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Study of Characteristics of Eggshell Waste Composite by Using Cold Compaction Method

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Abstract: Eggshell is a new engineering reinforcement retaining excellent properties such as low density, renewable, eco-friendly, and high thermal stability. The research aims to study the characteristics of an eggshell waste composite by using the cold compaction method. This research investigates the potential of eggshell waste to be used as water filters. Physical and microstructure tests were performed after eggshell waste was mixed with kaolin clay and wheat flour as a binder in various compositions. The result shows that the eggshell has a low-density value and a composition of 50% eggshell has a lot of large pore size compared to other compositions. Thus, it can be concluded that eggshells are suitable as water filters because microstructural tests show that the sample has pores for water flow.

Keywords: Eggshell, cold compaction, water, kaolin clay, microstructural tests

1. Introduction

Every year, approximately 65.5 million metric tonnes of eggs are produced globally. Between 2000 and 2010, European output increased by 10%, while Chinese manufacturing increased by nearly 50% [1]. By 2030, global egg production is expected to exceed 90 million tonnes. Given that the eggshell accounts for approximately 11% of the weight of each egg, nearly 7.2 million tonnes of eggshell waste are generated each year. In comparison, this amount is roughly equivalent to the 8 million tonnes of plastic garbage that enters the seas each year, out of a total of around 275 million tonnes of plastic waste generated on land [1].

The recovery of food waste eggshells to produce new material for water filters is proposed as a recycling strategy in this study. The use of eggshell waste as a water filter or adsorbent would help to reduce waste and environmental issues [2]. The waste eggshells will be turned into a composite material through the use of the cold compaction method. Mechanical and physical tests can be employed to determine the mechanical and physical properties of eggshell wastes after they have been cold compacted.

Based on the findings of this study, a new method and solution for producing water using recycled waste could be developed, cutting the cost of producing water filters in comparison to current products. Cold compaction of eggshell wastes can assist the egg production industry to reduce environmental issues related to food waste and reduce the percentage of eggshell wastes disposed of [3]. This research could aid the government in coming up with new ideas for reducing food waste and creating new products, mainly from eggshell waste. Water has an

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important role in preserving the health and welfare of human beings, and it is the right of every person to get safe drinking water. Water quality and appropriateness are determined by taste, aroma, colour, and organic and inorganic content [4,5].

2. Materials and Methods

The main material that was used in this research was eggshell waste. Eggshells had been collected from a burger stall, a bakery, a household, and a restaurant. The other raw materials used are kaolin clay and wheat flour. The kaolin clay was prepared by a ceramic laboratory, and the wheat flour was bought from the grocery store. Wheat flour and kaolin clay are used as the binder. This research had four different compositions of eggshell waste, kaolin clay, and wheat flour. Table 1 shows the composition of eggshell waste, kaolin clay, and wheat flour.

Table 1 - Composition of eggshell waste, kaolin clay, and wheat flour

Eggshell Waste, %	Wheat Flour, %	Kaolin Clay, %
20	40	40
30	30	40
40	20	40
50	10	40

The process of this research started with the preparation of eggshells wasted as a sample and wheat flour and kaolin clay as a binder. Eggshell waste was sieved to achieve a particle size of, 126µm, whilst both binding agents were sieved to get a particle size of 65 µm. After the sieving process, the two materials were combined using a ball mill. After a dry pressing process, the sample is fired at a temperature of 100°C for 1 hour. The objective of the drying procedure is to prevent the clay from cracking during the heating in the sintering process to prevent kaolin from adhering to the mold. Subsequently, the drying procedure is finished with the ceramic membrane being prepared for the sintering process using the furnace. If the final procedure is successful, the sample will be examined. Otherwise, if the procedure fails, it will be repeated until the intended outcome is achieved. The density test, shrinkage test, microstructure analysis, and compound analysis were performed to determine the physical, microstructure, and compound characteristics.

3. Results and Discussion

The density of a material is defined as its mass per unit volume [6]. To determine the density by theoretical calculation, the radius and height readings of the sample are recorded with a vernier caliper to determine the sample volume. After the reading data is collected, density calculations are performed using the density formula. Based on Fig. 1, the highest average density is achieved by the composition of 50% eggshell. Based on the average density, the higher the percentage of eggshell content in the sample, the higher the density value. Meanwhile, the lower the eggshell content, the lower the density value. This is consistent with previous results that suggest if the density increases, the porosity will decrease [7,8]. From the results obtained, it can be concluded that the content of eggshells can affect the value of density. In addition, 20% of the eggshell composition is the sample with the lowest density value. According to [9], density and porosity transformations can be evaluated as increasing sintered density results in a lower fraction of the pores. Meanwhile, based on the results shown, the porosity properties have the opposite effect of density due to the percentage of pores related to the volume of porous solid. The average density value for the 20% composition of eggshell is 0.0349, which has a difference of 0.0135 from the value of the 50% composition of eggshell, which has the highest density value.

