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Application of peanut biochar as admixture in cement mortar

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Abstract. Nowadays, waste problem has become critical because of the increasing of population, so how to manage them is an important issue. Due to high content of carbon in daily waste, some researchers pyrolyzed these materials to make biochar which can be used in many fields. In civil engineering filed, concrete has become the main material used to build most of buildings, due to its excellent performance and low cost. As the main component of concrete, the using of mortar cement is a large number. Thus, this study aimed to research some information about peanut biochar which were from normal daily waste and measure some parameters about peanut biochar, then explored the feasibility of replacing part of mortar cement by peanut biochar.
This study researched different percentage mixing of peanut biochar (1%,3%) in cement mortar and measured some properties such as compressive strength to check the feasibility of using biochar in cement mortar under water curing. In these tests, mixing peanut biochar also can improve the 7-day and 28-day density of cement mortar. Meanwhile, 1% and 3% addition of peanut biochar in cement mortar does not perform an obvious improvement in 7-day compress strength, but a slight increase happens in 28-day compressive strength about these two different percentage of mixing. From these results, peanut biochar can be a replacement to mix into mortar cement.

1. Introduction
In recent years, global warming has become a severe problem and an important cause is the huge number emission of green-house gases. Due to the development of infrastructure, the demand of mortar cement also increases. However, the increasing usage of cement will release more emissions of green-house gases. One research showed that the cement industry may discharge around 1.8Gt of CO2 emissions in the world that occupied 5%-7% of the total CO2 generation [1]. Therefore, more and more researches have been started to explore the replacement of cement by biochar. According to Tommaso and Bordonzotti [2], if 1% of biochar can be mixed into cement, it can decrease 0.5Gt of CO2 emissions which took over 20% of CO2 emissions released by concrete industry. It is reported that biochar can reduce greenhouse gas emission by 870KG-CO2, 62%-66% of which is contributed by the carbon stored in the biochar [3]. Green cement mortar made by biochar reported to exhibit improvement in physical properties compared to control samples [4]. 5% weight of cement replaced by hardwood biochar can enhance the compressive strength of mortar by around 10% [4]. The past study showed that the biochar made from food and wood waste can improve ductility and water tightness of cementitious composites[5][6].Thus, biochar can be a suitable material to replace cement partly which can reduce the amount of CO2 emissions and the burden of waste disposal.

2. Methodology

2.1. Peanut biochar waste

The experimental material was peanuts shell that was collected from a food business in Sydney. As a part of food waste, the content of peanuts shell is rich in lignin (25%-30%). High content of lignin can offer more carbon and micro-porosity of biochar during the pyrolysis.

2.2. Experimental procedure of peanut biochar

1.Before experiment, peanuts wastes were grinded into small piece to keep the sufficiency of pyrolysis. Then the feed stock was covered by aluminium foil and putted into a tray.

2.The pyrolysis was started in an oven and it was oxygen-free environment in this chamber. Meanwhile, the aimed temperature was 500℃ and the pyrolysis rate was 10℃ per minute. When it arrived at 500℃, the oven kept this temperature for 40 minutes.

3.After pyrolysis, the specimen was taken out by high temperature gloves and waited it to cool down. Then these pyrolyzed peanuts were placed into a grinding miller. The grinded time was 5 minutes and the rotated speed was 500 cycles per minute. Finally, the grinded biochar was stored into a sealed contained and labelled "grinded peanut biochar", that can be mixed into concrete directly. The comparison of raw peanut biochar and grinded biochar was showed in figure 1 and figure 2

Figure 1 Grinded biochar

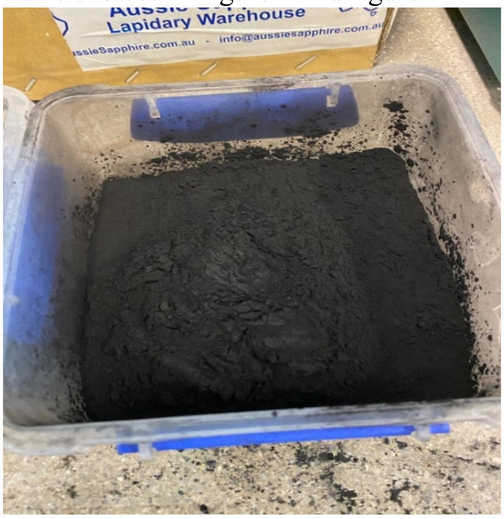

Figure 2 Raw peanut biochar

2.3. Tests of cement mortar

2.3.1. Compressive strength test

Procedure of compressive strength test [7]

1)Keep the test in a wet environment and clean the testing machine.

