

Effect of Carbon Reinforcement on the Properties of Seashell Ceramic Composite

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Abstract

Seashell wastes generated from food industries has potential to be explore for use in material application. In this study, ceramic was produced from seashell waste and carbon powder was added between 0.1 to 0.3wt% to reinforce the ceramic. The effect of carbon composition on the physical and mechanical properties of the ceramic was investigated. The addition of carbon increase the density of the ceramic up to 1.897 g/cm³ for the composition of 0.3wt%. Meanwhile the porosity shows the opposite trend which decreased by the addition of carbon reinforcement. The impact property of the ceramic also been increased with the addition of carbon which the sample with 0.3wt% carbon has the highest impact strength which recorded 0.37J respectively. The influence of carbon in the structure of ceramic has been observed through optical and scanning electron microscope. The analysis shows that the addition of carbon plays an important role in improving the fracture of ceramic.

1. Introduction

Seashells especially Anadara Granosa are the most often consumed seashells in Malaysia. As a result, a high number of shells are dumped, resulting in foul smells owing to the lack of a post-treatment process. The post-treatment operation will be a high-cost procedure in and of itself. The seashells are then processed and transformed into more useful items to limit the impact of the discarded shells and to lessen the pollution of odours [1].

Seashells are a type of natural ceramic that has qualities comparable to human bones and teeth. The main component of seashells is calcium carbonate (CaCO₃), which accounts for more than 90% of their weight and contains very few chemical components. The chemical makeup is quite like that of limestone powder. Seashells may be utilised in a variety of applications, including concrete construction, medicinal applications, finishing goods, and microelectronics [2]. Ceramic is a fragile material, but it may be strengthened by combining it with a polymer composite [3]. Ceramic elements are classified as intermediate between metallic and non-metallic elements. Heat treatment gave most ceramics their characteristics.

Sucrose was one of the good binders used to bond the seashells [4]. Sucrose is a kind of sugar used extensively in the food business. Sucrose emerged as an odourless, colourless crystalline powder with a delicate, sweet flavour. The sucrose melts and decomposes into glucose and fructose when heat is applied. The sucrose becomes 'caramelised' because of the constant heating. Caramelization is a condensation process in which the

water in sucrose is evaporated. After the procedure, sucrose takes on a dark and sticky look. The sticky characteristic allows the virginin gredients to bond more tightly.

Carbon powder is a crystalline form of the element carbon with its atoms arranged in a hexagonal structure. There are several types of ceramic fabrication that employ foreign materials as binders and reinforcing agents. This is utilised to improve the characteristics as well as the final strength of the ceramic's original material. Numerous types of reinforcing agents are employed to increase the final strength of ceramics, each of which delivers a distinct scale of strength to the ceramic material. Carbon is a better approach to improve and overcome industries limitations. Carbon offers the best features for use as reinforcing agents since it has a high strength and minimal thermal expansion [5].

2. Experimental

2.1 Materials Preparation

There were three primary materials that each played an important part in the production of the ceramic composite. The materials in question were comprised of seashells, sucrose, and carbon powder. The seashells were collected from the shores at Sungai Lurus Batu Pahat. They were brushed and cleaned to eliminate all of the algae and grime that had accumulated on them. After that, the shells were exposed to the sun so that the moisture contained within them might evaporate. The shells were crushed and ground into powder with particles ranged in size 150 μ m. The composition of the mixture was set up as shown in Table 1.

Table 1 *Composition of samples*

Sample	Seashell (wt%)	Sucrose (wt%)	Carbon (wt%)
A	70.0	30	0.0
B	69.9	30	0.1
C	69.8	30	0.2
D	69.7	30	0.3

2.2 Fabrication of samples

Powdered seashells, sucrose, and carbon powder were combined by mixing them together. The mixing of these three components is carried out by using planetary ball mill for a duration of one hour, until the mixture is completely uniform. After the process of mixing, the mixture is next dried at a temperature of 100°C for 30 minutes to remove any remaining moisture and to dry the powder.

After all the components had been thoroughly combined, the mixture was next subjected to compression in order to confirm the specific form and dimensions of the specimens. After pouring the powder into the mould, it was compressed. The technique was carried out using a machine that had a hydraulic press. The powder mixture was poured in the mold and compressed for 15 minutes each under 8 tons of hydraulic press.

After every piece of the specimen was extracted from the mold. The specimen was then put through a drying process, the goal of which was to fortify the specimen and make it hard by plasticizing the sucrose. Additionally, during this process, any moisture that was caught inside the specimens evaporated. The concept of thermal heat served as the foundation for this procedure. The notion of evaporation is also employed in order to protect the specimen qualities and make certain that the specimens are not damaged as a result of being exposed directly to heat. The drying process is carried out at a pace of 10°C per minute, with the temperature remaining at 160°C for an hour.