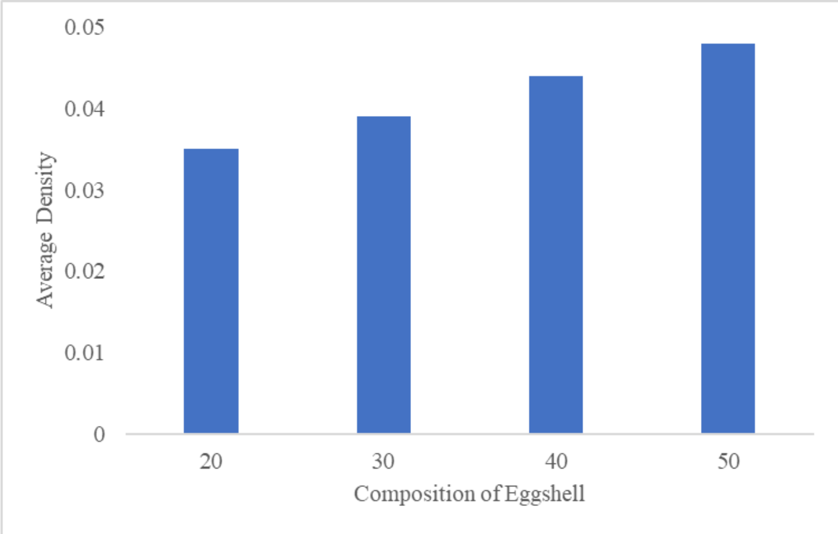


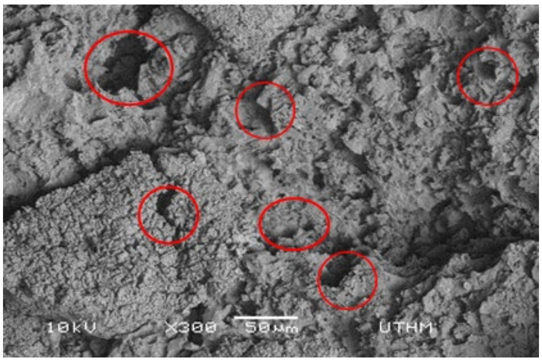
Fig. 1 - Density of different composition of eggshell waste

All data for percentage of shrinkage has been recorded in table 2, with the average shrinkage calculated after the sintering process. Based on table 2, the shrinkage is in the range of 7.6034% to 2.7232%, and if the composition is increased, the shrinkage percentage will be decreased. According to [10], shrinkage is an important issue during sintering of ceramics as it affects the structural and mechanical properties.

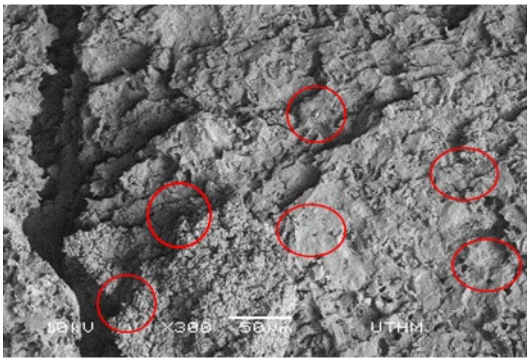
Table 2 - Shrinkage percentage

Composition of Eggshell (%)	Shrinkage (%)
20	7.6034
30	6.1557
40	3.2190
50	2.7232

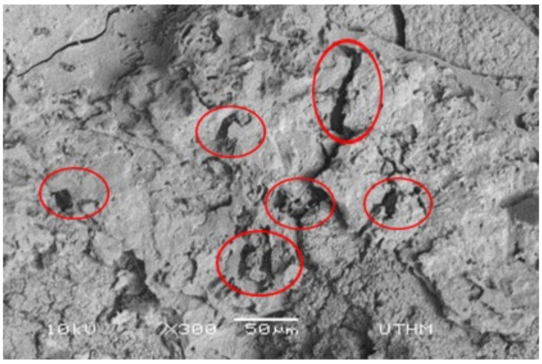
After the sintering process, the sample is subjected to microstructure analysis. The aim of this microstructure analysis is to investigate the number and size of pores. The size and number of pores affect the flow rate of the water. A ceramic filter with high porosity will have more void spaces than usual, allowing water to pass through the filter elements. Water may flow through the filter more quickly if there are more pores [7]. Based on Fig. 2, it can be concluded that the greater the percentage of eggshell used in the sample, the larger the pores. The red circle in each figure shows the pores. When the eggshell content is between 20% and 30%, there are many fine pores on the surface. According to previous research [11], these microscopic pores are gel pores and can be observed clearly dispersed in each corner of the sample. Samples with 40% to 50% eggshell content have a lot of large pores, which can be seen on the sample.



