

The Study of the Strength of Eco-Bricks Containing Cockle Shell as Substitution Material

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Abstract

To significantly reduce environmental pollution and waste, it is necessary to find a substitute for cement. Cockle shells are found to have advantages as a substitute for cement in the construction of cement bricks because they are a renewable energy source and an environmentally friendly material. This study was conducted to examine the use of cockle shell powder (CSP) as a substitute for Ordinary Portland Cement (OPC) in the production of cement sand bricks (CSB). The percentage of CSP used as a cement substitute was 10%, 20%, and 30% of the cement composition, and it was cured for 7 and 28 days. The objective of this study is to optimize compressive strength and the optimal water absorption of cockle shell and to determine the initial absorption rate of bricks with different percentages of cockle shell waste as a substitute for cement. Compressive strength tests were conducted at 7 days and 28 days of age, while water absorption and the initial absorption rate were conducted at 28 days of curing. At the end of this study, CSP20 at the ages of 7 and 28 had the highest compressive strengths of 8.12 N/mm² and 9.22 N/mm². While CSP20 also has the highest value for water absorption, which is 14.49%. Then, the highest value for the initial absorption rate is CSP10 with 151.79 g/min/193.55 cm². Overall, the CSB samples produced in this study comply with and exceed the established standards, making them suitable for use in the construction industry in Malaysia.

1. Introduction

In the construction sector, cement bricks, also known as concrete bricks, have been the main building material for centuries. Cement bricks are a type of brick that is often used in various types of development in Malaysia (Afif, *et al.*, 2019). It is considered Malaysia's major productive industry, with a continually rising demand. At the same time, the need to produce brick cement materials also increased. During the cement manufacturing process, the CO₂ produced from cement is extremely harmful to the environment. According to estimates, the annual global cement production of 2 billion metric tons contributes around 1.65 billion metric tons of CO₂ to the atmosphere, or approximately 8% of the total greenhouse gas emissions (Naik, 2005).

Nowadays, many studies have been conducted to limit the use of OPC in concrete. The purpose is to reduce dependence on raw materials such as cement because obtaining natural resource materials is limited to producing bricks. Malaysia and can reduce the problem of environmental pollution (Ismail & Khalid, 2022). Utilizing cockle shell as a cement substitution in cement bricks is one example of an effort in this course. In the past, (Lertwattanaruk, *et al.*, 2012) had done studies using CSP as a cement replacement for CSB. Cockles shell, also known as bivalve molluscs, are common in Malaysia. In Malaysia, this species is highly desired by both suppliers and consumers (Sainudin, *et al.*, 2020). Cockle shell contains 90% calcium carbonate (CaCO_3) (Bakh, *et al.*, 2017). Cockle shells have a significant potential for application as a partial cement substitution in concrete. The limestone used in the production of Portland cement contains similar amounts of calcium carbonate.

According to a study that was conducted by (Shahidan, *et al.*, 2019), the use of cockle shell as a cement substitution in a concrete mixture increased the quality of the concrete. It was discovered that adding ash from CSP to concrete results in comparing concrete with shell ash to concrete without; there are differences in increased setting time, durability, compressive strength, and a lower rate of capillary water absorption (Sainudin, *et al.*, 2020). Cement bricks with a presence of calcium carbonate (CaCO_3) are more durable and exhibit fewer signs of disintegration. The CaCO_3 compound that has been integrated into the brick could have the potential to serve as a binder and filler material in the process of filling the microstructure pores (Sainudin, *et al.*, 2020). According to past research, increases in the percentage of CSW have led to an increase in compressive strength compared to cement bricks that have 0% cockle shell and have the lowest compressive strength value. It can be concluded that the presence of CS as a partial cement substitution for cement bricks leads to the composition of calcium carbonate in the CSW, which catalyses the process of compressive strength in cement bricks. The increase in cockle shell will lead to a reduction in water absorption and an increase in density due to the hydration process, which reduces the number of air voids on the cement brick and has a small percentage increase in cockle shell. Through previous studies, the mechanical strength of brick is affected because it is affected by the filler material's effect on the cement brick (Kwan & Li, 2015).

