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Mechanical Properties of Seashell Structure under Different Drying Temperature

Ranjhini a/p Anpalagan[1], Kamarul Azhar Kamarudin[1*], Muhammad Iqbal Haikal Roslan[1], Mohamed Nasrul Mohamed Hatta[1]

[1]Mechanical Failure Prevention and Reliability Research Centre(MPROVE), Crashworthiness and Collision Research Group (COLORED), Faculty of Mechanical and Manufacturing Engineering, University Tun Hussein Onn Malaysia, 86400 Batu Pahat, Johor, Malaysia.

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Abstract

This study investigates the mechanical properties of seashell structure samples with different composition of sucrose as binder. It consists of 10%, 20% and 30% of sucrose with 2% wt for water and total weight of 14grams for each specimen. The size of seashell powder is between 150µ - 200µ and compacted in the mould with 8 ton pressure. Samples went through a sintering process for an hour in the oven with 100ºC and let it cool in room temperature for 24 hours. The mechanical properties were investigated by using a three-point bending test and Charpy impact test. For the three-point bending test, the standard used is ASTM C1161-13 at head speed at 1mm/s. The result for three-point bending test and Charpy impact test showed that the value increased simultaneously with increases in a percentage of sucrose. Porosity and density test were also done to support the results of physical properties for each specimen.

Keywords: *seashell, binder, mechanical properties, cockle shell, low velocity impact*

1. Introduction

Protection is the outer surface of building, vehicle, or body which use to prevent from directly hit by any object such as bullet or projectile. The protective material is one of the essential things in any defensive system. A protective device, especially for the bulletproof jacket, need to increase the time of impact so, it can decrease impact towards the body. Due to that reason, the protective device needs to be built or invented by using suitable material[1][2].

Kevlar was known as a protective material for decades. It is due to properties in high modulus, low density and sufficient flexure[3]. Synthetic fibre reinforced composite has become significantly popular because its application has considerably become very wide due to its excellent mechanical properties such as light in weight, unique flexibility, corrosion-resistant and ease of fabrication[1].

The traditionally manufactured layering numerous woven fabric layers had been changed by great innovation silk to Kevlar and Ceramic, which results in the weight of 3 kg to 5 kg [4]. Protective materials made from ceramic has been used in many applications due to its good in strength, but too small fracture toughness that tendency to fragile. Sintered ceramic is brittle during the experiment to increase its material properties[5]. The main reason to choose ceramic for ballistic protection is that it has strong covalent bonding, decrease the time of speed of impact of the bullet and transform into small pieces [6][7].

Due to certain outstanding properties such as high-temperature and corrosion resistance, dimensional stability, hardness and wear resistance, ceramic has always been chosen for structural component and machine parts[8].

Apart of using ceramic, another potential and naturally abundant materials were seashells which known as its unique structure and toughness. Collaboration between seashell powder and sucrose as the binder will give another potential result that people never know their capability[9][10].

This research is motivated by the lack of knowledge in the study of seashell structure mechanical properties under influence of drying temperature. The experimental work presented here provides one of the first investigations into how seashell becomes a dominant material instead of as a filler. Experimental results on samples of the seashell structure were subjected to quasi-static loading, and dynamic impact using Charpy test is reported in this study. Various behaviour, which influences the damage resistance, are identified.

2. Methodology

Materials and sample preparation

Seashell used in this study is Anadara granosa which can easily found at beaches near Senggarang in Batu Pahat, Johor, Malaysia.

Seashell is soaked for several hours to remove the unpleasant smell, and unwanted dirt hides within the shell. The shell was crushed using a granulator machine to the size of approximately 5mm. It went through the ball mill before proceed to the sieving machine which results of powder size between 150µm to 200µm. The powder is then compacted using specific mould at the size of 100mm × 10mm × 8 mm. The samples are weighted at the same weight of 14 grams with three different seashell/sucrose ratio. Sample A contains 10% of sucrose, 88% of seashell and 2% of water. Sample B contains 20% of sucrose, 78% of seashell and 2% of water. Sample C contains 30% of sucrose, 68% of seashell and 2% of water. The specimens then heated in the oven for an hour at 100ºC.

Mechanical Testing

Specimens tested for three-point bending is using ASTM 1161-13 standard. The length span to support the sample horizontally is 80mm with indenter head-speed at 1mm/s.

For low-velocity impact, Charpy test was used to determine the energy absorption of the specimen. After the hammer hit the sample, the needle will indicate the energy that specimen absorbed.

The density and porosity of the specimen were done by using Archimedes' method. This test aimed to study the effect of binder on density and porosity each sample. The value of the percentage of porosity required to calculate by using equation (1)

$$\text{Porosity } (\%) = \frac{w_w - w_d}{w_w - w_s} \times 100\% \qquad (1)$$

Results of three-point bending and low velocity impact on samples with difference percentage of sucrose and seashell powder are compared with previous research conducted by Haritha[11]. The difference between Haritha work to this study are sintered temperature which is 160ºC for an hour while present study use temperature sintered at 100ºC at an hour.

