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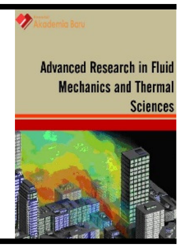

Seashell Structure under Binder Influence

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Kamarul Azhar Kamarudin[1,2,*], Mohamed Nasrul Mohamed Hatta[2], Ranjhini Anpalagan[2], Al Emran Ismail[1,2], Noor Wahida Ab Baba[2], Mohd Khir Mohd Noor[1,2], Rosniza Hussin[3], Ahmad Sufian Abdullah[4]

[1] Crashworthiness and Collisions Research Group (COLORED), Mechanical Failure Prevention and Reliability (MPROVE), Universiti Tun Hussein Onn Malaysia Batu Pahat 86400 Johor, Malaysia
[2] Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia Batu Pahat 86400 Johor, Malaysia
[3] Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia Batu Pahat 86400 Johor, Malaysia
[4] bARTeC, Fakulty of Mechanical Engineering, Universiti Teknologi MARA, Pulau Pinang 13500 Permatang Pauh, Penang, Malaysia

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ABSTRACT

Since the very beginning, evolution on protective materials keep going on where the material utilized as a part of plate armour continue changing, from steel, Kevlar, ceramic and the materials that can give better impact and benefit to the user. A study has been led to distinguish either seashell can be one of the fundamental source to produce protective material due to its properties calcium chloride. Seashell is crushed and chipped using variable speed rotor mill and is compressed into specimen shape. A batch of samples is tested made from seashells that mix with three different binder i.e. water, kaolin and polyethylene glycol (PEG). One batch of samples is dried at room temperature which another batch of samples are sintered at elevated controlled temperature before testing to determine their mechanical properties results. Result shows that at high temperature, specimen with water and PEG gives the highest value of Young's modulus and ultimate strength compared to sample without temperature effect. However, temperature effect shows no differences on kaolin samples compared to room temperature curing samples.

1. Introduction

Human body's design to provide protection against whether, cushion blows and even repair its own injuries. However, it has not fast enough to keep pace with the threats posed by human's recent inventions. Our bodies are not fireproof or bullet-proof, they cannot protect us against the types of injuries sustained during high-speed accidents. Fortunately, evolution of a different kind of technology has developed a range of protective materials that offer better defence against the trials of modern living.

* *Corresponding author.*
E-mail address: kamarula@uthm.edu.my (Kamarul Azhar Kamarudin)

Protective material is one of many equipment used in defensive system. As the evolution going on, the material used by the army for protection during war continue changing, from steel, Kevlar, ceramic and the materials that can give better impact and benefit to the user. During World War I (1914 – 1918), the army use soft body armour which is made of silk as protection. However in the World War II (1939 – 1945), the protective covering the army have been develop to ballistic nylon [1,2]. During war, plate metal was added when the chainmail that used have weakness that can make the weapon get through [3]. Kevlar is then created which becomes the most excellent material that can resist damage and could stop the most common lead bullet. An idea for this fibre is to replace steel belting in tires but it end up to be most effective bullet proof [4-6].

Ceramic is a brittle material that sensitive to shock and it offers very little ballistic protection. However, ceramic gives excellent strength protection when mixing with polymer composites. By improving the glass ceramic, it can be produce to provide incremental ballistic performance at incremental cost. During impact the ceramic gets pulverized which helps in abrading the projectile further, however, ceramics being brittle usually lack multi-hit capability. This means, ceramic cannot sustain successive impact without quickly losing much of their strength property [7,8].

As there are few exploration has been made to discover new material in delivering defensive covering, seashell was picked as one of the trial material because of its mechanical properties that can possibly be uncovered. Cockle is one of the famous seafood among Malaysian despites any races and ages. However, after consumed the cockle, the shell was litter away untreated. Cockle contains a strong shell and there is a study shows that cockle shell can increase the strength of the cement when the cockle shell used as coarse aggregate [2,9,10]. Reuse the unwanted and untreated cockle is one of the best way in order to optimise the usage of cockle shell beside it is also economic because there are several benefits can be obtained from it. Therefore, this research is a small step in order to introduce cockle shell as green natural composite that can be replace the usage of the synthetic composite. The structure of shell can be illustrated as a brick or mortar wall [6]. The placement of the organics and inorganics materials in a 'brick' shape make the shell becomes hard and tough. Another reason why shell resist fracture/cracking very well because the calcium carbonate platelets are able to slide somewhat along the protein matrix, which allows the shell to dissipate forces that applied [11].