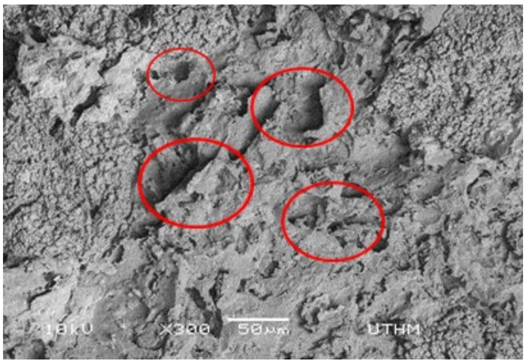
(a)



(b)



(c)



(d)

Fig. 2 - Microstructure of (a) 20%; (b) 30%; (c) 40% and; (d) 50% of eggshell composition

FT-IR investigations of filters assist in identifying minerals in filter elements by the composite of eggshell, wheat flour, and kaolin clay. Fig. 3 shows the Fourier Transform Infrared (FT-IR) raw material before sintering with further description in Table 3. The wavenumbers used to get the IR spectra for group CH bending vibrations ranged from 1430 cm^{-1} to 1470 cm^{-1}. The 869 cm^{-1} vibrations may imply CH bending [6]. Typical characteristic bands corresponding to the carbonate group of the CH bending vibration around 1407cm^{-1}. The fundamental and overtone bands of formaldoxime-13C (13CH2NOH) were identified, and their relative infrared band intensities were measured, using the Fourier transform infrared (FTIR) spectrum, which was recorded in the 600-3800 cm^{-1} range with a resolution of 0.50 cm^{-1} [12].

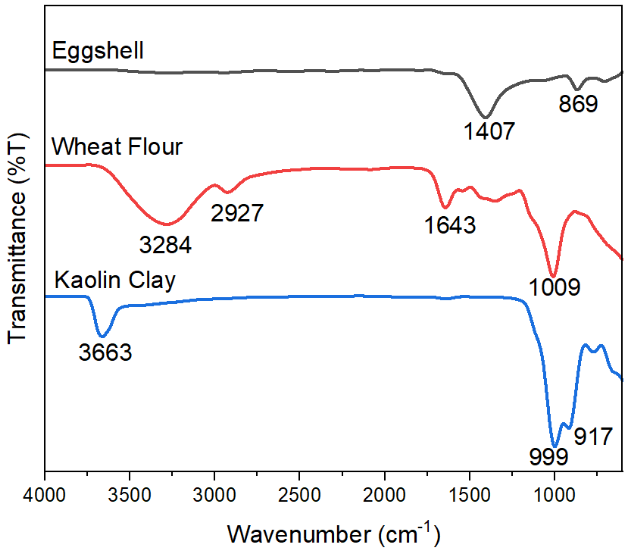


Fig. 3 - FTIR spectra of Eggshell composite wheat flour with kaolin clay

Table 3 - Wavenumber, chemical group of the FT-IR spectrum of eggshell wheat flour, and kaolin clay

Sample code and Wavenumber (cm^{-1})			Chemical Group
Eggshell	Wheat Flour	Kaolin Clay	
869			CH out of plane bending vinration in substituted ethylenic systems
	1009	999	C-OH Stretching Vibrations
1407			CH bending Vibrations
	1643		C=C Stretching Vibrations
	2927	3663	OH Stretching Vibrations
	3284		CH Stretching Vibration

Table 4 describes a spectrogram of synthesized Hap before and after sintering with the different compositions. The composition before sintering has two chemical groups. The characteristic bands corresponding to the carbonate group of the OH Stretching Vibration are around 3663 - 3664 cm^{-1}. 1001 - 1004 cm^{-1} is the C-OH Stretching Vibrations. Due to the interaction of the sample with its surroundings, the broad band in the region of 3000 to 4000 cm^{-1} corresponds to a hydrogen (H- O- H) bond, which may be ascribed to water adsorption. The 20%, 30%, 40%, and 50% eggshell compositions were found to have CH2, methyl (the CH Bending Vibrations group) bonding at 1419 - 1426cm^{-1}. When calcined at 1200°C, a qualitative comparison reveals that 20% eggshell composition has a sharper peak, followed by 50% eggshell composition. However, when calcined at 1200°C 40% eggshell composition exhibits the lowest peak.

Table 4 - Wavenumber, chemical group of the FTIR spectrum of composition 20%, 30%, 40%, 50% eggshell

Sample code and Wavenumber (cm^{-1})				Chemical Group
20%	30%	40%	50%	
1001	1004	1002	1001	C-OH Stretching Vibrations
1419	1423	1426	1422	CH Bending Vibrations
3663	3664	3663	3663	OH stretching Vibrations

4. Conclusion

The composition of 50% eggshell is a composition that has a lot of large pore size compared to other compositions. This is supported by the density test, which is the composition 50% eggshell has the highest density value. The percentage of shrinkage decreases with the addition of the percentage of eggshells in the composition. Analysis showed that eggshell, wheat flour, and kaolin clay are suitable candidates as water filters due to the porous condition of the sample. However, a lot of experiments need to be considered in order to confirm the effectiveness of this material.

Acknowledgment

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