2.3 Testing and Characterization

Ceramic is a type of material substance which has and consists of porosity. In the density and porosity test, for each sample mixture, a spherical specimen was made for the test. These two tests were conducted to determine the specimen density and porosity. For this testing, usually water is used as a medium for the specimen but in this testing, ethanol was used as a medium to measure the density and porosity because the sample is made up of sucrose which will dilute in water. Using water will damage the specimen. Meanwhile, ethanol has the properties to mitigate this factor and enables the experiment to be conducted.

Ceramic is a form of ductile material with low toughness. Therefore, it is essential to study the toughness by using impact test. Impact test evaluates the ability of the sample to withstand a sudden impact load. The specimen was loaded and positioned horizontally for this experiment. The hammer has been raised after being given a 4 joule weight. The needle scale is then set to the hammer's 4 joule weight and aligned accordingly. A

retaining clip serves as the pins were withdrawn to release the hammer. As a result, the specimen will be struck by the hammer, giving the strength to read.

A horizontal plain ceramic composite beam supported by rollers and loaded vertically during flexural testing; ASTM C 1161 was used. When the load was applied, the tension caused the lower section of the beam to grow longer, while the compression stress caused the upper part to shrink. When the applied stress was more than the tensile strength, the ceramic composite fractured. The specimen can easily shatter if the composite was not reinforced. Up until the break reached the top half of the beam, testing was conducted. At the proper angle to the applied tensile force, the crack may be seen. This procedure took very little time [5].

During this morphological examination, an optical microscope (OM) and scanning electron microscope (SEM) were utilised. Using a scanning electron microscope was yet another approach that was taken (SEM). The target is to characterise the specimen surface as well as determine its microscopic structure. These goals will be accomplished by analysing the specimen. Analytical imaging is a type of imaging that makes use of a high resolution to obtain photographs of very small particles or chemicals, which the human eye is unable to detect because of their size.

3. Results and Discussion

3.1 Density and Porosity

Figure 1 shows the density of the specimen increased when the ratio of graphite increased. Thus, the graph shows a increment pattern but there is only a slight change in density value. The highest density is at the specimen with 0.3 wt% ratio of carbon and the lowest is at the specimen with 0.0 wt% ratio of carbon which has a density value of 1.897 g/cm³ and 1.647 g/cm³ respectively. Besides that, the reading for the standard deviation is closer to the average when the value is closer to zero. By the removing of seashells and adding of the carbon, the density is increase due to contribution by density of single carbon which is higher than seashells. Thus, it can be summarized that the higher the carbon ratio, the higher the density of the specimen.

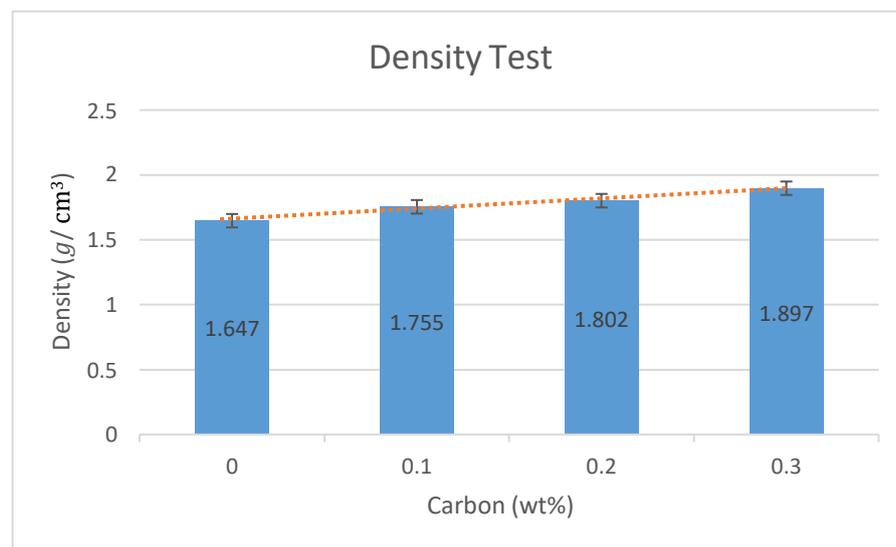


Fig. 1 Density of Seashell Ceramic reinforced with Carbon

Figure 2 shows the porosity of the specimen decreases when the ratio of carbon increases. Thus, the graph shows a decrement line pattern, and it is obvious that the changes in porosity value are higher than the changes in density value from the density test. The highest porosity value is at the specimen with 0.0 wt% ratio of carbon and the lowest is at the specimen with 0.3 wt% ratio of carbon which has a density value of 8.149% and 5.983% respectively. Besides that, the reading for the standard deviation is closer to the average when the value is closer to zero. It can be summarized that the higher the carbon ratio, the lower the porosity of the specimen whereby the specimen can provide a better strength based on the porosity value. Thus, the lower the porosity percentage, the better the strength of the specimen.

