Effect of Mechanical Properties Under Temperature Influence and Sucrose Composition on Cockleshell Structure.

Ranjhini Anpalagan¹², Kamarul-Azhar Kamarudin¹², Mohamed Nasrul Mohamed Hatta¹², Rosniza Hussin³, Zaleha Mohamad¹²
¹Mechanical Failure Prevention and Reliability (MPROVE) Research Centre, Crashworthiness and Collisions Research Group (COLORED), ²Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia, 86400 Batu Pahat, Johor. ³Faculty of Engineering Technology, Department of Mechanical Engineering Technology, Universiti Tun Hussein Onn Malaysia, Pagoh Higher Education Hub, 84600 Pagoh, Muar, Johor.
E-mail: ranjianbu46@gmail.com

Abstract. Cockle shell is one of the marine organisms that easily found in Malaysia. This invertebrate type of animal lived by depending on their shell that contains of high calcium carbonate which makes it so tough and can be explored for further application. In this study, a ceramic material was fabricated from cockle shell and sucrose as a binder. The cockle shell was crushed and milled into small size at around 160 µm - 200 µm. The cockle shell powder then was mixed and compacted with sucrose binder by ratio of 10, 20, and 30 wt%. The drying process was carried out in 2 methods which are heating at 150ºC for one hour and normal drying at room temperature for 1 day. The effect of binder percentage and drying method on flexural properties, density and porosity of ceramic were investigated. Flexural test result shows that the samples with oven drying produced better resistance compared with samples dried at room temperature and the highest strength was obtained by sample with 20wt% sucrose dried in oven. The sample with 20wt% sucrose dried in oven also has the highest values of density. 20 wt% sucrose binder has higher ultimate strength and higher maximum force. The comparisons of sample morphology were determined by scanning electron morphology (SEM).

Keywords: Cockle shell, sucrose, binder, drying process, flexural test

1. Introduction
Presently, the recycling of waste by-products is a necessary part of waste management policies in many countries of the world. The main benefits of waste recycling are decrease in environmental pollution and conservation of natural resources (Onuaguluchi & K.Panesar, 2014). In addition, it was indicated that by reusing waste materials could also ensure waste conservation, and subsequently, decrease waste disposal in the involved sectors (Khanhajje, et al., 2017). Considering this approach, a
study was conducted to investigate the mechanical properties of ceramic made of wasted cockle shell powder.

In Malaysia, cockle aquaculture areas extend about 10,383.09 hectares contributing a production of 78,024.7 tonnes in year 2010 (Department of Fisheries Malaysia, 2010). This amount will increase every year (Department of Fisheries Malaysia, 2010). Additionally, it indicated that the active and lucrative industry has resulted in a significant amount of waste shells (Boey, et al., 2011). Moreover, left untreated and dumped irresponsibly, cockle shell may produce unpleasant odour (Mustakimah Mohamed & Suzana Yusup, 2012). Othman conducted the cockle shell powders are studied in the making of concrete in order to reduce production cost of concrete and reduce waste of shells. (Othman et al., 2013) made use of cockle shells to replace cement and filler in concrete. It is concluded that higher cockle shell ash in concrete shows decline in compressive and tensile strength.

Thus far, Kamarul (2018) established small step in order to introduce cockle shell as green natural composite that can be replace the usage of the synthetic composite (Kamarula Azhar, et al., 2018). Therefore, this research to be carried out will be able for us to maximize the use of cockle shells as an environmentally friendly alternative material.

Besides that, previous study of Kamarula (2017) have found that cockle shell has capability to be one of the fundamental source to become protective material base (Kamarula Azhar et al., 2017). Moreover, a number of studies showed that the shell can improve the strength of the other ingredients when used as aggregate (Paper et al., 2012). Moreover, shell structure is a composite material that is formed naturally (Olivia, et al., 2017). Therefore, the present study focuses on the mechanical properties of cockle shell structure.

2. Materials and Methods

2.1 Preparation of cockle shell powder

Cockle shell for this study was collected from food based seafood area around Batu Pahat, Johor. Shells were initially cleaned using plain water to remove all dirt in the shell. The shells were dried completely under the sun. The shells were crushed to the size of 5 mm using a granulator machine. Then the granulated shells were transferred to Los Angeles abrasion machine to produce fine powder. After rotating the drum for 5000 rotations, the powder were removed and sieved at particle size between 160 to 200 μm.

