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COCKLE SHELL ASH REPLACEMENT FOR CEMENT AND FILLER IN CONCRETE

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Abstract: The concepts of eco-friendly building are getting more attention today. The use of materials from natural sources is an alternative to the realization of the green building concept. Considering this approach, a study was conducted to investigate the potential of cockle shell ash as a material for partial cement replacement or a filler material. The study was to determine the chemical composition of cockle shell ash and were determined using Fluorescence X-ray analysis. The observation of on the morphology structure based on SEM analysis was also performed. The next phase involved in determining the concrete properties such as compressive strength, tensile, modulus of elasticity, water permeability and porosity made from mixture of cockle shell ash of 5%, 10%, 15%, 25%, 50% and compared to normal concrete cured in ordinary water at the 7, 28, 90 days and up to 120 days for water permeability test. As a result, with the inclusion of 5% and 10% of cockle shell ash, morphology structure seems compacted that effected the strength, modulus of elasticity, permeability and porosity of the concrete.

Keywords: *Cockle, concrete, filler, cement replacement, morphology*

1.0 Introduction

Cockle (blood cockle) is one of the main species in the aquaculture industry in Malaysia and Figure 1 illustrates the shape of the cockle shell. Cockle is also known as bivalve molluscs and *Anadara granosa* was the most common species available in this country. Statistics by the Department of Fisheries Malaysia expressed 57,544.40 tonnes of cockle were harvested along the west coast of Peninsular Malaysia including Johor and Pahang in year 2011 (Department of Fisheries Malaysia, 2011). This value indirectly, not only indicates the number of cockle production but also amount of waste shells generated.

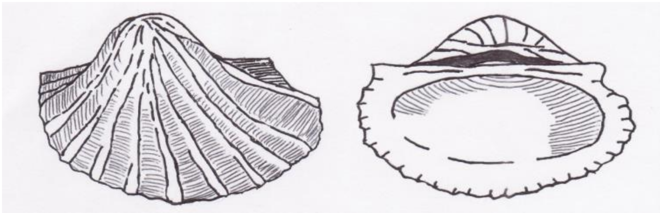

Figure 1: Shape of cockle shell

In conjunction with the high demand from consumers to use cockle as an ingredient in food industry, promote the existence of cockle's processing plants. With more factories doing the suckling process, meaning more shells will be thrown to the surrounding ares. As the shells take a long time to decay, it will become a pollutant to the enviroment.

For this purpose, based on the concept of reduce, reuse and recycle, especially in the construction industry, it is better to consider to use cockle shell as a biodegradable material. The concept of green technology in construction should be concomitant with the current development in this industry.

1.1 Research on Application of Shell in Concrete

Shell by-products (such as mussel shell, oyster shell, scallop shell etc.) have long been applied in industries (Barros *et al*., 2009). For example, in the construction of roads, replacement of industrial lime, ash cements, fertilizer, lime agent, moisturizers and tile. Other than that, the uses of shell waste as a replacement material in concrete also have been increasing now. The table below has shown the list of research using various shells as a replacement material in concrete mix.

Table 1: Various types of shells used as a replacement material in concrete

Researchers	**Country**	**Type of shells**	**Replacement material in concrete**
Sugiyama, (2004)	Japan	Scallop	Coarse aggregate
Falade, (1995)	Nigeria	Periwinkle	Coarse aggregate
Eun-Ik Yang *et al.*,(2005)	Korea	Oyster	Fine aggregate
Yusof *et al*,. (2011)	Malaysia	Clam	Fine aggregate
Muthusamy & Sabri, (2012)	Malaysia	Cockle	Coarse aggregate

Awang-Hazmi *et al.*, (2007) have used cockle shell ash as a mixture in making bone substitutes and as a sand replacement material in the making of artificial reefs has been done by Faridah Sahari and Nurul Aniza, (2011). Cement product for masonry and plastering also use ground waste seashells (short-neck clam, green mussel, oyster and cockle) were investigated by Lertwattanaruk *et al.*, (2012).

Relying on the literature review, the potential of using shells as an aggregate would decrease the strength and workability of concrete compared to normal concrete. More proportion of shell used would decrease the strength of concrete.

