IOP Conference Series: Materials Science and Engineering

PAPER • **OPEN ACCESS**

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To cite this article: A S Leman *et al* 2017 *IOP Conf. Ser.: Mater. Sci. Eng.* **271** 012007

Durability of coconut shell powder (CSP) concrete

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Abstract. The rising cost of construction in developing countries like Malaysia has led concrete experts to explore alternative materials such as coconut shells which are renewable and possess high potential to be used as construction material. Coconut shell powder in varying percentages of1%, 3% and 5% was used as filler material in concrete grade 30 and evaluated after a curing period of 7 days and 28days respectively. Compressive strength, water absorption and carbonation tests were conducted to evaluate the strength and durability of CSP concrete in comparison with normal concrete. The test results revealed that 1%, 3% and 5% of CSP concrete achieved a compressive strength of 47.65MPa, 45.6MPa and 40.55% respectively. The rate of water absorption of CSP concrete was recorded as 3.21%, 2.47%, and 2.73% for 1%, 3% and 5% of CSP concrete respectively. Although CSP contained a carbon composition of 47%, the carbonation test showed that CSP no signs of carbon were detected inside the concrete. To conclude, CSP offers great prospects as it demonstrated relatively high durability as a construction material.

1. Introduction

The use of fillers in concrete is common in the construction industry nowadays. In many developing countries, concrete mixes which contain no fillers tend to be an exception. Fillers can be quite costly. That is the main reason why it is so important to explore alternatives in order to reduce the cost of fillers. On the other hand, waste generated by industrial and agricultural processes has created disposal and management problems which threaten the conservation of the environment [1-2]. Hence, using waste materials as a filler in concrete not only helps in reducing disposal and management problems, but also helps in protecting the environment from possible effects of pollution [3].

Malaysia was among the top coconut producers in the world back in 2005 [4-6]. Coconut trees are also famous as all parts of the tree can be used in multiple ways. After the coconut flesh is scraped out, the shell is usually discarded as waste. Due to the increasing production of agricultural waste, researchers have attempted to use coconut shells as filler material in concrete. Previous studies have shown that by using coconut shells as filler material, a lightweight concrete can be produced. As time passes, concrete structures tend to deteriorate when they come into contact with carbolic acid especially for buildings in the city where vehicles release carbon dioxide which reacts with water and form carbolic acid. Thus, the demand for high durability concrete is growing. In this paper, concrete which contain filler material in the form of coconut shell powder is tested in terms of durability to

IOP Conf. Series: Materials Science and Engineering **271** (2017) 012007 doi:10.1088/1757-899X/271/1/012007

meet the demand of highly durable concrete. In order to conserve the environment, it is vital to solve the problem of the excessive production of agricultural waste.

In a nut shell, reduction of cost in terms of transportation [7-8], improved landfill management [9] and higher durability in concrete are among the benefits of using coconut shell as s filler material in concrete mix design. Many studies have been carried out are using coconut shell as a partial replacement for cement or aggregates. Therefore, this study mainly emphasizes on the durability of coconut shell powder (CSP) concrete in comparison with normal concrete.

2. Coconut shell powder properties

Coconut shell in the form of powder was sourced from a local coconut miller. It is a light brown material which has a bulk density of 0.7gcm-3 [10]. Also, coconut shells are found to have varying thickness between 2-8 mm and have an approximate density value of 1.60g/cm^3 [11]. Also, previous studies have shown that coconut shell in the form of powder has a complex structure [10]. A wide range of particle sizes with a mean value of 34.2 microns was observed. Results from the scanning electron micrograph revealed under a magnification of 300 showed a range of shapes and sizes from very small pebble-shaped particles to much larger particles measuring 75 microns which have a distinctly uneven rough surface and irregular shape.

3. Material and laboratory work

Basically, concrete is made up of Portland cement, aggregates and water. In this study, CSP was added into the concrete mix as a filler material by the percentage of volume of 0%, 1%, 3% and 5%. The total number of samples used in this experiment was54samples.