2)Wipe surface moisture and grit off the concrete sample

3)Set the specimens into the machine and ensure the hydraulically activated platen and upper platen satisfy experimental requirements

4)Apply the force gradually at a rate of 20MPA compressive stress per minute until no increased force can be stood.

The compressive strength is calculated by the maximum force is divided by the cross-section of area. And the area shall be the average of two diameters of cylinders.

2.3.2. Drying shrinkage test

According to AS1012.13[8], some apparatus shall be used in this test, such as dry chamber and length comparator. Two measurements shall be carried out and all the process shall be in dry chamber. At initial measurements, set the specimen in the horizontal comparator and record the length difference. Then repeating this step at least five times and use the average number of there five determinations. For vertical comparator, set the specimen into it and rotate the specimen axially until the front face is parallel

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to the face of the dial gauge. Then read the dial gauge and repeat the step at least 5 times. The next is subsequent measurements, take the length measurements for each specimen at each step and check the zero setting of the comparator as suitable.

The deviation shall be not more than 20mm and the repeatability expressed as a percentage of the mean of the set of specimens is 8% at the 95% probability level.

2.3.3. Concrete density test

The water displacement method was used to measure concrete density. Every three cubes which separately came from control samples, 1% biochar samples and 3% biochar samples were measured to keep the accuracy of results. Meanwhile, different samples under water curing and carbonation curing are also measured to compare.

Procedure of concrete density test:

1) Put the cube samples on the laboratory balance which is in the air and record the weight of these samples. Put them into the bottom balance which is in the water and record their weight.

2) The equation is used to calculate the density below:

Density (kg/m^3) = (Weight of samples in the air ×1024) / (weight in the air- weight in the water)

3. Results and analysis

3.1. Harden density of cement mortar

There is a fluctuation about cement density which is from control cement,1% and 3% biochar cement in 1-day density test. Moreover, the average density of 1% biochar is the highest than the others. However, it is average density which comes from three samples and there is a standard deviation that can not be ignored. The standard deviations of these three groups are large (28KG/M3,47KG/M3,38KG/M3), which means this fluctuation is a normal situation. Therefore, 1% and 3% biochar may not have an influence in the1-day density of cement under water curing. The 7-day and 28-day cement density is rising with the increasing of biochar content. Meanwhile, the standard deviation is small and the rising trend is significant between plain cement and 1% biochar cement. Thus, mixing biochar into cement can improve the early density of cement. One reason is that biochar has a smaller particle size than cement which can fill the pores of cement. The particle sizes of cement and biochar can be testified in particle size distribution that is showed in Figure 4. Moreover, biochar can absorb some water added during mortar mixing, which causes the reduce of evaporated water leading to creating pores in cement. As a result, carbonation curing can accelerate the speed of reaction in mortar cement which improves the early density of cement. It is same with some results from Devender and Shweta's study [9]. The accelerated carbonation curing (ACC) can reduce porosity and increase 20% of the strength for each cement sample than traditional water curing at early age stage.

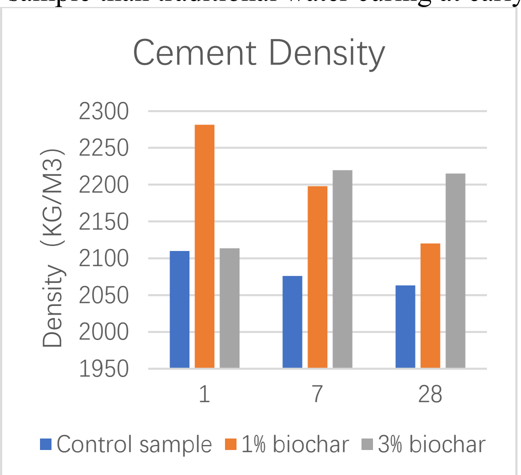

Figure 3 Density of cement mortar

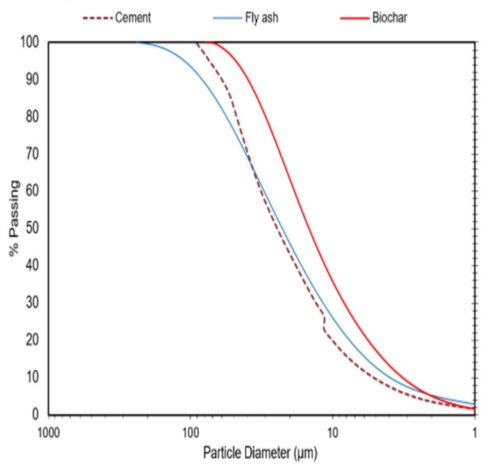

Figure 4 Particle size of materials

3.2. Compressive strength

3.2.1. 7-day compressive strength
For the accuracy of results, each different types of mixing materials used three samples to measure. Figure 5 shows the 7-day compressive strength of cement mixed different contents of peanuts biochar under water curing. At the early age curing, there is a gradual increase of compressive strength under water curing with increasing of biochar content. However, standard deviation is not ignored, because results are average numbers from three samples. From that table, the standard deviation shows that it is a normal fluctuation in the range, even if it may increase slightly. Therefore, 1% and 3% addition of biochar may not have an influence in compressive strength about mortar cement at 7-days water curing or this increasing strength is not significant.