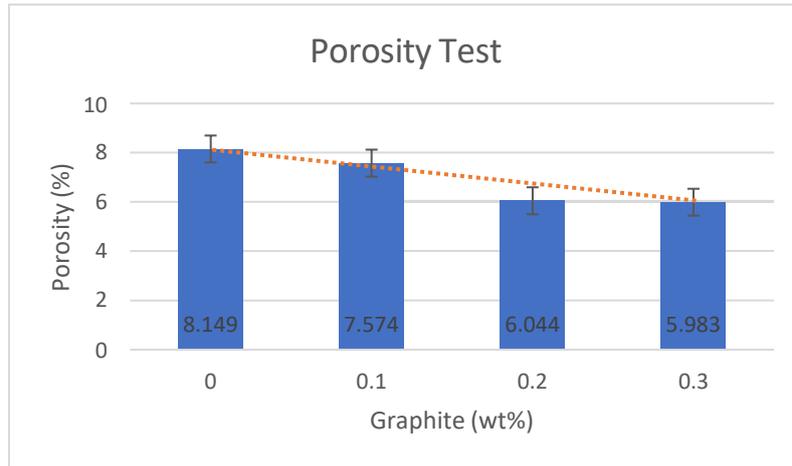


Fig. 2 Porosity of Seashell Ceramic reinforced with Carbon

3.2 Impact Properties

Figure 3 shows the impact of the specimen increase when the ratio of carbon increases. Thus, the graph shows a increment line pattern and it is obvious that the changes in porosity value are higher than the changes in density value from the density test. The highest porosity value is at the specimen with 0.3 wt% ratio of carbon and the lowest is at the specimen with 0.0 wt% ratio of carbon which has a density value of 0.37J and 0.28J respectively. Besides that, the reading for the standard deviation is closer to the average when the value is closer to zero. Based on other research, seashells unique brick-mortar architecture makes them tougher and stronger than their constituents [6]. Thus, it can be summarized that the higher the carbon ratio, the higher the impact energy of the specimen.

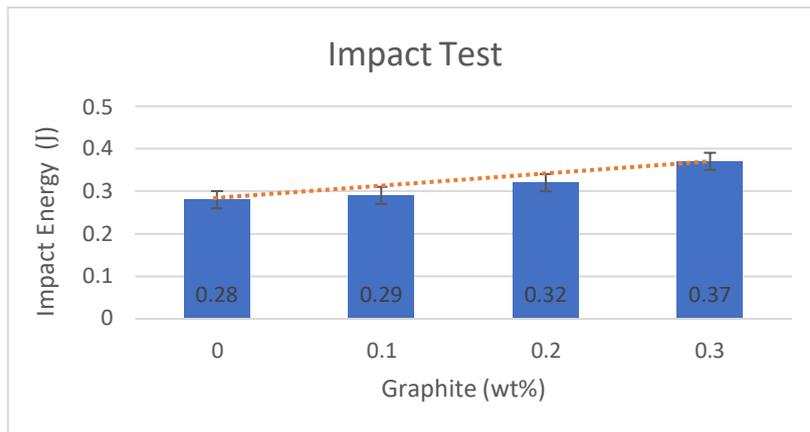


Fig. 3 Impact Energy of Ceramic reinforced with Carbon

3.3 Morphology and Fracture Analysis

Analysis and research may be done on the surface morphology of the specimen. The observation was focused on the fracture area of samples after impact test to study the fracture mechanism. For the optical microscope observation, magnifications ranging from 7x to 20x were used to observe the side surface of fracture area.

