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Utilization of Cockle Shell (*Anadara granosa*) Powder as Partial Replacement of Fine Aggregates in Cement Brick

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Abstract: Waste from fishery sector such as seashells are widely used in construction and building materials in order to reduce waste quantity. This study investigates the utilization of cockle shell powder (CSP) as partial replacement for fine aggregates in producing cement brick (CB). Bricks specimen are designed with three different percentages of 5% (CSP5CB), 10% (CSP10CB) and 15% (CSP15CB) replacements including control cement brick (CCB). An analysis conduct in this study are included sieve and specific gravity for materials testing while compressive strength, density and water absorption are for harden specimens. A rectangular brick shape specimen with 200mm × 100mm × 100mm in volume were used then cured using tap water for 7 and 28 days. The result revealed that compressive strength for specimens containing CSP are higher compared to CCB specimens. Besides that, CSP brick given a higher density with 2381.25 kg/m3 and lower water absorption 0.31% contrast from control specimens. According to overall data collected, the optimum composition for CSP in cement brick was 5% which indicated higher compressive and lower water absorption. Thus, the incorporation of CSP as sand replacement in bricks could improve and enhance physical and mechanical developments of bricks with the increment of curing time.

Keywords: Cockle shell powder, cement brick, fine aggregate replacement, partial replacement, performance

1. Introduction

Seashell is one of abundant materials from mollusk species. It can be classified as a type of waste generated from fishery sector including seafood store, supermarket and etc. It has been compromised about 0.9% from total amount of waste generated [1]. These wastes are very relatable with the quantity of mollusk been produced per year respectively. According to Food and Agriculture Organization of the United Nations (FAO) [2], mollusk production had shown an increasing trend which is more than 20 million tonnes from 2011 until 2016 worldwide. Since there is a huge amount mollusk species produced each year, it is realistically followed with the increment quantities seashell's waste. Thus,

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these could cause negative visual impact towards environmental condition due to increments of waste quantity each year [3].

Cockle (*Anadara granosa*) [4] or blood clam is one of mollusk species that are highly demand among supplier and consumer in Malaysia. According to Malaysia Fishery Department [5], it production had increased from 9596.76 tonnes on 2016 to 12,482.34 tonnes on 2017 which led to increment of retail value of aquaculture production. On the other hand, it shells or mollusk have very low commercialize value thus will be discarded to the land fill [6]. Thus, this will imply a compelling effect on the environment condition which may promoting spreading of diseases such dengue, leptospirosis and etc. due to dirty surrounding area.

In recent year, issue related to waste from seashells had become one of concerned among research in order to promote a sustainability in development. Seashells is one of waste materials that contain high amount of calcium carbonate ($CaCO_3$) more than 90% [7]-[9]. A study by Mohamed et al. [10], it was declared that cockle shell made of aragonite and other minerals such as vaterite and calcite which formed in a compound named calcium carbonate ($CaCO_3$). It was also observed by Othman et al. that cockle shell has a major compound of calcium oxide (CaO) with 99.00% compared to other oxide form [11]. However, existing of oxide compound such CaO in cockle shells can be presume as concurrency of $CaCO_3$. It is due to thermal decomposition process turned $CaCO_3$ to CaO as in the following Eq. (1) [12] [13]. Hence, it was generally can be assumed that present of CaO are slightly similar to the present of $CaCO_3$.

$$CaCO_3 \rightarrow CaO + CO_2 \quad (1)$$

A study by Sainudin et al. [14], application of seashell as an additional material in concrete mixture improved concrete properties. It was observed that addition of seashell ash gives a higher setting time, workability, compressive strength and lower capillary water absorption compared to control concrete. Similar result also has been reported on concrete mechanical strength by Othman et al. [11] with seashell ash as cements replacement in concrete mix. Positive experimental outcomes also declared by Olivia et al. [15]. The application of seashell is not only can be applied in concrete mix design but potentially used in bricks production. According to Böke et al. [16], brick present of $CaCO_3$ are more durable and less deterioration effects. The incorporated of $CaCO_3$ compound potentially act as binder and filler materials in filling micro-structure pore in brick. Thus, it resulting less permeable and inhibit the ingression of moisture and ion penetrate in to brick specimens.