The binder used in the study was sucrose at different percentages which were 10%, 20%, and 30 wt%. Shell powder, sucrose and water were blended together to produce a sample in accordance with specific ratio.

2.2 Specimen preparation and test setup

![Figure 1: Schematic of flexure test of 3 point bending test (Sim, 2016)](image)

The experiments were carried out according to the guidelines of ASTM C1161-13 (ASTM, 2013) as shown in Figure 1. The sample size used for flexural test is 10 mm wide, 7 mm thick and 100 mm
length. 14g sample powder was compressed in a mould under 8 MPa pressure for 10 minutes holding
time. 2 sets were prepared for each percentage of sucrose as binder. Each set has 5 samples to be
tested. One set was placed in oven at 160˚C for 1 hour and then kept at a normal place for 24 hours
and another set was placed as normal under room temperature for 24 hours without using the oven.

3. Results and discussion

3.1 Mechanical property

![Ultimate Strength (MPa)](image)

**Figure 2**: Ultimate strength (MPa) of different drying process

The Figure 2 shows that the oven drying process has maximum value for all three variation of sucrose
binder percentages tested. Based on the graph, the specimen takes the highest strength to fracture
when it was mixed with 20% sucrose in oven drying process which is 8.616 MPa. Whereas when
mixed with 10wt% and 30wt% sucrose binder, its were fractured at 6.704 MPa and 4.756 MPa
respectively. Therefore, it can be concluded that this happens due to the characteristics of each
element in the specimen which are sucrose and cockle shell. The strongest specimen is when it only
has 20% sucrose mixed in it, not more or less. This issue happened due to the 78% contain of cockles
shell powder at 20% sucrose reached optimum level. If lesser cockle shell powder or higher cockle
shell powder doesn’t reach the highest flexural strength as 20% sucrose binder gained.

On the other hand, the strength of specimen under room temperature drying was proportionally
increased with percentage of sucrose binder. However the strength of all sample was extremely lower
compared to the specimens under oven drying. Even the maximum ultimate strength of room
temperature 2.61 MPa is lower than the lowest ultimate strength of oven 30% sucrose binder which is
4.76 MPa. This shows that drying at room temperature doesn’t react much at bonding strength
between sucrose and cockle shell powder as much as react with oven drying process.
3.2 Physical property

3.2.1 Density

The effects of drying process with different sucrose percentage on density presented in Figure 3. Density of oven drying process increased at 20% sucrose percentage as highest value but decreased at 30% sucrose as lowest value of density. It can be noticed that the trend was similar to the strength of specimen. This indicates the density of specimen influences the strength of specimen where when the density increased, the ultimate strength also increased. Hence, the flexural strength value depends on the density.

3.2.2 Porosity

![Figure 3: Density (g/cm3) Analysis for Oven and Room Temperature](image)

![Figure 4: Porosity (%) analysis for Oven and Room Temperature](image)
The porosity of samples from different composition and drying process are shown in Figure 4. As shown in the figure, the oven drying process has the lowest porosity which is 0.68 % and the room temperature showed the lowest porosity which is 0.81 % among the sucrose binder percentage. This is probably due to the density of samples is related could reduce porosity. Figure 4 shown the oven drying process has lowest density and room temperature has highest density. This probably, the densification of internal structure avoids the intrusion of water.

3.3 Scanning electron microscope (SEM)

3.3.1 10% Sucrose composition

Figure 5. 10 wt% of Oven Drying

Figure 6. 10 wt% of Room temperature

Figure 5 and 6 shows the SEM images of the flexural fracture surface of 10% sucrose composition of oven drying and room temperature. The microstructure of fracture surface of sample under oven drying shows more compact than the sample under room temperature drying. The compaction of oven drying process surface has produce good strength compare to room temperature drying process.