3. Results and Discussion

Three-Point Bending Test

To identify the value of elasticity and strength of specimen, formula (2) and (3) are used with force (F) by the plunger, length (L), width (d) and thickness (b) of the sample.

$$\text{Strength, } \sigma = \frac{3FL}{2bd^2} \quad \text{(MPa)} \qquad (2)$$

$$\text{Elasticity, } E = \frac{L^3 m}{4bd^3} \quad \text{(MPa)} \qquad (3)$$

Table 1: Strength and elasticity against composition of sucrose.

Percentage Sucrose (%)	Strength (MPa)	Elasticity (MPa)
10	2.57	3458
20	5.39	8841
30	8.87	11046

Table 1 shows the strength and elasticity value of specimens of 10%, 20% and 30% sucrose in the seashells structure. Samples with 30% sucrose show the highest elasticity and strength values. The value of strength increases simultaneously with the increases in percentage sucrose in the specimen.

Charpy Impact Test

There are clearly shows in Table 2 that the impact of 4J of the hammer is increased when the composition of sucrose binder increased. The bonding between seashell powders become much stronger because the amount of sucrose is added into the specimen increase from 1.4g, 2.8g and 4.2g. Haritha (2018) [11] also claimed that the increased of addictive composition in the specimen, the impact strength also increased due to changes in mechanical properties.

Table 2: Charpy impact result

Composition of sucrose (%)	Impact (J)
10	0.082
20	0.090
30	0.102

Porosity and Density

Table 3 shows that when the percentage of sucrose is 10% the porosity is 16.84%. The value is the highest percentage of porosity compared to other samples with higher sucrose mixture due to the amount of binder is only 1.4g from the total weight. Meanwhile, the highest density value of the specimen samples with 30% of sucrose which is 2.446 g/cm^3. For the least percentage of porosity is 5.66% and same with the density, 2.176 g/cm^3.

Table 3: Porosity and density result

Composition of sucrose (%)	Porosity (%)	Density (g/cm^3)
10	16.84%	2.176
20	14.98%	2.287
30	5.66%	2.446

The flexural strength exhibited a decreasing trend for an increase in the total porosity fraction and proved to be a better useful parameter than open porosity fraction[13].

Morphology Test

Energy disperse x-ray spectroscopy (EDS) is used to analyse the specimen with the magnification of ×1500 and point was randomly selected on the surface of the specimen.[12]

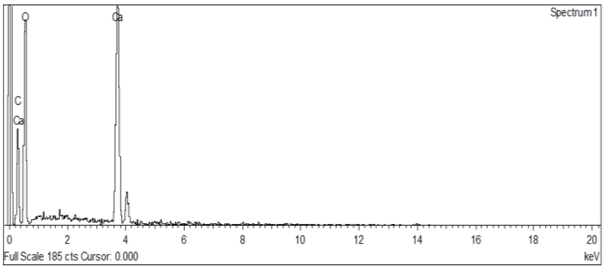

Figure 1: EDS result of 10% of sucrose

Figure 1 shows the EDS result of structure with 10% sucrose. Results have shown that specimens contain numbers of carbon (C), oxygen (O) and calcium (Ca). The highest element in this specimen is oxygen which is 57.02%.

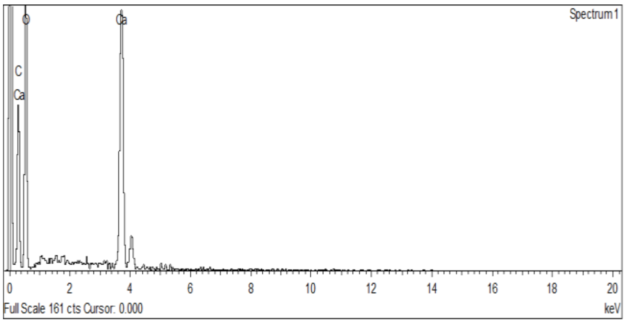

Figure 2: EDS result for 20% of sucrose

Figure 2 shows the variation of the element in the sample with 20% of sucrose. It is seen that most element is rich with carbon (C), oxygen (O) and calcium (Ca). In this specimen, oxygen dominated with 60.78% while calcium is the least element with 11.72%.

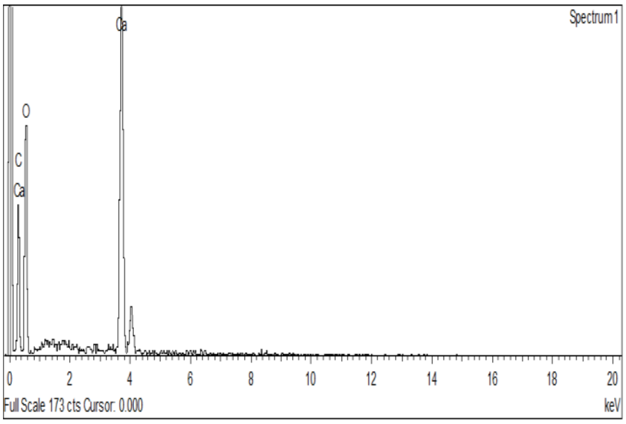

Figure 3: EDS result for 30% of sucrose

Figure 3 shows that specimen with 30% of sucrose contains carbon (C), oxygen (O) and calcium (Ca). The least element in the specimen is silicon with 0.41% and the major element in the specimen is oxygen with 61.55% due to pore excessive in the specimen.