Overall, based on previous literatures, it shows that seashell is potentially to be used in construction materials such as bricks production and etc. due to existing of $CaCO_3$ compound in it similar to lime which are widely used in cements production, plastering and masonry work. Formerly, brick is a construction material made from non-organic material with good durability. Common types of brick include clay brick, cement brick and sand brick which commonly used in making internal or external wall structure. According to Hashim [17], application fine aggregates which came from quarry mining may also cause river pollution and landslides. Thus, in this study, utilization of cockle shells powder (CSP) as partial replacement for fine aggregates in brick production was applied as an alternative method to minimize highlighted issue mentioned. The scope of analysis was evaluated according to it physical and mechanical properties in this study in order to identify CSP potential ability when incorporated with cement bricks. Through this analysis, the optimum percentage of cockle shell powder used can be determined.

2. Materials and Method

2.1 Raw Materials

Raw materials that are used in this study are including water, cements, fine aggregates and cockle shells. The cockle shells were obtained and collected in Benut, Pontian, Johor. Fine aggregates and cockle shell powder with specific gravity of 2.60 and 2.44 according to BS EN 197-1: 2000 were used as the main replacement component in cement brick design [18]. The cockle shell was cleaned using tap water and sun dried for 3 days in order to avoid present of moisture in it. Then, it was crushed using milling crusher and sieved using 2mm sieve. Passing sample of 2 mm sieves were used as replacement for fine aggregates. Fine aggregates and CSP then were sieved with specification of BS EN 12620: 2013 [19] and result was shown as in Fig. 1. The CSP and fine aggregates undergone sieve analysis test to determine whether it is compatible to be used as a partial replacement of fine aggregates in cement bricks. It shows that fine aggregates having fines modulus of 3.08 while CSP is 3.18 respectively. Since the trend line and fines modulus for both materials are almost similar, thus CSP are potentially suitable to be used as fine aggregates replacements.

2.2 Brick Design Preparation

The ingredients are mix with four different separate design with mould design of 200mm × 100mm × 100mm brick sizes. Cement bricks with composition ratio cement: sand as 1:2 was prepared with fine aggregates partially replaced by cockle shell whereas water to sand ratio used were 40%. Brick design used are by 5%, 10% and 15% replacement of fine aggregates. The cockle shell cement bricks were casted for 1 day and cured for 7 days and 28 days. The mix design ratio of cockle shell cement brick can be seen as in Table 1.

Table 1 - Mix design ratio in cement bricks

Type	Cement (%)	Fine aggregates (%)	CSP (%)
CCB	33	67	0
CSP5CB	33	62	5
CSP10CB	33	57	10
CSP15CB	33	52	15