3.3.2 20% Sucrose composition

Figure 7. 20 wt% of Oven Drying

Figure 8. 20 wt% of Room temperature

Figure 7 and 8 shows the SEM images of the flexural fracture surface of 20% sucrose composition of oven and room temperature. The microstructure of fracture surface at oven shows compacted than the other percentage of fracture surface. Because of this, 20% oven has more strength than other specimens.
3.3.3 30% Sucrose composition

Figure 9. 30 wt% of Oven Drying  
Figure 10. 30wt% of Room temperature

Figure 9 and 10 shows the SEM images of the flexural fracture surface of 30% sucrose composition of oven and room temperature. The microstructure of fracture surface at oven shows compacted and less pores than the fracture surface of room temperature. Therefore, the oven drying process has good strength than the room temperature drying process.

4. Conclusion

Based on the results obtained from conducting the experiments, it is seen that the mechanical properties obtained from the test using the drying process of oven shows the best results compared to the specimens dried at room temperature. Meanwhile, when the percentage of sucrose binders of 10%, 20%, and 30% is put in comparison, the result were different for both oven and room temperature as drying process. The oven drying process shows good result compared to room temperature which shows that the specimens which had excess of moist had a weaker force compared to the less moist value which had an optimum characteristic. As a conclusion, the oven drying process is the best method for drying the specimen. Hence, the ideal percentage of sucrose mixture to increase the cockle shell specimen’s strength is only 20% sucrose, 78% cockle shell powder and 2% water under oven drying process.

References

[1] Boey, P. L., Maniam, G. P., Hamid, S. A., & Ali, D. M. H. (2011). Utilization of waste cockle shell (Anadara granosa) in biodiesel production from palm olein: Optimization using response surface methodology. Fuel, 90(7), 2353–2358.
[2] Kamarudin, K. A., Hatta, M. N. M., Baba, N. W. A., Hussin, R., & Ismail, A. E. (2017). Binder effect on seashell structure. AIP Conference Proceedings, 1891.
[3] Kamarula Azhhar, Mohamed Nasrul Mohamed Hatta, Ranjhini Anpalagan, A. E. I. (2018). Akademia Baru Seashell Structure under Binder Influence Akademia Baru, J(1), 122–128.
[4] Khankhaje, E., Rafieizonooz, M., Salim, M. R., Mirza, J., & Hussin, M. W. (2017). Comparing the effects of oil palm kernel shell and cockle shell on properties of pervious concrete pavement. *International Journal of Pavement Research and Technology, 10* (September), 383–392.

[5] Olivia, M., Oktaviani, R., & Ismeddiyanto. (2017). Properties of Concrete Containing Ground Waste Cockle and Clam Seashells. *Procedia Engineering, 171*, 658–663.

[6] Onuaguluchi, O., & K.Panesar, D. (2014). Hardened properties of concrete mixtures containing pre-coated crumb rubber and silica fume. *Journal of Cleaner Production, 82*, 125–131.

[7] Othman, H., Hisham, B., Bakar, A., Don, M. M., Azmi, M., & Johari, M. (2013). Cockle Shell Ash Replacement for Cement and Filler in Concrete. *Malaysian Journal of Civil Engineering, 25*(2), 201–211.

[8] Paper, C., Hazurina, N., Universiti, O., Hussein, T., Azmi, M., Johari, M., … Othman, N. H. (2012). Potential Use of Cockle (Anadara granosa) Shell Ash as Partial Cement Replacement in Concrete. *Potential Use of Cockle (Anadara Granosa) Shell Ash as Partial Cement Replacement in Concrete, 2251*(August), 369–376.

[9] Supakorn Boonyuen, Monta Malaithong, & Apisit Prokaew. (2015). Decomposition study of calcium carbonate in shell. *Thai Journal of Science and Technology, 4*(2), 115–122.

[10] Retrieved from Department of Fisheries Malaysia. *Department of Fisheries Malaysia. (2011)*. Retrieved from <http://www.dof.gov.my/v2/>

[11] Standard Test Method for Flexural Strength of Advanced Ceramics at Ambient Temperature. In ASTM, *C1161 − 13*.

[12] Sim, S. (2016, February). Mach-1-3-point or 4-point Bending test. *Biomementum*.

[13] Bellis, M. (2017, April 15). *History of Body Armor and Bullet Proof Vests*. Retrieved September 20, 2018, from Thought Co: https://www.thoughtco.com/history-of-body-armor-and-bullet-proof-vests-1991337

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