The invention of protection, which starts from protecting body become greater to surrounding such as building and vehicles[12]. Since the protective material had conceived, there is consistently research to discover the best material that can give most effective result to prevent the damage occurred [13].

In this study, seashell is crushed, ball-milled and sieved to specific size. It is then blended with water, kaolin and PEG and pressed at required pressure to form samples and perform test following the ASTM standard requirement. Results obtained on elastic properties and flexural strength was to distinguish either seashell capability to be one of the fundamental sources to become protective material base.

2. Materials and Methods

The seashell is washed and dried at room temperature before being crushed using granulator machine, chipped by using variable speed rotor mill machine and sieved until it reached size of approximately 50μm. The additive acted as a binder is added to improve bonding between particles of the seashells. There are three types of binder used in this study i.e. water, kaolin and PEG. The mixture of seashell is shown in Table 1 and the mixture of powder/binder were placed into the mould and pressed for ten minutes at five bar pressure.

Table 1
Seashell/binder mixture

	Water (10%)	PEG (5%)	Kaolin (12.5%)
Seashell	14.175 g	14.175g	14.175g
Binder	1.4175 g	0.7087g	1.7719 g

In this study, the sample dimension is 8×6×90mm for thickness, width and length. There are two types of samples that been produced, one under room temperature and another one under high temperature condition where the samples were heated in an oven and are sintered at 400°C. Then the samples are tested for flexural testing as shown in Figure 1 which to determine the flexural strength and elastic modulus. The seashell mixture followed the ASTM C1161-13 standard using universal testing machine. The expression can be used to determine the stress and flexural modulus are as follows.

$$\sigma = \frac{3FL}{2wh^2} \tag{1}$$

$$E_f = \frac{L^3 m}{4wh^3} \tag{2}$$

where F is the force acting on the centre of length L of the support span, w is width, h is thickness and m is load over displacement (F/d) due to force acting at the fracture point.

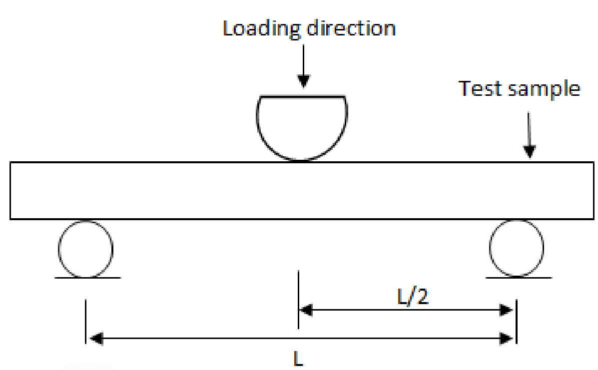

Fig. 1. Schematic diagram of test sample

3. Results and Discussions

Figure 2 presents graph force versus displacement for seashell and binder from water. It is shown that with sintering process at 400ºC, the average maximum force for seashell with water as binder is approximately 1.5N. Compared with samples with binder using water at room temperature drying, the results show an average of 0.9N which is approximately 40% lower compared to sintered samples.