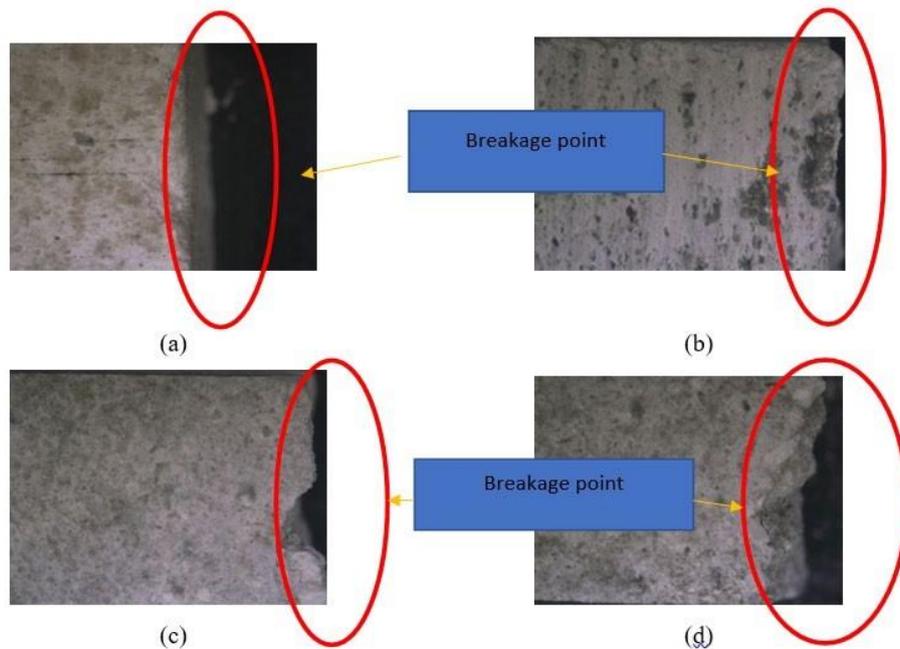


Fig. 4 Breakage point from the side view for all specimen composition. a) 0.0 wt% carbon b) 0.1 wt% carbon c) 0.2 wt% carbon d) 0.3 wt% carbon

Observation as in Figure 4, sample without carbon showed smooth break of specimen after undergoing the impact test. According to the impact test, this specimen has the lowest strength in general compared to the other specimens. As seen in the optical microscope results, the specimen without carbon has no crack due to rapid crack propagation which occurs instantaneously. However, the visual of fracture changed when added the carbon reinforcement. For the 0.1 percent of carbon, the small cracks occur throughout the breakpoint at multiple levels, since the interlocked carbon with seashell is not much. The energy from the impact test surpasses the bond strength between the seashell and the carbon. Furthermore, for the 0.2 and 0.3 percent of carbon, it can be observed that the amount of crack increases, as more carbon is added to make it more saturated. More strength of the bond causes the specimen to stretch more before it breaks off. The result is also agreed by Zhang et al, where the composite showed more improvement as more carbon is added, as it enforces the material overall strength [7]. Addition of carbon, has cause the bonding between seashell counterpart stronger because the side view of break point shows much more rigidity for it to break into two pieces

Scanning electron microscopy (SEM) was another method of morphology testing that was utilised in this investigation. The purpose of the SEM that was utilised in this investigation was to observe the distribution of the carbon composition inside the specimen and to view the interlocked of carbon between the base materials. For the specimen to be able to fit into the SEM machine, it was first broken down into smaller pieces. Before it was put through its paces, the specimen was given a layer of gold plating. This investigation made use of a scanning electron microscope. In the study, magnifications ranging from 30x to 1000x were used throughout the process. The distribution of carbon was studied at a magnification of 500x, and the surface condition of the fracture site was evaluated.

The specimen with no carbon (0.0 wt%) as shown in Figure 5 shows a smooth surface which is formed by the seashell and sucrose bond together after the compact pressing. After sintering process under 160°C for an hour, it can be noticed that there are some pores that were formed. The pores formed promote the porosity of the specimen, which affects the strength of the specimen. The specimen was observed under 350x magnification as shown below.

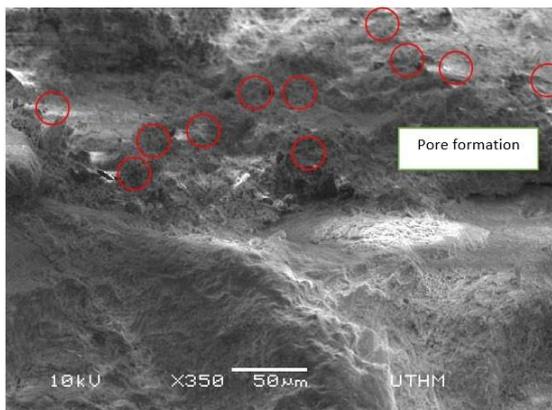


Fig. 5 SEM micrograph of sample with 0.0 wt% of carbon

For the specimen with 0.1 wt% of carbon ratio as in Figure 6, it can be seen the specimen formed rougher surface than the 0.0 wt% sample. The carbon pulls and integrates the seashell together to make it stronger. The specimen was observed under 200x magnification as shown below.