The aim of this study is to optimize the compressive strength and optimal water absorption of cockle shell and to determine the initial absorption rate of bricks with different percentages of cockle shell waste as a substitute for cement. The uses of CSP as cement replacement are 10%, 20%, and 30%. All bricks were cured for 7 and 28 days. This study was focused on the strength of eco-brick containing CSP as a substitution material for partial cement substitution, which would reduce the significant reliance on natural aggregate supply and contribute to the preservation of a safe environment for future generations.

2. Materials Preparation and Laboratory Testing

This methodology focuses on preparation of materials such as OPC, CS and sand, cement brick design mix, casting process, curing procedure and testing method.

2.1 Materials

Materials used to produce sustainable eco-bricks or cement bricks containing cockle shells as substitutes for the use of ordinary Portland cement (OPC), sand, different percentages of cockle shell, and water cement. For this study, the ratio of materials used is cement-sand 1:6 and water-cement 0.5. The ratio used to mix the samples is 1:6, which means 1 ratio of cement to 6 ratios of sand. The targeted density of brick is 2000 kg/m^3 . The total weight of the material is used to produce the value of the control sample.

2.1.1 Ordinary Portland Cement (OPC)

The production of cement bricks is achieved through the use of Ordinary Portland Cement (OPC) in this study. Materials OPC is provided at E17 in UTHM FKAAB's Concrete Laboratory. OPC is the one of the major materials that was replaced with different percentages of CSP. The specification for OPC is the MS EN 197-1:2007 CEM I 52.5N of the Malaysia standard. The classification and types OPC according to ASTM C150 of type 1.

2.1.2 Sand

Sand is utilized as a fine aggregate in the production of cement sand-brick in this study. The material of sand is an essential component in the production of cement sand-bricks. Sand is provided at E17 in UTHM FKAAB's Concrete Laboratory. Sand was sieved to obtain fineness of 200 microns per meter.

2.1.3 Cockle Shell Powder

The cockle shells were collected from the beach near Parit Raja. Before this material is mixed into the cement brick mixture, the CSW is crushed to produce shell ash, and then The CS is dried in an oven at 105°C for 2 hours during a drying process. After that, the CS is sieved to obtain cockle shell powder (CSP) with a fineness of 75 microns per

meter. The percentages of cockle shell replacing cement are 10%, 20%, and 30% by weight as a total. Table 1 shows the cement sand-brick proportion for 1 sample.

Table 1 Cement sand-brick proportions

| Type of Sample | Percentage of CSP % | W/C Ratio | Sand (kg) | Water (kg) | Cement (kg) | CSP (kg) |
|----------------|---------------------|-----------|-----------|------------|-------------|----------|
| CSP0 | 0 | 0.5 | 0.306 | 0.025 | 0.051 | 0 |
| CSP10 | 10 | 0.5 | 0.306 | 0.025 | 0.0459 | 0.0051 |
| CSP20 | 20 | 0.5 | 0.306 | 0.025 | 0.0408 | 0.0102 |
| CSP30 | 30 | 0.5 | 0.306 | 0.025 | 0.0357 | 0.0153 |

2.2 Sample Preparation

Fig. 1 shows the process flow of making cement sand-bricks with the cockle shell powder mixture at E17 in UTHM FKAAB's Concrete Laboratory. This section focuses on the initial preparation of materials for the processing of cockle shell powder, followed by the mixture of cement brick design, casting process, and curing procedure using curing water conditions.



Fig. 1 Flow Chart of Cement sand-brick process

2.3 Laboratory Testing

A total of 48 specimens were made using brick cube moulds. The required dimensions are 107.5mm x 51.5mm x 32.5mm. This study used percentages of 10%, 20%, and 30% CSP as partial cement replacement in CSB. The laboratory tests were conducted on the samples when the brick samples had passed 7 and 28 days of the curing process.

