Effect of Calcined Ground Seashell Ash (GSA) in Concrete by Using Liquidation Technique

S Ismail\textsuperscript{1,}\textsuperscript{*}, M K Abd Rahman\textsuperscript{2} and M N Muhammad Sidek\textsuperscript{1}

\textsuperscript{1} Faculty of Civil Engineering, Universiti Teknologi MARA 40450 Shah Alam, Selangor
\textsuperscript{2} Faculty of Civil Engineering, Universiti Teknologi MARA, 13500 Permatang Pauh, Pulau Pinang
\textsuperscript{*}Corresponding author: shafi026@uitm.edu.my

Abstract. This research explores the potential of seashell being used in normal concrete. Experimental work has been carried out to determine the compressive strength of concrete by adding the calcined ground seashell ash (GSA). Liquidation technique was used to liquidise the GSA. A total of 4 mixes of GSA were prepared with different variation, which are 1%, 2%, 3% and 4%. All samples were water cured at 3, 7 and 28 days. The findings were yielded in good performance of compressive strength and specimen with 2% of GSA marked the highest strength of 59.77 N/mm\textsuperscript{2} compared to other specimen.

1. Introduction
Kerang or local people called ‘Blood cockle’ is common seashell species found in coastal Malaysia. This seashell species is called scientifically by the name of\textit{Bivalve Molluscs} and\textit{Anadara granosa} as depicted in Figure 1 [1]. According to Department of Fisheries Malaysia in 2013, almost 40,000 tons of cockles were harvested in few states expressed with 40,172.21 tonnes of seashell were harvested in Kedah (407.12 tonnes), Penang (9,231.78 tonnes), Perak (25,126.31 tonnes) and Selangor (5,407.21 tonnes) [2]. The mounting amount of seashell harvested is mainly due to high demand in food industry. Instantly, the adverse effect from this demand would give negative impact in long term on healthy life of community surrounding and future generation as seashell waste takes longer time to decay and promotes pollutants to the environment. Therefore, there is an urgent need to exploit the goodness in seashell waste as an alternative green material for concrete industry by recycling the seashell waste into by products. It is evident the seashell as biodegradable by products are rich in calcium due to high content of Calcium Carbonate (CaCO\textsubscript{3}) and has similar compound content as in limestone [1, 3-4]. Most of the seashell by products have been utilised in the construction industry from road construction, lime replacement, cement ash, fertilizer lime agent, moisturizers, and tiles production [5-6].

Figure 1. The commonly found seashell in Malaysia.
Realizing in discovering the potential of using seashells in concrete industry is greatly to explore, Table 1 shows the seashell were greatly researched in various function as concrete materials to be utilised in replacement of cement, replacement of aggregates, replacement of sand and act as a filler in concrete. However, the outcome of the results established were contrary as per expected some of concrete strength decreased and the workability of concrete were reduced compared to normal concrete. Many loop holes need to be filled up, under the series of modification and adjustment by previous researchers on the mix proportion, improvising techniques, improvement of concrete quality, manageability, acceleration, or retardation of setting time, among other properties that could be altered to get specific results [1, 6-8].

Table 1. Various type of shells used as a replacement material in concrete.

| Author           | Country  | Type of seashell | Type of usage in concrete | Sources of seashell | Preparation method | Result (28 days)                        |
|------------------|----------|------------------|----------------------------|---------------------|-------------------|----------------------------------------|
| Muthusamy et al. (2012) | Malaysia | Cockle           | Coarse aggregate           | Food                | Seashells size 10-14 mm | Reduce workability and compressive strength |
| Azmi and Johari (2013) | Malaysia | Blood cockle     | Cement and filler          | Processed food factory | ground to powder, burned in a gas furnace at 1000°C for 1 hour | Reduce Compressive strength |
| Olivia et al. (2015) | Indonesia | Blood cockle | Cement and filler | Local seafood vendors | burned at 500°C for 3 days | Reduce compressive strength |
| Adewuyi et al. (2015) | Nigeria | Snails, periwinkle, cockle | Coarse aggregate and cement | Not specific | Seashells was calcined at 800°C for 2 hours | Increase compressive strength |

Thus, the present research explores the possibility of utilizing calcined ground seashell ash (GSA) to improve the strength performance in concrete. The experimental work has been carried out to determine the compressive strength of concrete with the inclusion of various percentage of calcined GSA. Some techniques were modified and innovated in order to optimise the goodness of seashell in concrete for this research.