3.2.2. 28-day compressive strength
For the accuracy of results, three samples were used to measure compressive strength and standard deviation was considered as well. From Figure 6, there is an obvious improvement of compressive strength among control samples, BC1% mixing samples and BC3% mixing samples under water curing. 1% addition of biochar can lead to 12% increase in compressive strength compared to control sample. Meanwhile, 3% addition of biochar cement shows an increase of 22% and 8.5% compared to control and 1% biochar respectively. One cause of increasing strength is the high water sorptivity and storage of biochar. During process of mixing and storing mortar cement samples, retained water can evaporate and leave many capillary pores inside which declines compressive strength. The addition of biochar can absorb part of water and this is beneficial to improve compressive strength. Besides, biochar also can fill some pores inside cement and make more pyknotic than before. Thus, higher mixing proportion of biochar can improve compressive strength.

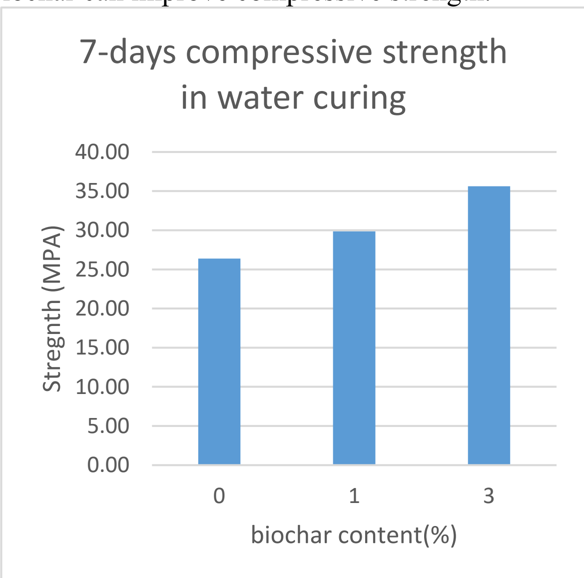

Figure 5 7-day compressive strength

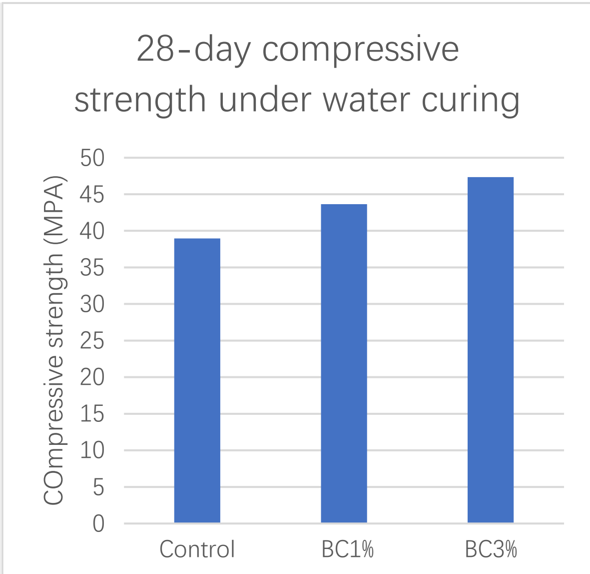

Figure 6 28-day compressive strength

3.3. Early drying shrinkage
Drying shrinkage is an important factor of mortar cement. Due to the evaporation of capillary water during the hardened process of mortar cement [10], it will lead to compaction and crack formation in cement. From Figure 7, biochar addition in mortar increased shrinkage than plain mortar about drying shrinkage. The drying shrinkage mortar with 3% biochar is the highest among these three kinds of mortar cement. This is linked to high fineness of biochar and its water absorbing property which is reported to increase drying shrinkage [11]. Besides, biochar also can not provide enough restraining effect compared to plain cement during the process of hardened mortar cement [11].