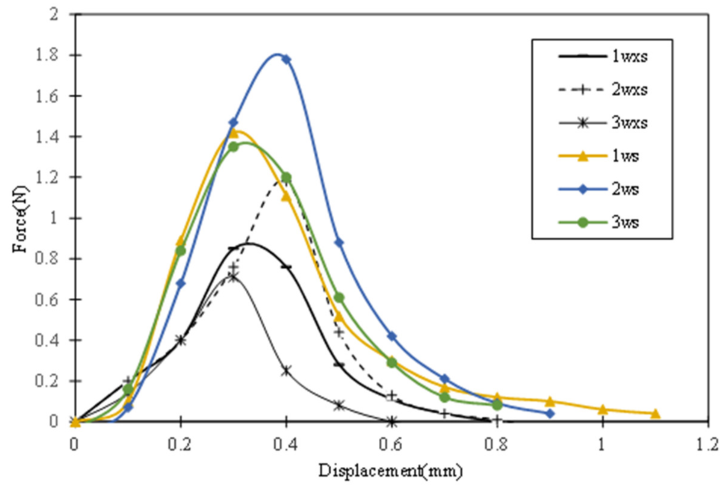

Fig. 1. Force versus displacement of seashell with water binder without sinter(wxs) and with sinter(ws).

Figure 3 presents the force versus displacement for seashell and kaolin as a binder. It is shown that with sintering process, the average maximum force for seashell with kaolin as binder is almost similar with samples at room temperature drying which is approximately 0.5N.

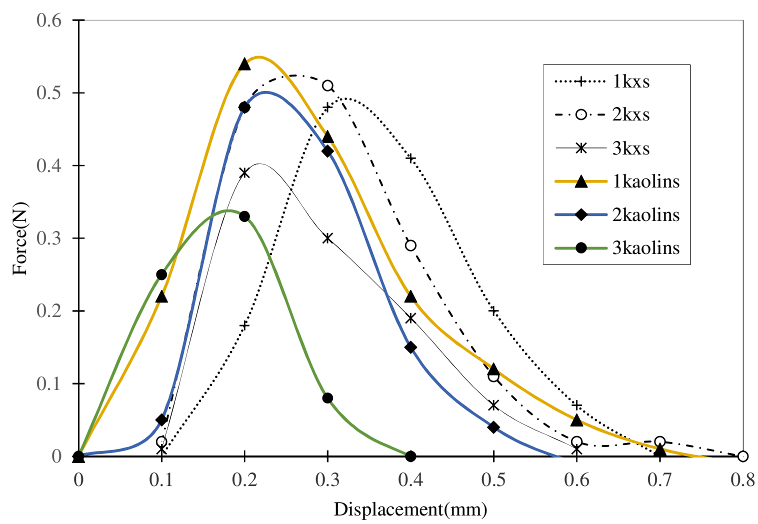

Fig. 2. Force versus displacement of seashell with kaolin binder without sinter(kxs) and with sinter(kaolins).

Figure 4 presents graph force versus displacement for seashell and PEG. It is shown that with temperature effect on samples at 400ºC, the average maximum force for seashell with PEG is approximately 0.8N. Compared with samples with binder using PEG at room temperature drying, the results show an average of 0.4N which is approximately 50% lower compared to sintered samples.

Figure 5 and Figure 6 compares the results on Young's modulus and ultimate strength obtained from flexural test on seashell mixture with water, kaolin and PEG. It is shown that sintered samples for seashell mixture gives higher results for Young's modulus for water and PEG.

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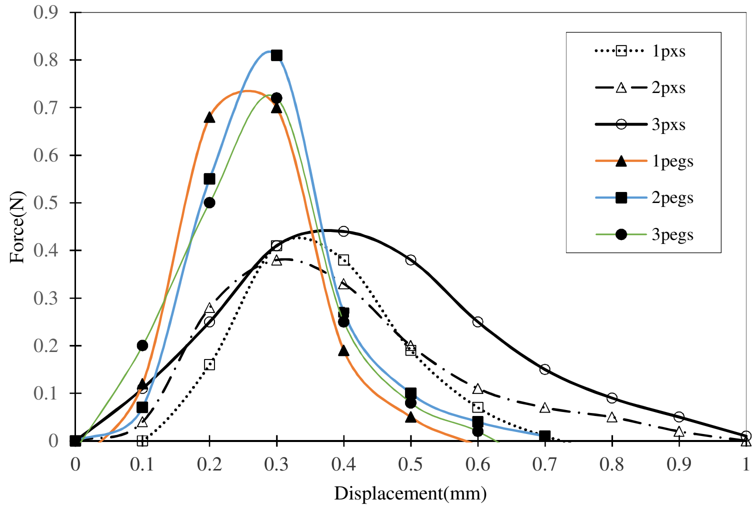

Fig. 4. Force vs displacement of seashell with PEG binder without sinter(pxs) and with sinter(pegs).