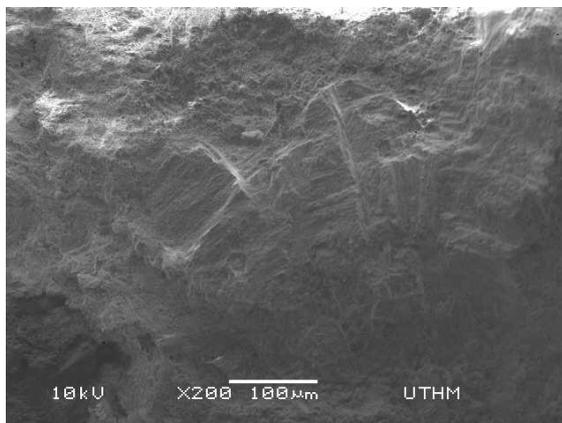


Fig. 6 SEM micrograph of sample with 0.1 wt% of carbon

Further observation on the sample with 0.2 wt% of carbon ratio in Figure 7, it shows even more improvement and seems to have better bonding with the seashell. As per the impact test and flexure test data, having more carbon increases its strength. For the 0.2 wt% we can see a bigger independent structure is formed. This specimen was observed under 400x magnification as shown below.

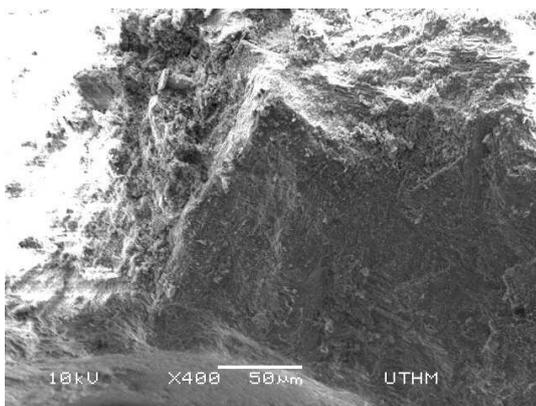


Fig. 7 SEM micrograph of sample with 0.2 wt% of carbon

The last specimen shown in Figure 8, which samples 0.3 wt% of carbon, shows more saturation and denser

packed bonding between the seashell and carbon. The specimen starts to form box structure more densely between them under smaller gradient sizes. This will eventually reduce the porosity and hence increases the strength of the specimen. The specimen was observed under 900x magnification as shown below.

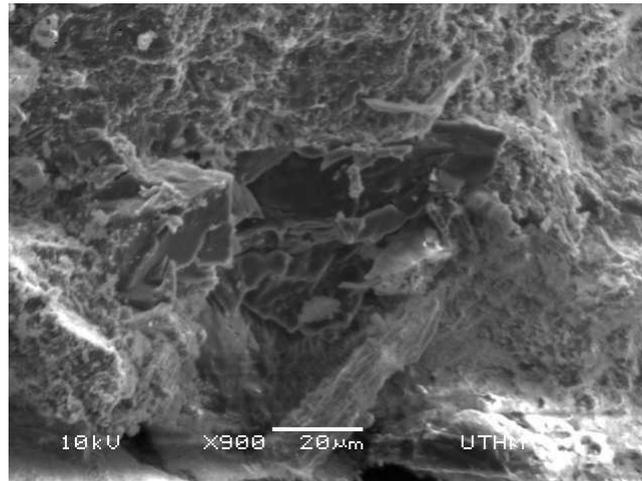


Fig. 8 SEM micrograph of sample with 0.3 wt% of carbon

4. Conclusion

This study was conducted with the intention of determining the characteristics of a ceramic composite made up of cockle seashells, sucrose, and carbon. The ratio of carbon was varied from 0% to 0.3wt% using these four parameters: 0%, 0.1%, 0.2%, and 0.3wt%. In order to determine the qualities of the ceramic composite physical and mechanical tests were carried out. The fracture mechanism has been observed by morphology and fracture analysis. The results of the density and porosity tests indicated that the values obtained from the computation reduced as the proportion of carbon increased. Regarding the impact test, the results that were obtained shows a linear uptrend, where it shows addition of carbon increases the strength of the samples.

It is further proved by conducting the optical microscope and SEM test to see the distribution and bonding of carbon and seashell. It's possible that the outcome will change depending on how the substance is distributed throughout the specimen. Utilizing an optical microscope, one may get a better look at the distribution. According to the photos, the powders were distributed in a consistent manner. Using the SEM, it is to be noticed that addition of more carbon helped the seashell to pull together in more closer manner, which promotes stronger bonding between the ceramic and the carbon.

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