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The Effect of Palm Oil Fuel Clinker Powder and Cockleshell Powder as Cement Replacement on Durability Properties of the Concrete Mortar

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Abstract. The concepts of eco-friendly building are getting more attention today. The standard materials of concrete that used such as cement and aggregate are not totally environmentally friendly. Thus, many materials from natural sources can be an alternative to the realization of the green building concept. As a result, many researchers have devoted their attention towards identifying eco-friendlier substitutions to be used in concrete. This study was conducted to investigate the efficiency of two different types of waste materials which are palm oil clinker (POC) and cockle shell (CS) as partial replacement of cement on durability aspects. The POC and CS materials were ground to achieve a small particle size to fit with the concrete mix as cement replacement. The replacement of cement was at different levels (10% and 20%). Six mix proportions were made with different percentage of palm oil clinker powder POCP and cockle shell powder CSP. The specimens were cured by immersing in water for 7 and 28 days. The tests that were conducted were acid resistance test and water absorption test. Therefore, the experiment result showed that the POC had a negative impact to the concrete in both tests while the CSP proved it is resistance to acid.

1. Introduction

With the huge pollution that been risen due to the tradition concrete-making materials the surrounding environment is been impacted. As result, there is a new trend in concrete engineering to produce concrete from sustainable sources. In addition, construction industry through concrete chemical materials production has represented a challenge to the global environment as it consumes significant large quantities of natural resources [1]. Moreover, it generates toxic gases, such as CO₂. The main aim of the producing concrete from sustainable sources are to reduce the concrete waste and preserve the natural resources through reduction of the usage of traditional materials of the concrete to make a green environment. By adopting and promoting eco--efficiency materials and utilizing less raw materials, a cleaner production that involves the processes was raise up the quality of the concrete production [2]. Therefore, scientists have developed concrete to enhance and increase the ability, hardness and durability to provide more economical, environmentally friendly concrete materials, construction of skyscrapers and huge structures.

Nowadays, there are various materials are used as additional alternatives in concrete mix, either blended with cements or added separately in the concrete mixture [3]. The use of the additional alternative materials such as blast-furnace slag, a by-product from pig iron production, or fly ash from coal combustion, represents an appropriate solution to partially substitute Portland composite cement (PCC). The utilization of such materials, where a zero additional clinking process is involved, leads



to a significant decrease in CO₂ emissions per ton of cementitious materials (grinding, mixing and transport of concrete use very little energy compared to the clinkering process) and is also it enhances to utilize by-products of industrial manufacturing processes [4]. Additionally, using these materials it was enhance the durability and mechanical properties of concrete in order to increase and achieve a high resistance to acid, as well as a high resistance to sulphate and water absorption [5].

Another potential waste material that is available in abundance is waste seashells. Since its rich with calcium it was cover the lack of calcium in the POC which was partially replace with cement [6]. Furthermore, oyster shells, mussel shells, scallop shells, periwinkle shells and cockle shells are types of waste seashell can be used. In China, which is the largest producer of shellfish in the world, about 10 million tons of waste seashells are disposed of in landfills annually. The large quantity of seashell waste mainly consists of oyster, clam, scallop, and mussel shells, most of which are landfilled with only a small fraction re-used for other purposes, such as fertilizers and handicrafts. The re-use is limited due to the restriction on the amount that can be used, the problem of soil solidification, and economic problems.

Palm oil clinker (POC) is one of the materials resulting from the burning of waste materials such as palm kernel shell and palm oil husk. POC is usually disposed in landfills, as a sequence it increases the volume of materials deposits every year and now has become an unfavourable disposal. With the increased in population, industrialization, and urbanization, the quantity and types of solid waste materials have also climbed significantly [7]. Non-biodegradable waste materials were remaining in the environment for hundreds, perhaps thousands of years. Non-biodegradable waste materials are difficult to disposal and thus pose a vital threat to the environment. Therefore, there is a steady increase in realizing the sustainability of concrete production using recycled waste materials as substitutes for conventional materials in concrete. For this purpose, several studies have been carried out to use wastes originating from different sources, most of these wastes are available in large amount in certain countries, and hence, have the potential to be re-utilized in large-scale concrete production. The trend towards re-using the waste materials in producing concrete may contribute to the reduction in the problematic excessive consumption of conventional materials which could help to minimize the waste generation [8].