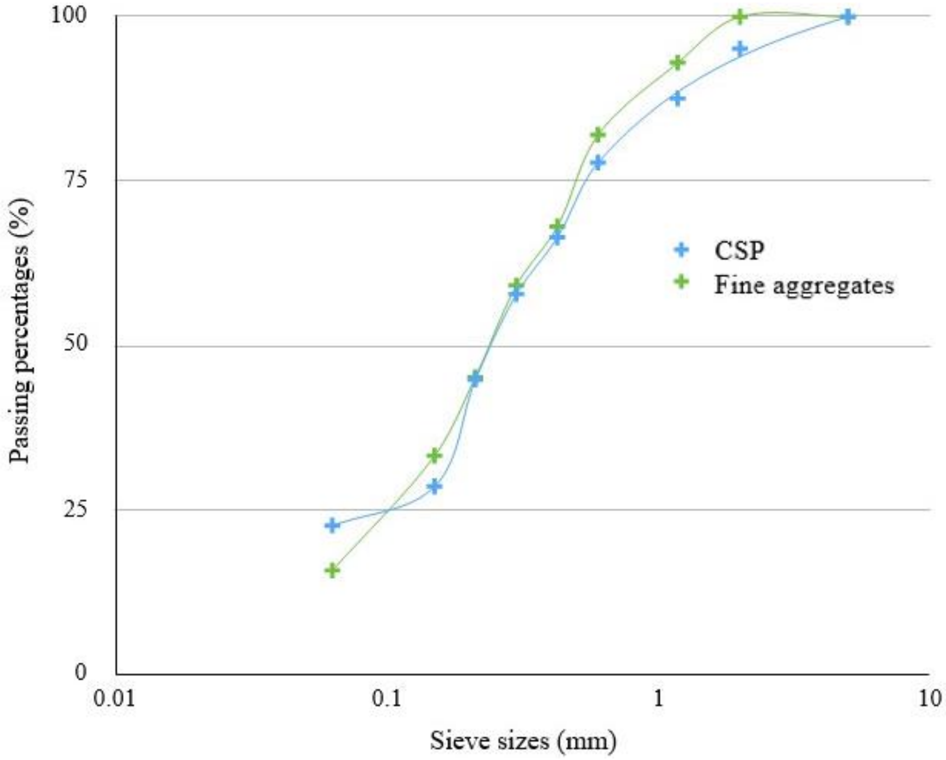

Fig. 1 - Sieve analysis results for cockle shell powder and fine aggregates

2.3 Testing Method

2.3.1 Density Test

This part is concerned on the physical behaviors of bricks containing PSA (CSP5CB, CSP10CB and CSP15CB) and control specimens (CCB). As well known, density of cement brick commonly identified through it cements and fine aggregates contain in it. Thus, this analysis was done to analyze effect of CSP on cement brick density. This test was proceeded base on BS EN 12390-7: 2009 [20]. Value of brick density can be identified and interpret according to a formula as mention in Eq. (2).

$$\text{Density}, \rho = \frac{m}{V} \qquad (2)$$

where: m = mass of brick (kg), V = volume of bricks (mm^3)

2.3.2 Water Absorption Test

Water absorption analysis was applied according to standard BS EN 772-11: 2011 [21]. This analysis was done in order to evaluate the rate of water absorption of CSP bricks and CCB. Result than were compared between the absorption value of CSP bricks and CCB. The percentages rates were used in order classified type of brick uses in this study. The specimens were dried using Ventilated Drying Oven with 108 ºC for 24 hours. It is preventing disturbance of water absorption rate due to interference of existing moisture in bricks specimens. Thus, the specimens need to be in fully saturated state. Percentages of water absorption can be calculated as mention in Eq. (3).

$$\text{Water absorption}, W_A = \frac{(m_2 - m_1)}{m_1} \times 100\% \tag{3}$$

where: m_2 = wet weight specimens (kg), m_1: dry weight specimens (kg).

2.3.3 Compressive Test

Compressive test is devoted to identify mechanical strength of a bricks. Bricks were subjected to load with speed of 7 kN until it failed using universal compressive machine. The results are obtained from the value of maximum load that been pointed to the bricks specimens. This analysis was carried out based on 7 and 28 days for all bricks specimens accordingly to BS EN 12390-3:2009 [22].

3. Results and Discussion

3.1 Density

Result for density analysis, presented in Table 2 indicates the density effect on the utilization of CSP with 0%, 5%, 10% and 15% in cement bricks design. As can be seen in Fig. 2, it shows that the density of CSP cement bricks decreased when the percentages of CSP used was increased on 7 days. It is due to the early age of brick which cause incomplete and ongoing hydration process of hydration product with CSP in brick micro-structure cause less effect of its incorporation reaction [7]. Higher percentages of CSP will increased duration for chemical interaction between cements minerals (C_3S, C_2S, C_3A and C_4AF) and $CaCO_3$ compound. Thus, it causes less density value in each specimen with the increments of CSP percentages.