The content of calcium carbonate, $CaCO_3$ (accounts 95-99% by weight) in the cockle shells was high and almost equal to limestone. Consequently, the physical and chemical properties of cockle shell ash is also similar to limestone and suitable to be used as a filler material in concrete. In this study, different proportion of cockle shell ash containing 5% (CSA5), 10% (CSA10), 15% (CSA15), 25% (CSA25) and 50% (CSA50) as a cement replacement material.

2.0 Materials and Methods

2.1 Materials

Concrete was manufactured with Type I Ordinary Portland Cement (OPC) supplied by Blue Lion Cement Brand as the main binder. Crushed granite with normal maximum size of 20mm, specific gravity of 2.72 and water absorption 0.52% was used as coarse aggregate. The relative density (specific gravity) and absorption of fine aggregate were 2.67 and 0.75% respectively.

2.2 Handling of Cockle Shell

Cockle shells was collected from surrounding area where it was dumped from the processed factory in Bagan Panchor, Perak. It was learnt that some of the waste was transported to low land area for landfill or used for the road crusher. The collected shells has been washed to remove the dirt and dried in an oven at temperature of 105±5ºC for 24 hours. The shells been grinded into powder to pass 5mm sieve using cone crusher before burnt at 1000ºC for 1 hour in a gas furnace at a heating rate of 10ºC/min. After that, the cockle ash was left to cool in room temperature for at least 24 hours before can be used. Specific gravity of the cockle shell ash was 2.07 and the test was conducted by using gas pyrometer. CILAS 1180 Particle Size Analyser was used to observe particle size distribution. The average size of cockle shell ash was 23.97µm and 96% of it passed through 150 µm sieve.

2.3 Mixture Proportions

Cockle shell ash (CSA) was used as partial relacement in OPC at prescribed amount of 5%, 10%, 15%, 25% and 50%. The mix proportions of the CSA used in this study are given in Table 2. The mixes were designed to achieve concrete grade 35N/mm^2 in 28 days. A water/binder ratio of 0.54 was used in all mix design.

Table 2: Concrete mix proportions.

Materials [kg/m^3]	OPC	CSA5	CSA10	CSA15	CSA25	CSA50
OPC	432	410.4	388.8	367.2	324	216
Cockle shell ash	0	21.6	43.2	64.8	108	216
Coarse aggregate	586	586	586	586	586	586
Fine aggregate	1089	1089	1089	1089	1089	1089
Water	233	233	233	233	233	233

2.4 Mixing, Casting and Testing

Mixing of concrete was done using pan type mixer and casting of samples was done in three layers. Specimens were compacted using a vibrating table in order to remove any entrapped air and attained maximum compaction. Each layer was vibrated for about 20 seconds. Samples were demolded 24 hours after casting and cured in water tank with 100% relative humidity at room temperature of 27±2ºC until the time of testing. Size and amount of specimens prepared for testing are shown in Table 3.

Table 3: Specimen prepared for testing.

Type of testing	Shape and size of sample	Amount of sample
Compressive strength	Cube (100x100x100) mm	54
Split tensile	Cylinder (Ø100x150) mm	54
Modulus of elasticity	Cylinder (Ø100x200) mm	18
Porosity	Cylinder (Ø50x40) mm	54
Water permeability	Cylinder (Ø50x40) mm	54

Chemical compositions were analysed using X-ray Fluorescence (X-RF) and Scanning Electron Microscopy (SEM) was utilized to enumerate the change in the morphology particle of normal concrete and all concrete mixtures with cockle shell ash.

Test for compressive strength of specimens conducted according to BS EN 12390-3:2009 (British Standard, 2009). Also the split tensile test and modulus of elasticity test were determined according to BS EN 12390-6:2009 (British Standard, 2009) and BS 1881-121:1983 (British Standard, 1983) respectively.

Test method of porosity was based on BS 1881: Part 208 (British Standard, 1996) and was calculated using the following equation:

$$P\,(\%) = \left(\frac{w_2 - w_1}{w_2 - w_3}\right)100 \qquad (1)$$

Where, w_1 is the mass of the oven dry sample, w_2 the mass of specimen in saturated and surface dry condition in the air and w_3 is the mass of specimen in water.