In addition, there are problems with illegal dumping of waste seashells into public waters and reclaimed land. These waste seashells, if they are left untreated for a long period of time, can cause foul odours due to the decay of the remaining flesh in the shells or the microbial decomposition of salts into gases, such as H₂S, NH₃ and amines [9]. These problems can negatively impact the quality of living for people near and result in environmental pollution issues [1]. Therefore, the importance of the study is to identify the suitability of POCP & CSP as cement partial replacement in concrete is very crucial for these researches convince people that POCP & CSP waste material can be re-used in the construction process. The analysis of the test is required to identify the result whether it is enough and satisfy the requirement or not. This is due to result from the test was show that whether POCP & CSP can achieve the minimum required for water absorption and acid resistance tests and even higher. The main objective of this research investigation is as follows:

- a) To investigate and test acid resistance of POCP & CSP on concrete when used as partial cement replacement according to ASTM C267.
- b) To validate the effectiveness of water absorption after adding POCP & CSP as partial cement replacement in concrete mixer according to ASTM C 642-06.

Malaysia for many decades has been known as the main manufacturers of palm oil. Through the production of palm oil, there is a waste known as clinker [10]. As the cement were reducing, inorganic material was explored as a suitable material as cement replacement. Malaysia is holding the main production for world palm oil production as 51%, 62% for the world exports and 30% for the oils and fats exportation [11]. To ensure a better bonding in concrete mix, the clinker and cockleshell have been ground to small particle form before replaced it with cement [12]. Furthermore, In Malaysia, cockle shell is richly available as a by-product from seafood industry. It is a cheap protein source which is quite common to be prepared as local dishes [13].

2. METHODOLOGY

2.1. Mixing Process

The preparation mixing process had be conducted once all materials needed for mixing are prepared. Since our mortar size 50 mm³ so the small concrete mixer was used. In the first cement, sand, CSP and POC were mixed without water for 3 minutes then the water was added, the amount of water added during concrete mixing needed to be poured gradually to produce uniform concrete compounds.

2.2. Compacting Process

After the concrete mixed is ready, the next step was to pour the concrete into mould that has been set up in the lab. At the same time, compaction process needed to be performed as soon as the concrete casting made. The concrete compaction process consists of two layers where each layer must be compacted first. For every layer the concrete was be blow 25 times with tamping bar. After the compacting process is done, the surface of concrete was flattened.

2.3. Curing Process

This process is the final stages in concrete production. Generally, curing process functions is to ensure the hydration occur properly where humidity in the concrete can be prohibited. The curing process can only be performed after the concrete that has compacted after 24 hours at room temperature. Then, the concrete mould was removed the hardened concrete produce added into the water tank. The hardened cubes concrete was immersed in water for 7 days for the three first cubes per mix proportion and 28 days for the others. After the curing process completed according to the days required, then the concrete is ready for tested.

2.4. Details of Samples

In this study, 54 cube samples were prepared with POCP&CSP as partial cement replacement for both tests. After the samples were prepared, then some tests can be applied. The main tests used are water absorption and acid resistance. For both of tests was performed cube shape. The dried clinker and cockleshell that been crushed were sieved through a 300µm sieve in order to remove bigger size of ash particles and impurities. Only the fine ashes passing through 300µm sieve were collected and ground in a modified Los Angeles abrasion test machine having 14 stainless balls which each of it is 12 mm diameter in order to acquire finer particles. The fineness of the clinker and cockleshell that had been grind was sieving through 75 µm sieve at every 30,000 cycle of 5kg clinker and cockleshell separately. As a result, obtained from both tests, the perfect samples are then used for further discussion to achieve the main objectives of this project.

2.5. Sample Preparation

The sample consists of cubes for concrete mixing. The sample is prepared using POCP & CSP as partial cement replacement and the materials used for concrete mixing. Table 1 shows the concrete mix design proportion that was be used for cubes testing. Acid resistance and water absorption tests were use the cube samples.