3.1. Material preparation

The coconut shells were crushed using a machine. The size of the coconut shells used was about the same as coarse aggregates which measured about 20mm. Next, the coconut shells were grounded until a fine powder was obtained. Now, the size of the coconut shell powder was about the same as the size of cement particles. After that, the coconut shell powder was sieved again to separate fiber-like material from the powder.

(a) (b) (c)

Figure 1.(a) Coconut shell, (b) grinding process of coconut shell, and (c) coconut shell powder.

3.2. Laboratory work

3.2.1. Compressive strength test. Concrete cubes measuring 100 mm x 100 mm x 100 mm according to ASTM C 192 standards were used. All concrete cubes were cured for a period of 7 days and 28days respectively.

3.2.2. Water absorption test. The water absorption test was conducted according to BS 1881: Part 122. 15 samples were weighed and placed inside an oven for 24hours at 105^{0}C. Next, the specimens were submerged in a tank full of water provided at the lab for another 24hours as shown in figure 2. After that, the specimens were taken out and weighed once again after the surface water was removed. The percentage of water absorption was calculated as according to equation 1

$$\text{Water Absorption (\%)} = \frac{m2-m1}{m1}\ x\ 100\% \quad (1)$$

Where:

m_1 = the dry weight of concrete sample (kg)
m_2 = the wet weight of concrete sample (kg)

Figure 2. Water absorption process.

3.2.3. Carbonation test. This test based on EN 14630:2006 (E) was carried out to determine the depth of concrete affected due to the combined attack of atmosphere, carbon dioxide and moisture causing a reduction in the level of alkalinity of concrete. A solution of 0.2% phenolphthalein was used as the pH indicator of concrete. Figure 3 shows the phenolphthalein solution used.

Figure 3. Phenolphthalein solution.

4. Results and discussion

4.1. Compressive strength

The compressive strength development of concrete is shown in figure 4. Normal concrete has an average compressive strength of 42.3Mpa after a curing period of 28days. Meanwhile, concrete that contained 1% of CSP achieved a compressive strength of 47.65MPa while concrete containing 3% and 5% of CSP achieved a compressive strength of 45.6MPa and 40.55MPa. This result was good as all specimens achieved a compressive strength above the minimum strength of grade 30 concrete. Furthermore, 1% and 3% of CSP concrete displayed higher compressive strength compared to normal concrete. Unfortunately, 5% CSP concrete recorded a value lower than normal concrete. However, the value was still higher than the minimum grade strength. It is clear that 5% of CSP was not suitable as it reduces the strength of concrete.

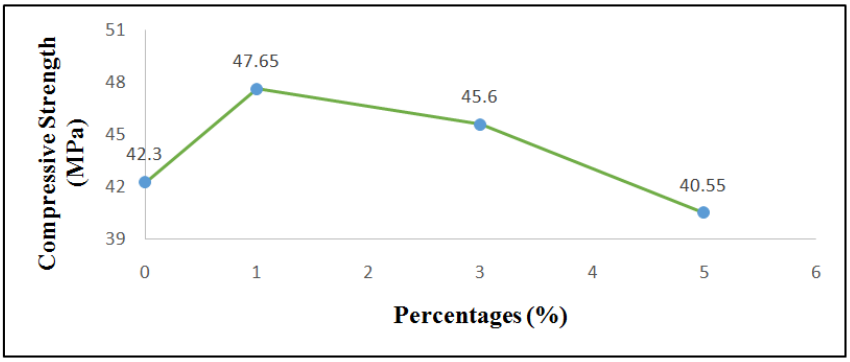


Figure 4. Compressive strength varies with percentages of CSP used.

The results on concrete density are shown in figure 5. Concrete with 1% of CSP had the highest density at 2500kg/m^{3}while concrete containing 3% of CSP achieved a density of 2470kg/m^3.Concrete with 5% of CSP had the lowest density of 2350 kg/m^3 compared to normal concrete which had a density of 2430kg/m^3. The data recorded in this study is related to a previous study which stated that if the density of concrete is lower, it will cause the strength of concrete to decrease [1].