Test procedure for water permeability test was carried out to observe the absorbed water penetrating the top surface and flowing through the sample under an applied pressure head of 2-4 bars. The coefficient of water permeability, K_W was calculated using the following equation (Valanta, 1970):

$$Kw = \frac{d^2 v}{2Th} \qquad (2)$$

where d is the depth of water penetration (m), T is the time of penetration (s), h is the applied pressure (m) and v is the total porosity (fraction). Porosity, v, calculated using the following equation:

$$v = \frac{m}{Ad\rho} \qquad (3)$$

where m is the gain in mass (kg), A is the cross-sectional area of the specimen (m^2) and ρ is the density of water (1000 kg/m^3).

3.0 Results and Discussion

3.1 Chemical Compositions and Physical Properties of Cockle Shell Ash

Results of X-RF analysis were shown in Table 4. Through a thermal decomposition process known as calcination $CaCO_3$ can be converted into lime, CaO (Mustakimah *et al.*, 2010) . The cockle shell ash enclosing 99% CaO as the calcite cockle shell.

Table 4: Chemical composition cockle shell ash

Oxide	Cockle Shell Ash
Na_2O	0.49
Al_2O_3	0.03
SiO_2	0.07
P_2O_5	0.03
SO_3	0.14
K_2O	0.06
CaO	99.00
Fe_2O_3	0.05
SrO	0.28
LOI	0.20

Figure 2 has shown the surface morphology of all concrete mixes as illustrated by SEM. Based on these observations, the morphological of concrete with 5% cockle shell ash have a rough cuboids structure with an average diameter size greater than 2µm. However, normal concrete has a rough irregular surface with an average diameter size of less than 2µm. Whereas, morphological structure from the rest of concrete mixes, the shape was in thin irregular plate with an average size over 2µm to 10µm. For that reason, increasing use of cockle shell ash in concrete would decrease the roughness of surface morphology structure.