4. Conclusion

This study investigated the feasibility of utilizing biochar from peanut waste as an admixture into mortar cement. The effects of biochar in some fundamental factors of mortar cement was also explored, such as compressive strength, hardened density, drying shrinkage. The proportion of biochar in mortar cement (1%, 3%) is another part that also was considered to compare their effects. Based on the experimental results and discussion, these conclusions can be drawn:

1. 1% and 3% addition of biochar does not have obvious change in 1-day density test because of its porosity, but it increases cement density in 7-day and 28-day water curing.
2. Mixing 1% and 3% peanut biochar in mortar cement does not obviously improve 7-day compressive strength under water curing compared with reference samples. 28-day compressive strength results show that biochar can increase strength under water curing.
3. Use of biochar in biochar increases drying shrinkage and carbonation shrinkage in early stage which is a negative effect about early mixed biochar cement.

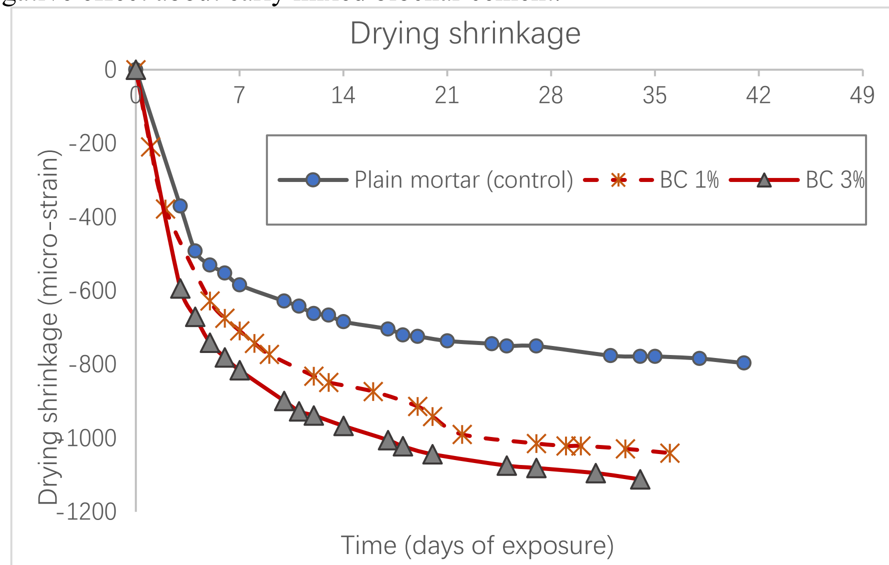

Figure 7 Drying shrinkage

Reference:

[1] T. Gao, L. Shen, M. Shen, F. Chen, L. Liu, L. Gao. (2015) Analysis on differences of carbon dioxide emission from cement production and their major determinants, J. Cleaner Prod. 103,160–170. [2] M.D. Tommaso, I. Bordonzotti. (2015) NOx Adsorption, Fire Resistance and CO2 Sequestration of High Performance, High Durability Concrete Containing Activated Carbon, Madrid

[3] Roberts, K.G., Gloy, B.A., Joseph, S., Scott, N.R., Lehmann, J. (2009) Life cycle assessment of biochar systems: estimating the energetic, economic, and climate change potential. Environ. Sci. Technol. 44 (2), 827–833.

[4] Choi, W.C., Yun, H.D., Lee, J.Y. (2012) Mechanical properties of mortar containing bio-char from pyrolysis. J. Korea Inst. Struct. Maint. Inspect. 16 (3), 67–74.

[5] Ahmad, S., Khushnood, R.A., Jagdale, P., Tulliani, J.M. and Ferro, G. A.(2015) High performance self-consolidating cementitious composites by using micro carbonized bamboo particles. *Materials & Design*, *76*, pp.223-229.

[6] Gupta, S., Kua, H.W. and Dai Pang, S. (2018) Biochar-mortar composite: Manufacturing, evaluation of physical properties and economic viability. *Construction and Building Materials*, *167*, pp.874-889.

[7]AS1012.2:2014. Australia Standard: Methods of testing concrete-Preparing concrete mixes in the laboratory. Sai global, Australia.

[8]AS1012.13:2015. Australia Standard: Methods of testing concrete-Determination of drying shrinkage of concrete for samples prepared in the field or in the laboratory. Sai global, Australia.
[9] Sharma, D. and Goyal, S. (2020) Effect of accelerated carbonation curing on near surface properties of concrete. *European Journal of Environmental and Civil Engineering*, pp.1-22.
[10] Gupta, S., Kua, H.W. and Koh, H.J. (2018) Application of biochar from food and wood waste as green admixture for cement mortar. *Science of the Total Environment*, *619*, pp.419-435.
[11] Gupta, S., Kua, H.W. and Dai Pang, S.(2018) Biochar-mortar composite: Manufacturing, evaluation of physical properties and economic viability. *Construction and Building Materials*, *167*, pp.874-889.