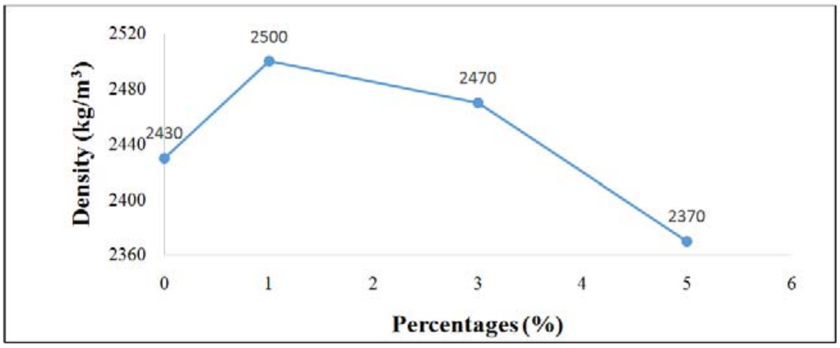


Figure 5. Density versus percentages of CSP.

4.2. Water absorption test

The results of the water absorption test are shown in figure 6. The highest water absorption was achieved by normal concrete (4.46), followed by concrete containing 1% of CSP (3.21). Concrete containing 3% of CSP had the lowest water absorption whereas the second lowest water absorption was achieved by concrete containing 5% of CSP. This shows that using CSP as a filler material in concrete is a good decision as it controls the ability of concrete to resist water absorption. Moreover, the control sample had the weakest rate of water absorption hence the use of CSP may improve the rate of water absorption of concrete.

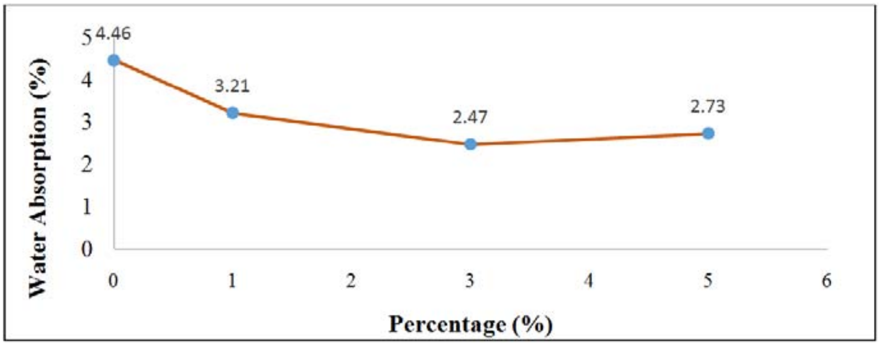
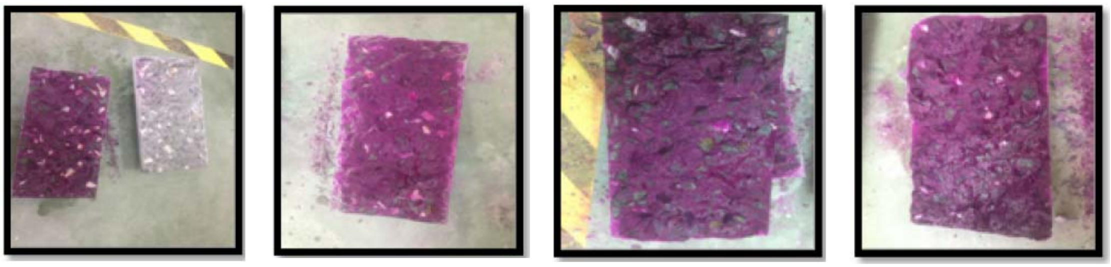


Figure 6. Different percentages of CSP in concrete vs water absorption rate.

4.3. Carbonation test

After a curing period of 28 days, the concrete was left at the lab for 60 days. The carbonation test results are shown in figures 7(a)-(d).



(a) (b) (c) (d)

Figure 7. (a) 0% after 60days, (b) 1% of CSP after 60days, (c) 3% of CSP after 60days, (d) 5% of CSP after 60 days.

The colour purple shows that there is no carbonation detected inside the concrete. The average depth for all samples was 1mm. This shows that 1%, 3% and 5% of CSP concrete are able to resist carbonation. This results also proved that although CSP itself contained47% of carbon[8], it is able to blend and produce good concrete that can resist carbonation attacks.