2.3.1 Compressive Strength

Compressive strength is defined as the ability of a material to withstand the direct pressure of an applied compressive force. The standard for brick CS testing is BS EN 12390-3:2009. The test was performed on a total of 24 CSB samples that included control samples, 10% CSP, 20% CSP, and 30% CSP of brick samples produced at E17 in UTHM FKAAB's Concrete Laboratory. Tests were conducted for sample periods of 7 and 28 days. Cement sand-brick samples are placed on a steel plate. The axial load should be applied at a uniform rate of 14 N/mm² (140 kg/cm²) per minute until failure occurs and the maximum load should be recorded when it does. When the specimen fails, the maximum load it can take is called the load at failure. Then, a compression machine was used to determine compressive strength. Average three cement sand-brick compressive strengths for each mixed design. Then, compressive strength was calculated from the following equation:

$$\text{Compressive Strength} = \frac{\text{Maximum load (N)}}{\text{Surface area of Specimen (mm}^2\text{)}} \quad (1)$$

2.3.2 Water Absorption

Water absorption tests are conducted to determine the moisture absorbed by the brick. This test is also effective in measuring the compactness of bricks because water is absorbed by the porous nature of the brick, and the amount of water absorbed by the brick increases as the number of pores increases. The WA test for specimens was carried out according to the BS 1881:122 series. Tests were conducted for sample periods of 28 days of curing. Then dry the brick specimen to a constant mass at 105 °C for 24 hours, then weigh the dry brick (W1) after the brick comes out of the oven. For 24 hours, the bricks are immersed in cold water at room temperature. After a period of 24 hours, the wet brick weight (W2) is recorded. Then, water absorption was calculated from the following equation:

$$\text{Percentage of Water Absorption} = \frac{(W2 - W1)}{W1} \times 100\% \quad (2)$$

Where, W1 is weight of Dry brick and W2 is weight of Wet brick.

2.3.3 Initial Rate Absorption

Initial Rate Absorption (IRA) test is to determine the amount of water that can be absorbed by each brick unit after being soaked in 5 mm of water for 1 minute. In the laying process, the IRA will demonstrate the amount of water the brick absorbs when it is exposed to mortar. The IRA test was carried out in compliance with ASTM-C67-11 at the CSB, which has finished the curing process after 28 days.

$$\text{Initial Rate Absorption} = \frac{(193.55)(W2 (g) - W1 (g))}{\text{Area bed face (cm}^2\text{)}} \quad (3)$$

Where, W1 is weight of Dry brick and W2 is weight of Wet brick.

3. Results and Discussion

In this chapter, the results of the compressive strength test, water absorption test, and initial rate absorption test were discussed. The results were analysed to obtain the optimum percentage of CSP as partial cement replacement in CSB.

3.1 Compressive Strength Test

The compressive strength data presented in Fig. 2, the average compressive strength of the CSP0 control sample after 7 and 28 days of curing was 7.92 N/mm² and 11.49 N/mm², respectively. The value of compressive strength at 7 days after curing increased with the increase in the amount of CSP in the CSB mixture. CSP10 has a lower compressive strength than the control sample, with a value of 5.45 N/mm². The compressive strength started to increase at CSP20 and then decreased at CSP30, where the corresponding values were 8.12 N/mm² and 6.12 N/mm². This is due to CSP contains smaller particles and fills the voids between the cement particles in CSB. In addition, the CS value of CSB at the age of 28 days after curing increased with the increase in the amount of CSP in the CSB mixture. The histogram graph shows an increasing trend for CSP10 and CSP20 with 8.63 N/mm² and 9.22 N/mm², respectively. CSP30 as a partial cement replacement for CSB observed a decrease in CSP's compressive strength after 28 days by 9.03 N/mm². In conclusion, the optimal result of compressive strength for 7 and 28 days

of curing is CSP20, where each obtained the highest value at 7 and 28 days. However, the value they possess is still less than the compressive strength of CSP0.