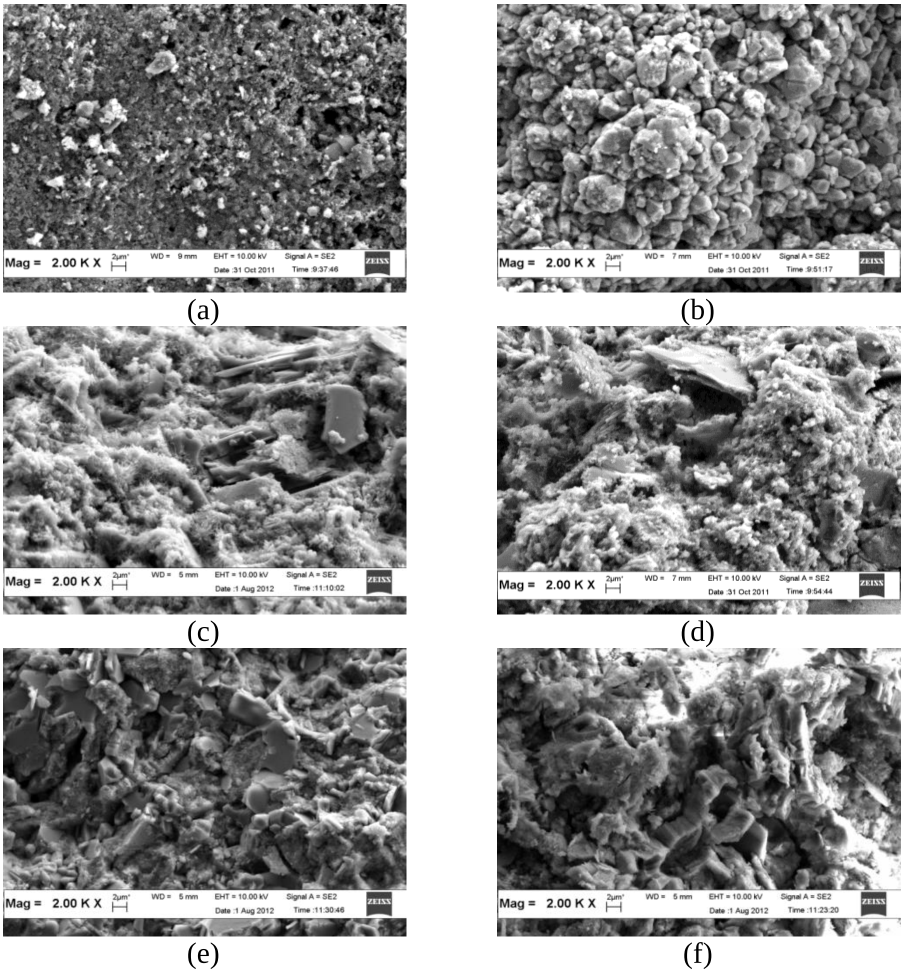

Figure 2: Particle morphology of concrete structure: (a) normal concrete, (b)CSA5, (c) CSA10, (d) CSA15, (e) CSA25 and (f) CSA50.

3.2 Compressive Strength

The results of 7-days, 28-days and 90-days compressive strength tests for concrete mixtures are shown in Figure 3. From the results, the compressive strength decreases with the increment of cockle shell ash content in the cement. However, a concrete mix with 5% and 15% cockle shell ash have similar compressive strength value at 28 days curing period wherein the concrete mixture has achieved 35MPa. Nevertheless, the concrete mix with 5% and 10% cockle shell ash have an increment of strength up to 47% compared with normal concrete that only increase 26% (during the curing period from 7 days to 90 days).

3.3 Tensile Strength

The results of the split tensile test of normal concrete and cockle shell ash concrete are shown in Figure 4. From the observation, by comparing the tensile strength of normal concrete was increased to 59% for curing period from 7 days to 90 days. Meanwhile, concrete mix added with 5% cockle shell ash gives an increment of 49% for the similar period of curing. Concrete mix with the cockle shell ash provides a high intensify of percentage when curing time up to 90 days. As a result, the long curing period is to ensure the continuity of the concrete strength in conjunction of the pozzolanic reaction and hydration of cement.

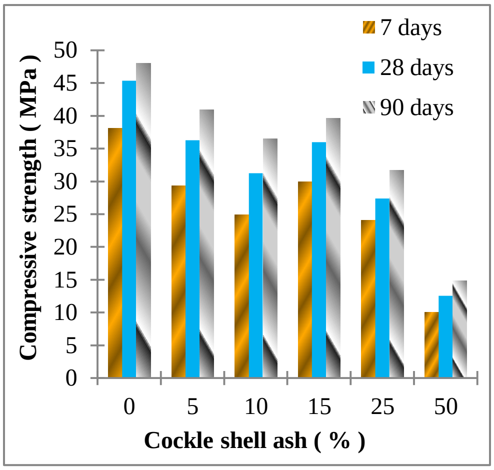

Figure 3:Compressive strength of concrete with different cockle shell ash content.

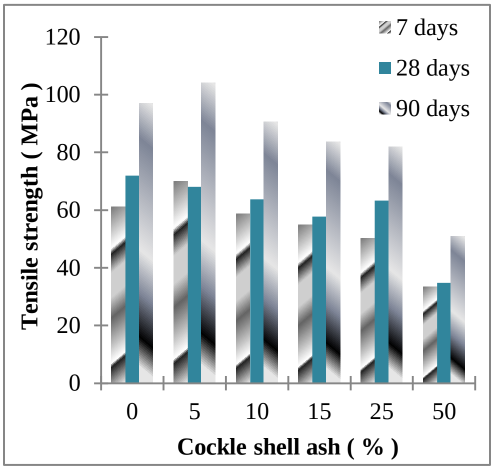

Figure 4: Results of split tensile test.

3.4 Modulus of Elasticity

Modulus of elasticity is the ability of concrete to deform under load and return to the original dimensions when the load is pulled out. Figure 5 shows the curve of the stress-strain for normal concrete and concrete mix with CSA. Derive from the graph shown that CSA10 gain high modulus of elasticity with a value 22.2 GPa. On the whole, concrete mixture with 5% CSA and above 10% added will give a low modulus of elasticity.