Three-point bending

From the result shown in Table 4, the maximum strength occurred on the specimen is higher when sucrose is 30% which is 6.7 MPa while the least stress is 20% of sucrose with 3.7 MPa. As compared to previous research, the higher stress on the specimen is also 30% of sucrose with stress 2.3 MPa. Based on the previous researcher, Haritha[11]reported that the higher value of addictive composition, the maximum force also increased. As expected, the least stress on the specimen is 10% for both experiments which 3.747 MPa and 0.934 MPa.

Table 4 and Figure 4 show comparison of strength for samples between present study and results by Haritha [11]. It can be clearly seen from Figure 7 that for both studies the strength graph become increasing as sucrose content increases. It is also shown that heating temperature of 100oC use for this study does increase the performance of the structure. Every each sucrose composition reveals the effect of temperature which contribute to the performance of the structure.

Table 4: Average difference of maximum force

	Composition of Sucrose (%)	Max Strength (MPa)
Present	10%	3.7
	20%	4.7
	30%	6.7
Haritha[11]	10%	0.9
	20%	1.6
	30%	2.3

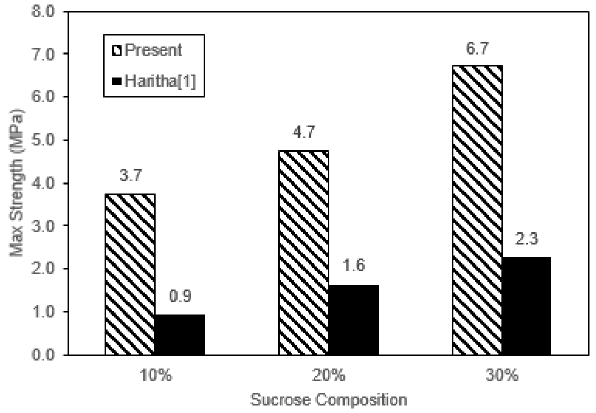

Figure 4: Stress against composition of sucrose

Charpy Impact

Table 5 and Figure 5 compare an average energy value of Charpy impact for present and by Haritha[11] study. Studies showed clearly that both data have same pattern of increment of value of impact as sucrose composition increase. Even the drying temperature is different, the energy produced by Charpy test is almost similar which started with 0.08J for 10% sucrose and 0.107J for 30% sucrose. In conclusion, when the composition of binder increased, the impact also increases due to bonding between seashell powder more stronger compare least of binder in specimen. Axial compression strength of all the concrete samples tested increased as the curing age increased, as with conventional concrete[14]

Table 5: Impact energy results from Charpy test.

Composition of sucrose (%)	Present (J)	Haritha[11] (J)
10	0.080	0.080
20	0.093	0.087
30	0.107	0.107

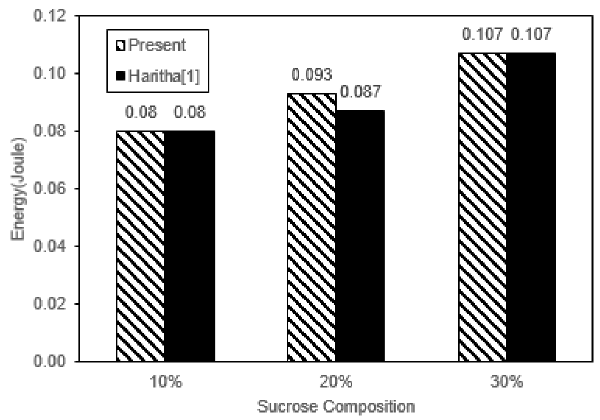

Figure 5: Impact energy against composition of sucrose

4. Conclusion

In this study, the seashell powder with size 150µm to 200 µm is mixed with sucrose and compacted at 5 bar and weighted 14 grams each sample. The experiment was done to identify mechanical and dynamic properties under the different composition of the binder. The results were compared with previous research with the difference in drying temperature. Each composition of binder having five samples.

The experimental result revealed that elasticity and strength of the specimen become higher when the higher percentage of sucrose in specimen increase. Similar results were also defined by Haritha's[11], which showed maximum strength becomes higher when it exerted onto the specimen that contains 30% of sucrose.

For porosity and density test, as the value of porosity decreased, the density of specimen increased simultaneously with the increasing of the composition of sucrose. Which might be contributed by powder bonding become stronger and least pore in the specimen.

Overall, the seashell is a material that can be continued in the study for protective material. However, the contribution is useful for low velocity and low-cost protective device. The finding shows that seashell as primary materials becomes less strength compared to seashell as a filler[2].

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