On the other hand, for 28 days, density for brick containing CSP resulting a higher density compare to CCB specimens. Cement brick with 5% of CSP (CSP5CB) used has the highest density. The density was affected by the minimum number of air voids in cockle shell cement bricks compared to control cement bricks. Density of cockle shell cement bricks were increased over curing period. Even though, it shows inconsistences in each reading for 28 days. However, the different percentage of cockle shell cement brick with control cement bricks density was 0.26% to 12.27%. Therefore, it does not effects on the physical properties of cockle shell cement bricks.

Table 2 - Density of cement bricks with different CSP percentages (Kg/m³)

Specimens	Curing (days)	
	7	28
CCB	2282.21	2343.80
CSP5CB	2089.58	2381.25
CSP10CB	2039.58	2368.75
CSP15CB	2002.08	2350.00

3.2 Water absorption

Table 3 show the outcome in water absorption analysis for each specimen. CCB indicates the highest water absorption percentages on 7 and 28 days respectively. It is because of the existing microstructure pore in CCB is higher. According to Zhang et al. [23], rate of absorption and liquid transportation attribute to the porous materials and permeability. Thus, high permeability materials will be giving high rate of absorption.

Based on Fig. 3, the histogram shows that cement brick with replacement of CSP giving low percentages of water absorption compared to CCB. Even though, water absorption was increased proportionally with the increment percentage of CSP used. However, it absorption percentages are below from control sample (CCB). Overall, the lowest water absorption was cement bricks with 5% of cockle shell powder (CSP5CB) used. Seashell such as cockle shell is one of materials that are potentially act as filler materials due to high amount of $CaCO_3$ other than limestone [1][7][8][24]. A study by Li & Kwan [25], application of filler materials in concrete potentially improving the depth of water ingression of water and reduce chloride permeability. Therefore, the minimum pore and voids in the cement bricks resulted in lower degree of permeability and the durability of cement brick increased as it resists to water and liquids.

Table 3 - Water absorption of bricks specimens (%)

Specimens	Curing (days)	
	7	**28**
CCB	0.88	0.59
CSP5CB	0.57	0.31
CSP10CB	0.60	0.40
CSP15CB	0.61	0.55

3.3 Compressive Strength

Result on brick specimens for 7 and 28 days are presented as in Table 4 and plotted in Fig. 4. According to data collected in this study, the compressive strength of cockle shell cement bricks was increased over curing period but decreased when the percentage of cockle shell powder increased. A similar result also was obtained from Martínez-García et al. as the percentage of seashell aggregate increases [26].

The highest compressive strength was given by the cement brick with 5% of cockle shell powder replacement. The composition of calcium carbonate in cockle shell powder had catalyze the hydration process of cement brick. The hydration process minimizes the number of air voids resulted in the increase of density and decreased the water absorption. Li and Kwan [25] states that filler materials exhibit filler effect by fully pore in concrete which will impair on it mechanical strength. The cement hydration is speed up due to the presence of calcium carbonate and its binding properties rapidly developed. Thus, as the cement brick is resistance to permeability due to the lower number of air voids, the durability also increased.

Table 4 - Compressive strength of cement bricks (N/mm^2)

Specimens	Curing (days)	
	7	**28**
CCB	36.00	44.60
CSP5CB	49.30	55.10
CSP10CB	44.90	48.30
CSP15CB	42.90	43.90

