materials.

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