4.4. Relationship between compressive strength, density and percentage of CSP

Results in figure 8 show the relationship between compressive strength, density and concrete added with different percentages of CSP. Concrete containing 1% of coconut shell powder had the highest density. This proves that coconut shell powder plays its role as a filler in concrete hence increasing the strength as well as the density of the concrete. Meanwhile, as the percentage of CSP increases, the compressive strength and density of CSP concrete will decrease. Hence, adding more than 1% of coconut shell powder to a concrete mixture is not suitable as it causes concrete to lose its strength as well as its density.

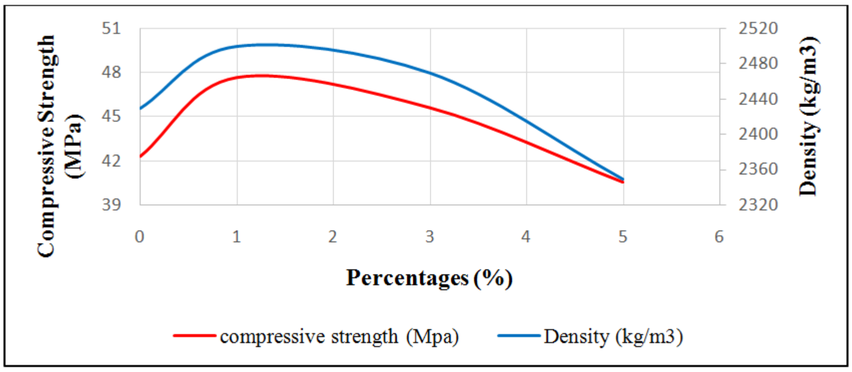


Figure 8. Relationship between compressive strength, density and percentages of CSP.

4.5. Relationship between compressive strength, water absorption and percentages

Figure 9 shows the relationship between compressive strength and water absorption which varies with different percentages of CSP in concrete. Again, 3% of CSP has been found to be optimal for obtaining concrete with high strength and low water absorption ability. The increase in water absorption maybe due to the development of micro cracks in the weak transition zone at an early stage which may reduce the strength of the concrete.

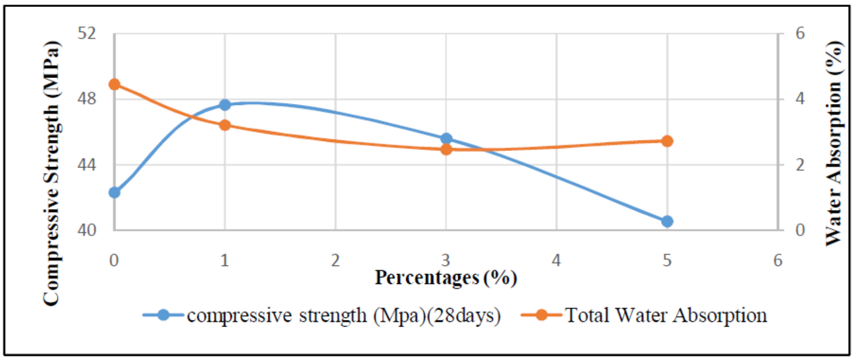


Figure 9. Relationship between compressive strength, water absorption and different percentages of CSP added to concrete.

5. Conclusion

Concrete added with CSP produce good durability and results from the water absorption test show that concrete added with CSP also can resist water absorption which proves its suitability to be used as an admixture. Also, 3% of CSP concrete has been shown to be better than normal concrete because of its relatively high compressive strength. On the other hand, the correlation between strength and durability of concrete was demonstrated by 3% of CSP concrete which has been found to be optimal for obtaining higher strength and durability. All in all, further studies on the durability of CSP concrete must be conducted as CSP has the potential to be used as filler material in concrete.

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Acknowledgments
The authors would like to thank Universiti Tun Hussein Onn Malaysia for theGPPS U449 grant as well as Vot U523.The authors are also grateful for the funds granted by theMinistry of Higher Education (MOHE) (MyPhD) which made this research possible.