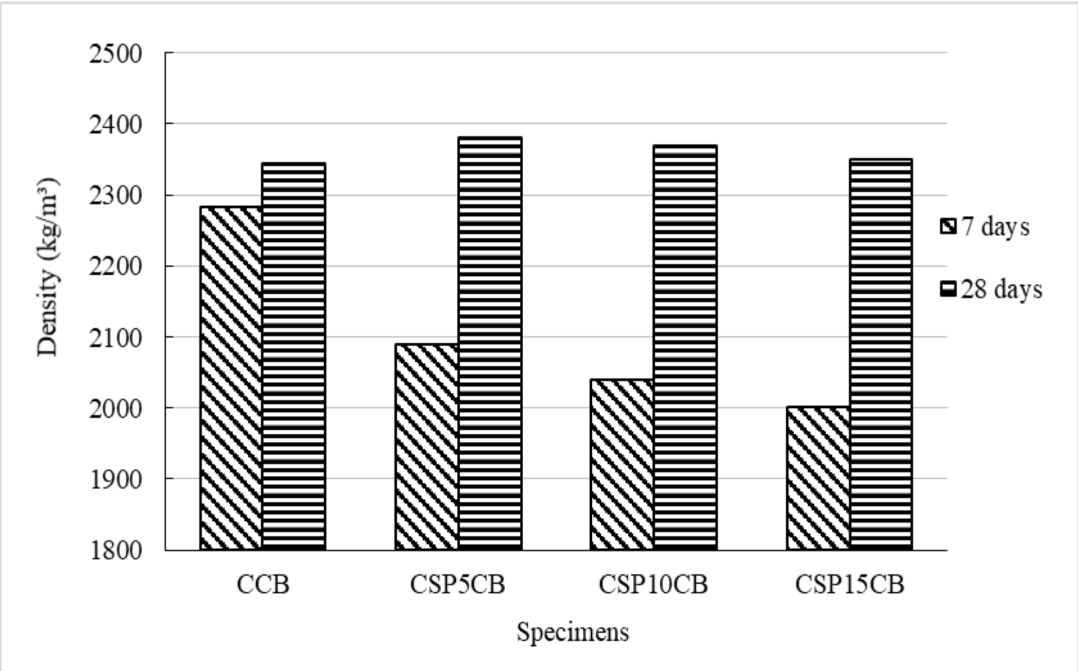

Fig. 2 - Density of cockle shell cement bricks

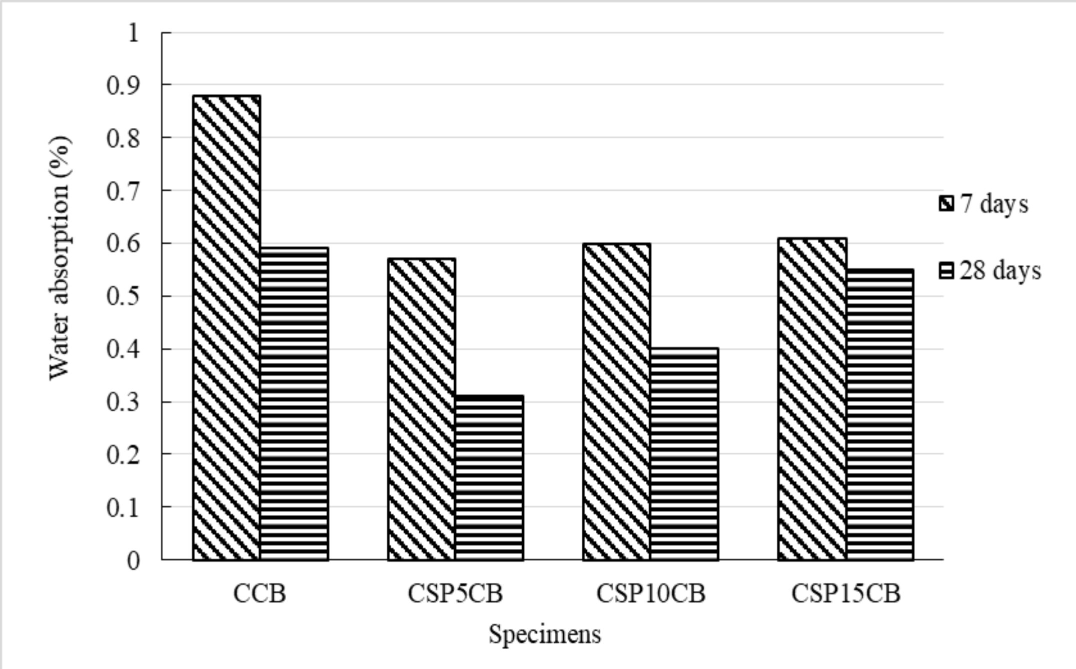

Fig. 3 - Water absorption of cockle shell cement bricks

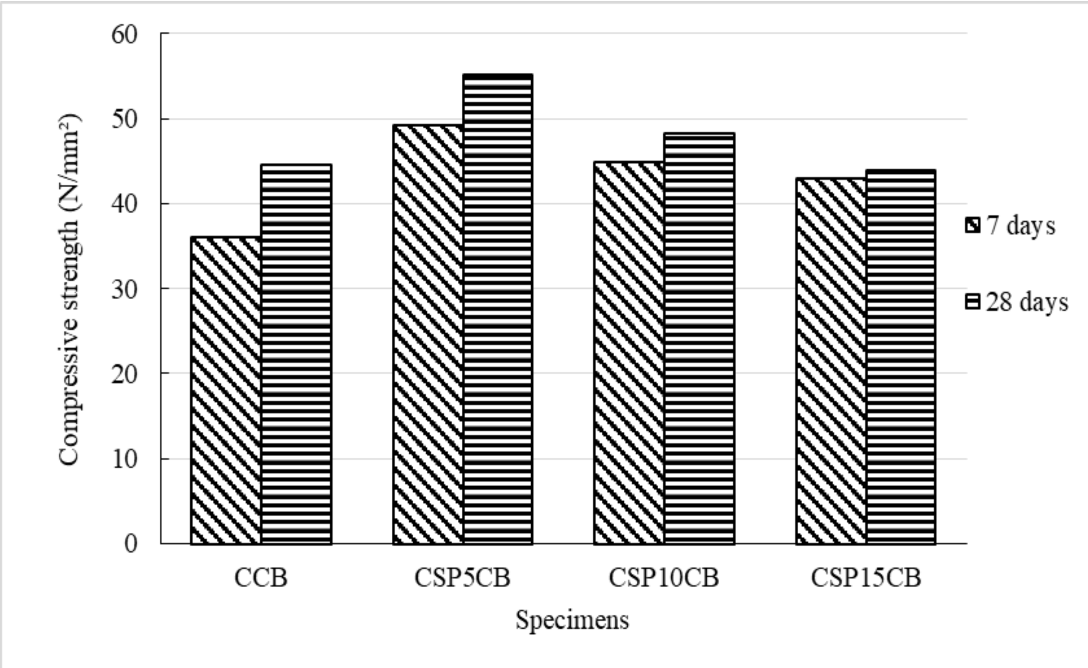

Fig. 4 - Compressive strength of cockle shell cement bricks

4. Conclusion

In this study, utilization of cockle shell in powder form as sand partial replacement (5%, 10% and 15%) in cement brick production has been observed. Material testing are included specific gravity and sieve analysis. While harden samples observed through it physical and mechanical behavior. Outcome for this study were made according to the following conclusion:

- CSP was compatible used as a partial replacement for fine aggregates. It is because the physical properties of cockle shell powder almost similar with fine aggregates. The specific gravity and fines modulus value for both materials are differ in small range. Thus, it been proved that CSP are suitable to be used as fine aggregates.

- The presence of CSP in brick potentially promoting the hydration of cement brick. According to density analysis, density of cement with CSP are higher compared to CCB. Density effect are very relatable to the hydration of cement to crystalize. Furthermore, filler properties of CSP also might resulting high density value which resulting more compacted specimens.
- Based on previous study, CSP is a materials that consist major amount of $CaCO_3$. Compressive strength of cockle shell cement bricks were increased due to the hydration process. The calcium carbonate in CSP catalyze the hydration process and minimize the size of air voids in cockle shell cement bricks. Due to lesser in void quantity, it cause less ingression and absorption rate of water in to specimens.
- Overall, CSP5CB resulting the highest density, compressive strength and low water absorption. Replacement percentages of 5% CSP are suitable in improving properties of cement bricks thus indicates it as the optimum percentages that suitable to be used in cement brick design.

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