2. Methodology

2.1. Specimen preparation of materials and testing

The cement used for this research is Ordinary Portland Cement, Tasek Cement. The cement was weight according to the calculated mix design, which is 4.86 kg. According to BS 1881-125: 2013 [9], the aggregate should be either oven dry or air-dried at (20 ±) °C. Fine aggregate with well graded sand and aggregate that pass through 2 mm pan were used. Whereas, coarse crushed aggregate gravel that passing 20 mm sieving pan and retain at 14mm sieving pan were used to boost the cement-aggregate bonding effect as the bond developed due to the interlocking of the hydration process due to the rough texture of the crushed aggregate particles, hence it will directly contribute the strength of concrete. A total of 4 mixes with different variation of GSA, which are 1%, 2%, 3% and 4% were prepared and totalling 45 cube of specimens with dimension of 100 mm x 100 mm x 100 mm were water cured at 3, 7 and 28 days. The compressive strength testing was conducted as stated in the BS EN 12390- 3:2009 (British Standard, 2009) [10].

2.2. Calcination process

The seashell used for this research were harvested directly from local beach at Pantai Bersih, Butterworth in Pulau Pinang. The seashell were cleaned and air-dried under the sun for 5 hours in order to remove the dirt, impurities and salt in the seashell. The seashell were finely grinds into powder form by using grinder machine. To exploits the goodness in seashell, this research has adhered the calcination
The seashell powder were burnt at high temperature of 800°C for 2 hours and its exhibited the seashell powder into white to greyish in colour as in Figure 2. This process has decomposed the structural composition of calcium carbonate (CaCO_3) into a smaller composition called calcium oxide, (CaO). This transformation has changed in the seashell’s structure from rough and disordered surface, and low porosity grains into a smoother and more uniform surface [3]. Hence, with this attractive smoothen structure has helped to improve the bonding of particles by filling up the voids in the porous concrete to become denser and more compact. Thus, with this new catalyst will improved the concrete’s strength by improving its function as a filler agent in concrete.

![Figure 2. The calcined ground seashell ash (GSA).](image)

2.3. Liquidation technique
The liquidation technique is a process to ensure the distribution of calcined GSA during the mixing process is evenly-well distributed in the concrete. This technique also, promotes to boost the process of hydration by producing larger amount of hydrate gel of calcium hydroxide (Ca(OH)_2) when in contact with water making the concrete internal structure become more compact and stronger through its bonding gel created before the mixing process [11-12]. Figure 3 shows the calcined GSA were liquidised with water by the ration of 1:4 from the total volume of water, this is to ensure the total amount of moisture content in the concrete is kept consistent throughout the process of mixing.

![Figure 3. The liquidation of calcined ground seashell ash (GSA).](image)

3. Results and analysis
Figure 4 presents the development trend of compressive strength for concrete with inclusion of calcined GSA. All specimens show trend of strength increment as curing age extended up to 28 days. The continuous water curing method promotes continuous hydration process resulting in large amount of hydrate gel of calcium hydroxide (Ca(OH)_2), thus making the internal and outer concrete structure become more compact and stronger. Looking at the effect of calcined GSA as a filler, it can be yielded that the concrete strength increases when appropriate amount of calcined GSA is added into the mix design proportion. The findings also indicate the calcination technique and liquidation technique has significant effect on the strength of concrete.

Table 2 and Figure 5 presents the compressive strength for concrete with the inclusion of calcined GSA for 3, 7, and 28 days. The strength performance of the concrete was significantly increased with calcined GSA up to 3%. The optimum compressive strength was yielded by the 2% of calcined GSA at 28 days but slightly higher than the control specimen with 59.77 N/mm^2. This promising result is
contributed to the function of calcined GSA as a filler making the outer and internal structure of concrete becoming denser and more compact, hence resulting in higher compressive strength. This can be proven as depicted in Figure 6, where the specimen of 3% of calcined GSA resulted cracked at all four exposed faces outer surface of the specimen approximately equally, generally with little damage to faces contact with plates and the failure classified as ‘Satisfactory Failure’ as referred in BS 1881-111: 1983 [13].