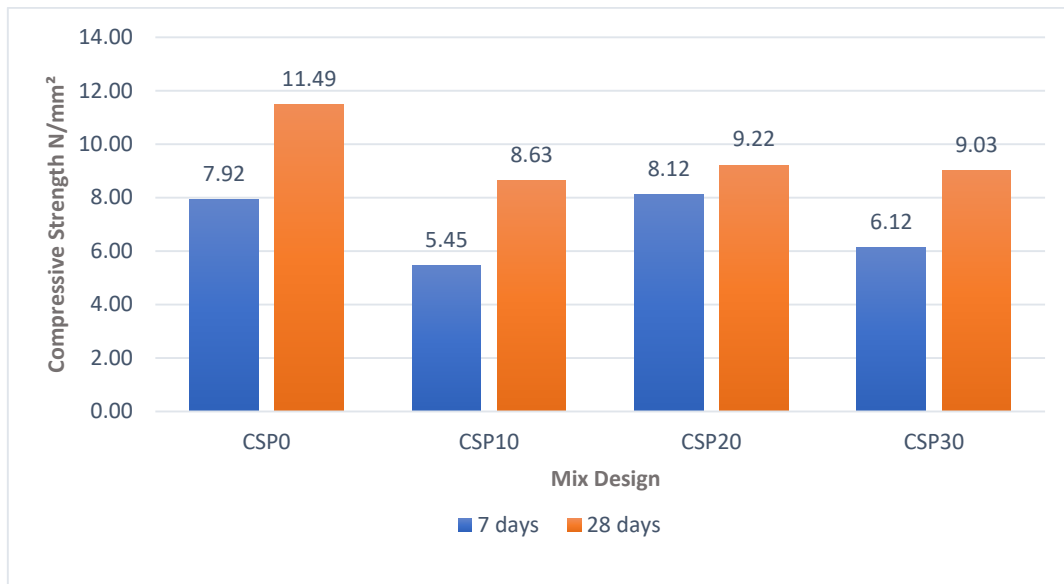


Fig. 2 The average compressive strength for 7 and 28 days

The compressive strength value of the CSB increased during the over curing period as shown in Table 2. The compressive value of CSP0 for CSB samples after 28 days increased by 45.07% compared to CSB samples that had been preserved for 7 days. The higher the addition of CSP to the CSB, the lower the percentage increased in compressive strength. This can be related to the fact that the control samples are higher than the other mixed designs because, naturally, the chemical properties of cement have their own strength through their properties compared to CSP, even though Cockle Shell contains 90% calcium carbonate (CaCO₃). The limestone used in the production of Portland cement contains similar amounts of calcium carbonate (Bakh et al., 2017). But overall, it still cannot match the strength of the original cement chemical properties. The CS values of samples CSP10 and CSP20 decreased by 58.34%, and 13.54% respectively. The percentage value of compressive strength CSP30 experienced an increase of 47.54%. According to the (Othman, *et al.*, 2013), it can be concluded that the calcium carbonate content of CSP, which catalyzes the hydration process in the CSB samples, results from the use of CSP as a partial cement substitute for CSB. Finally, although there are samples whose compressive strength value is above CSP0, it still exceeds the minimum requirement of compressive strength of 3.45 N/mm² for individual unit bricks and 4.41 N/mm² for average of three-unit bricks (Civil, 2021).

Table 2 The Compressive strength of CSB samples

| Type of Sample | 7 Days (N/mm ²) | 28 Days (N/mm ²) | Differences % |
|----------------|-----------------------------|------------------------------|---------------|
| CSP0 | 7.92 | 11.49 | 45.07 |
| CSP10 | 5.45 | 8.63 | 58.34 |
| CSP20 | 8.12 | 9.22 | 13.54 |
| CSP30 | 6.12 | 9.03 | 47.54 |