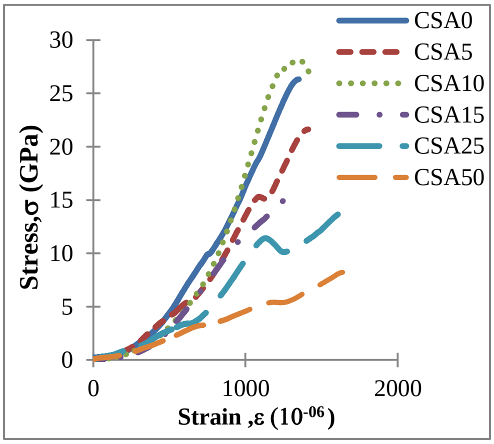

Figure 5: Stress-strain curve for modulus of elasticity test results.

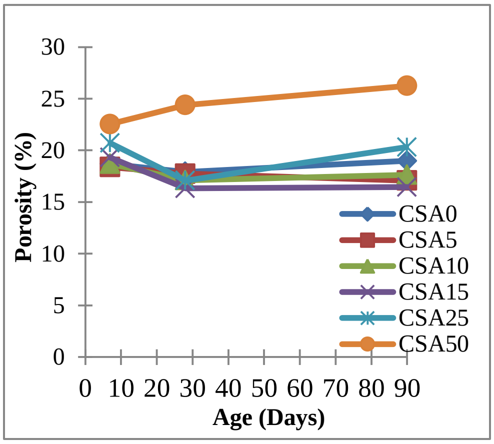

Figure 6: Results of porosity test.

3.5 Porosity

Porosity is the void occurring on the inner and outer surface concrete as well as affecting the quality of concrete in continuous or discontinuous. Test results for porosity are shown in Figure 6. From the graph, porosity from all mixes of concrete was just approximately same as normal concrete when it was cured for 7 days and 28 days. However, at the age of 90 days, porosity of concrete mixtures with CSA5, CSA10 and CSA15 are less than normal concrete with the lowers porosity is from CSA15. For overall finding in porosity, it can be concluded that the porosity of concrete would decrease when increased the percentage of cockle shell ash replacement in concrete excepted CSA25 and CSA50. It is also mentioned that the amount of cockle shell ash as a cement replacement was not approximately above 15%.

3.6 Water permeability

Permeability is a process to determine the toughness of concrete against external action and a good concrete should be impermeable (waterproof). Table 5 shows the results of water permeability of the concrete mixtures. From the observation, at the age of 28 days and 90 days of curing defined that the permeability of the concrete mixtures with cockle shell ash was higher than normal concrete. In spite of that, at the age of 120 days of curing the water permeability of the concrete mix with cockle shell ash was lower (especially CSA10 concrete) than a normal concrete. Otherwise, CSA50 showed higher permeability.

Table 5: Water permeability of concrete mixtures.

Curing age [days]	Water permeability [x10^{-11} m/s]					
	Proportions of cockle shell ash					
	0%	5%	10%	15%	25%	50%
28	2.58	5.90	5.45	3.56	3.05	4.70
90	12.40	13.10	21.80	20.10	35.40	38.70
120	28.50	14.40	11.30	17.50	18.20	33.40

4.0 Conclusions

The subsequent common findings are based on the laboratory research reported in this paper. The specific conclusions that can be outline from this study are as follows:

1. The high content of CaO in the cockle shell ash will cause the slow hydration process that will reduce the strength of concrete in the early age of curing. Conversely, the percentage of increment in strength is higher than normal concrete with longer curing period.
2. The strength of concrete with cockle shell ash mixture is lower than normal concrete. Nonetheless, for a long time curing period (up to 90 days), the percentage of strength increased compared to normal concrete especially concrete with CSA5 and CSA15.
3. The modulus of elasticity would decreased with the increment of the proportion of cockle shell ash in concrete except for concrete with CSA10 gave higher modulus of elasticity than others.
4. The permeability and porosity of the concrete decreases when the increment amount of cockle shell ash except in a mixture with CSA25 and CSA50 principally when the age of concrete achieve 90 days of curing.
5. As a whole, the morphological structure of concrete with CSA5 and CSA10 which seems compacted would affect the strength, modulus of elasticity, water permeability and porosity of the concrete.

5.0 Acknowledgements

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