**Figure 4.** Effect of calcined ground seashell ash (GSA) on compressive strength of concrete.

**Table 2.** Compressive strength test result.

| Sample | Day 3  | Day 7  | Day 28 |
|--------|--------|--------|--------|
| GSA0   | 42.76  | 47.68  | 59.68  |
| GSA1   | 31.87  | 40.84  | 51.24  |
| GSA2   | 41.21  | 47.99  | 59.77  |
| GSA3   | 44.45  | 50.91  | 58.72  |
| GSA4   | 37.86  | 43.53  | 52.11  |

**Figure 5.** Effect of calcined ground seashell ash (GSA) on compressive strength of concrete.
However, the results were observed low in compressive strength at 1% and 4% percentage of calcined GSA. The compressive strength for day 3, 7 and 28 in average is 9% lower than the control specimen. It can be concluded that the amount of calcined GSA greatly influenced the compressive strength in concrete.

Figure 6. The crack pattern of concrete cube at 3% of calcined of ground seashell ash (GSA).

4. Conclusion
Decisively, this research presents the inclusion of 2% calcined ground seashell ash (GSA) act as an active filler that empower to produce better concrete performance of compressive strength as compared to normal concrete. Another alternative sustainable construction material that could offer as greener material to concrete with some modification and adjustment for marine-waste based product.

5. References

[1] Nor Hazurina O, Badorul Hisham Abu B, Mashitah Mat D and Megat Azmi Megat J 2013 Cockle shell ash replacement for cement and filler in concrete Malaysian J. Civ. Eng. 25 201-211
[2] Department of Fisheries Malaysia 2013 Annual Fisheries Statistics 2013 Retrieved from http://www.dof.gov.my/senarai-perangkaan-perikanan-tahunan-2013
[3] Nurfatirah N, Zainab H, Othman H, Farizul H K and Rozaini A 2015 Effect of temperature in calcination process of seashells Malaysian J. of Anal. Sci. 19 65-70
[4] Alhozaimy A M, Soroushian P and Mirza F 1996 Mechanical properties of polypropylene fiber reinforced concrete and the effects of pozzolanic materials Cem. Concr. Compos. 18 85-92
[5] Barros M C, Bello P M, Bao M and Torrado J J 2009 From waste to commodity: Transforming shells into high purity calcium carbonate J. Cleaner Prod. 17 400-407
[6] Adewuyi A P, Franklin S O and Ibrahim K A 2015 Utilization of mollusc shells for concrete production for sustainable environment Int. J. Sci. Eng. Res. 6 201-208
[7] Monita O, Annisa A M and Lita D 2015 Mechanical properties of seashell concrete Procedia Eng. 125 760-764
[8] Muthusamy K, Sabri N A, Resources E and Razak L T 2012 Cockle shell: A potential partial coarse aggregate replacement in concrete Int. J. Sci. Environ. Technol. 1 260-267
[9] BS 1881-125 2013 Testing concrete - Part 125: Methods for Mixing and Sampling Fresh Concrete in the Laboratory (London: British Standards Institution)
[10] BS EN 12390-3 2009 Testing Hardened Concrete. Compressive Strength of Test Specimens (London: British Standards Institution)
[11] Sulaiman M A, Muthusamy K, Mat Aris S, Mohd Rasid M H, Paramasivam R and Othman R 2017 Effect of unground oil palm ash as mixing ingredient towards properties of concrete IOP Conf. Series: Earth and Environmental Science 140 012150
[12] Sidek M N M, Hashim N H, Rosseli S R, Nor M R M, Ismail S, Saman H M, Arshad M F, Alisibramulisi A and Zainudin F 2018 Utilisation of palm oil fuel ash (POFA) as cement replacement by using powder and liquidation technique AIP Conference Proceedings 2020 020069

[13] BS 1881-111:1983 Testing Concrete- Part 111: Method of normal curing of test specimens (20°C Method) (London: British Standards Institution)

Acknowledgments
Authors are grateful for UiTM in supporting the research work through its financial and constant encouragement from the Management and Colleagues from Faculty Civil Engineering UiTM Cawangan Pulau Pinang (UiTMPP).