3.2 Water Absorption

The use of CSP as a partial substitute for cement causes a decrease in water absorption percentage. Fig. 3 shows that CSP0 or control sample has the highest percentage water absorption after 28 days curing age with a value of 14.88%. This is because CSP0 already has microstructural pores that have higher chemical properties of OPC. The histogram graph shows that CSB with CSP replacement has a lower percentage of WA compared to CSP0. With the addition of CSP in cement, CSP10 has a higher value than CSP20, CSP30 but still below the control sample value. Increasing the percentage of CSP as a cement partial replacement in CSB results in a decrease in the percentage WA for CSP 10 and CSP 20, where the values are 14.49% and 11.68%, respectively. However, for CSP 30 there is a slight increase in the percentage water absorption, with a percentage value of 12.78%. According to the (Kwan

& Li, 2015), reduction of WA and increase in density due to the hydration process, which reduces the number of air voids on the CSB and has a small percentage increase in cockle shell. CSP can act as a filler. It fills the voids between the cement particles in the CSB and increases its compactness. Therefore, WA decreases when CSP is replaced with cement, and it is influenced by the CSP filler that fills the voids in CSB.

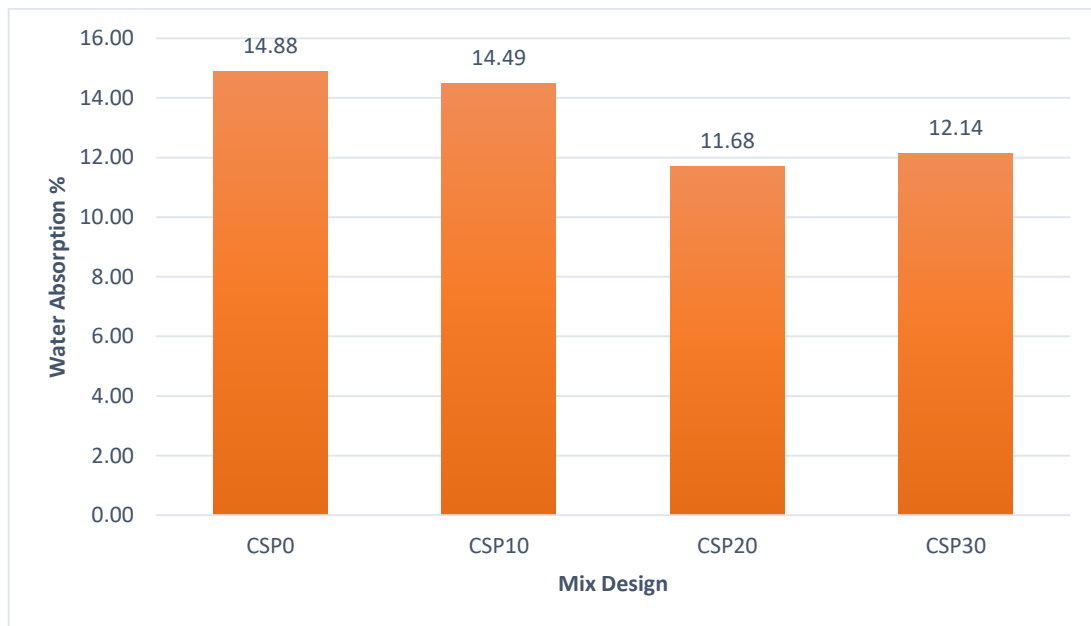


Fig. 3 The water absorption versus mix design

3.3 Initial Rate Absorption

The Fig. 4 illustrates the initial absorption rate of CSB samples with various mix designs after 28 days of curing. According to the collected data, the additional CSP in CSB leads to a decrease in the value of the IRA. CSP0 has an IRA value of 132.11 g/min/193.55 cm². CSP10 has the highest IRA value for absorption rate with 151.79 g/min/193.55cm². CSP20 as a partial replacement of cement for CSB showed a reduction in the initial absorption rate of CSP at 28 days by 128.66 g/min/193.55cm². Then it slightly increases the moisture absorption rate for CSP30 with 130.69 g/min/193.55cm². CSP10 and CSP30 have a higher IRA than the CSP0. In this case, the voids found between cement particles have been filled by CSP particles which reduce more water to pass through CSB. material bond between CSB and mortar is significantly influenced by IRA of CSB. This correlation shows that CSB with a higher IRA value, is allowing CSB to absorb water at a faster rate. The bonding of the particles between bricks and mortar is positively influenced by the IRA of the bricks. The higher IRA means the mortar absorbs moisture faster, resulting in a weaker bond in the bricks (Aesline & Sarani, 2020). It can conclude that with the addition of CSP in bricks can absorb water faster than OPC.