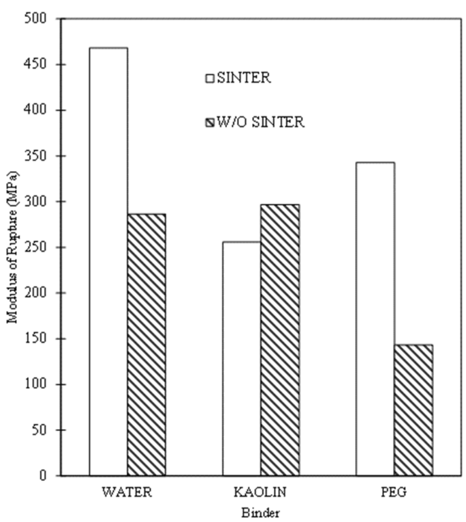

Fig. 5. Mechanical properties of binder /seashell mixture

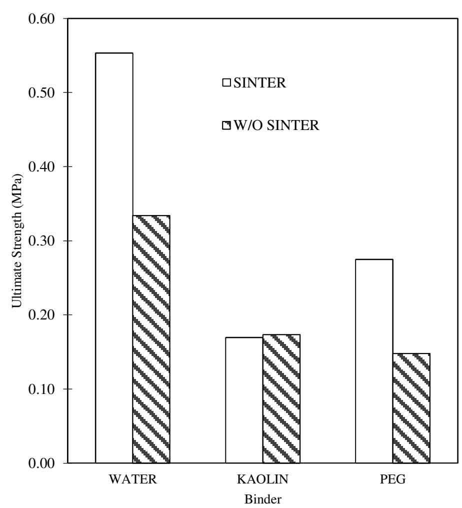

Fig. 3. Ultimate strength of binder/seashell mixture

A. Sample Effect at Sinter Temperature of 700ºC

For specimens heated at 400°C, it can be tested directly after sintering process, however the specimen sintered at 700°C, the samples coming out from oven was totally damaged. The thermal decomposition process that been done managed to decompose a fraction of the sample into calcium oxide. From thermo gravimetric analysis result as in Figure 7, cockle shells begin to decompose at 700°C and loss 55% of the weight regardless the particle sizes[14,15]. Same behaviour happened for seashell-PEG mixture when PEG start to decompose at approximately 200ºC (see Figure 7).

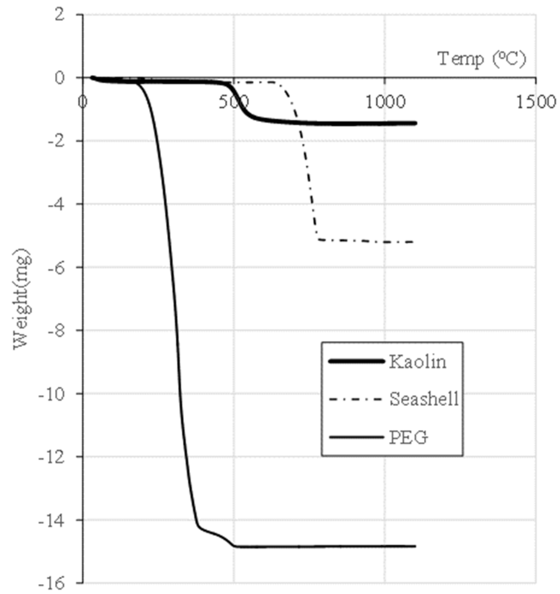

Fig. 7. Thermal balance curves

4. Conclusion

This paper presents result on mechanical properties of seashell mixture with different binders drying under room temperature and 400°C temperatures. From the results, the seashell-water mixture gives higher Young's modulus and ultimate strength compared to kaolin and PEG mixture. It is concluded that water can also be the best binder for seashell compared to kaolin and PEG. At higher temperature, seashell mixture with water remains attached. However, mixture with kaolin and PEG become detached due to grain elimination.

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