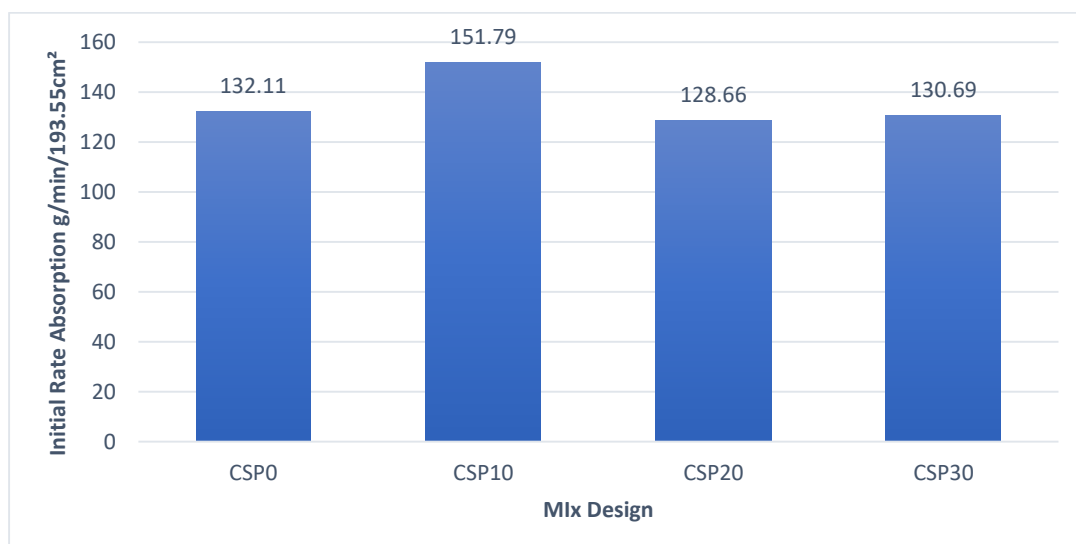


Fig. 4 Initial Rate Absorption versus Mix Design

4. Conclusion

In conclusion, it can be concluded that added cockle shell waste in CSB has the potential to change and improve the chemical properties and characteristics of cement in the CSB mixture. From the test results, the objective of the study is to be achieved. The first objective of this study is to optimize the compressive strength and optimal water absorption of cockle shells. The optimal result of compressive strength for 7 and 28 days was CSP20, where each obtained the highest value at 7 and 28 days and exceeded the compressive strength of the control sample at 28 days of curing. In the water absorption test, CSP20 showed the lowest value compared to the control sample at 28 days. Therefore, the lower the water absorption, the higher the performance of CSB. Next is the second objective, which is to determine the initial absorption rate of bricks with different percentages of shell waste as a replacement for cement. According to the results, CSP20 showed the lowest initial absorption rate value at 28 days and got a lower value than CSP0. CSP is a small particle that acts as a filler, which fills the voids found in CSB, so it tends to absorb water more slowly. In general, a low IRA value will increase the bonding between particles in CSB. Therefore, 20% of CSP is suitable to be the optimal percentage as a partial replacement of cement in CSB.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

This journal requires that all authors take public responsibility for the content of the work submitted for review. The contributions of all authors must be described in the following manner:

*The authors confirm contribution to the paper as follows: **study conception and design:** Azlan and Yassin; **data collection:** Azlan; **analysis and interpretation of results:** Azlan, Yassin; **draft manuscript preparation:** Azlan, Yassin. All authors reviewed the results and approved the final version of the manuscript.*

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