Table 1. Concrete Mix Design Proportions

MIX	CEMENT	POCP	CSP	SAND	WATER / g
A(control)	100%	0	0	100%	0.485
B	90%	10%	0	100%	0.485
C	90%	5%	5%	100%	0.485
G	90%	0	10%	100%	0.485
E	80%	15%	5%	100%	0.485
F	80%	13%	7%	100%	0.485

3. Testing Procedures

First and foremost, the samples were prepared into six categories, namely, the control sample and five samples which contain 10% and 20% of palm oil clinker powder POCP and cockle shell powder CSP. The control sample contains 0% of POCP & CSP was casted as common cement. On the other hand, the other five different categories of samples are composed of 10:0, 5:5, 0:10, 15:5 and 13:7 ratio of POCP & CSP as illustrated in Table 1 above. The samples were labelled and cured according to its assigned amount of curing days. All samples are subjected to water curing. The samples are then tested for water absorption test to determine the amount of water they absorbed also the resistance to acid attack was tested. A total of 54 samples were casted and cured in different curing times; 7 and 28 days. A total of 36 samples were used for water absorption test for curing period of 7 and 28 days, and 18 samples were used for the acid resistance test after 28 days of curing. For all categories, a total of 9 samples were casted with 3 specimens for 7 days and 6 specimens for 28 days.

3.1. Acid Resistance Test

Acid resistance was assessed by immersing the concrete specimens that were cured for 28 days with 5% hydraulic acid solution. The test duration was chosen so that the concrete specimens started to exhibit serious damage. The choice of acid and the acid concentration in solution were made to represent the exposure conditions of concrete in sanitary sewer pipes. cubes (50 mm × 50 mm × 50 mm) concrete specimens were kept fully immersed in acid solution for a duration of 1,3,7 and 28 days. High dosage of acid solution was used because the testing is carried out for short period due to time constraint. Whenever the specimen immersed for long period of exposure to acid solution it was loss itself weight due to acid attack. Acid resistance was evaluated on a weekly basis through visual inspection, the change of the appearance and measurement of the change in weight. Figure 1 show the specimens immersed in acid solution.



Figure 1. Appearance of specimen out shape

3.2. Water Absorption Test

This test was done according to ASTM C 642- 06 by oven-drying method the procedure used in the water absorption test by immersion the specimens in the water for 7 and 28 days. In this study, six 50 mm cubical specimens per mix were tested at 7 and 28 days. After curing process was done, the specimens are dried in a ventilated oven for a specified time and temperature and then placed in a desiccator to cool. The specimen was being dried in a ventilated oven for 48 hours. The weight of the specimen was then being recorded as dry weight. After drying, the specimen was being cooled in a drying room with relative humidity around 70%. The specimen was then being submerged in clean water at 30°C for 24 hours. The surface water of the specimens was be wiped with a damp cloth and the weights of the specimens was again weighed and recorded after removing the specimen from the submerged condition.

4. Result and Discussions

4.1. Acid resistance test results

As shown in Table 2 and Figure 2, the results obtained showed that all the samples that contained POCP produced low resistance to acid attack. The average weight loss of the samples from first day to 7 days was 2.6%. In contrast, the highest weight loss was recorded by the sample B with the value of 6.48 % at 7 which contained 10% of POCP only. On the other hand, the best result was obtained in sample G which contained 10% CSP only and the value that was recorded 3.89% at 7 days. The difference between the highest and the lowest percentages of weight loss at 1, 3 and 7 days was 1.69%, 1.53% and 2.59% respectively.

Table 2. Result of acid resistance test at 1, 3 and 7 days

PERCENTAGE OF POCP: CSP	Weight loss percentage %		
	1 day	3 days	7 days
A 0:0	3.06	4.48	5.06
B 10:0	3.73	5.5	6.48
C 5:5	3.36	4.97	5.86
E 15:5	3.39	5.09	5.99
F 13:7	2.97	5.37	6.28
G 0:10	1.37	2.95	3.89

In short, sample G showed higher acid resistance absorption compared samples containing POCP & CSP together in addition of control sample. The results proved that the sample containing 10% CSP had the lowest weight loss compared to that of the other mixes. This indicates that the weight loss may increase if the control mix contained POCP. Although the sample E and F contained 15% and 13% of POCP which is more than sample B except it gain more resistance by added the CSP which may due to calcium (ca) that CSP is rich with. CSP may function as filler to fill the void in the concrete mix, making the concrete much denser. Thus, the concrete void could be reduced and would resist more any acid attack. It can be said that the size and the chemical composition of CSP would influence the density, strength, water absorption and acid resistance. The use of waste such as CSP as an alternative for conventional concrete materials were benefit the environment and resist the acid attack.

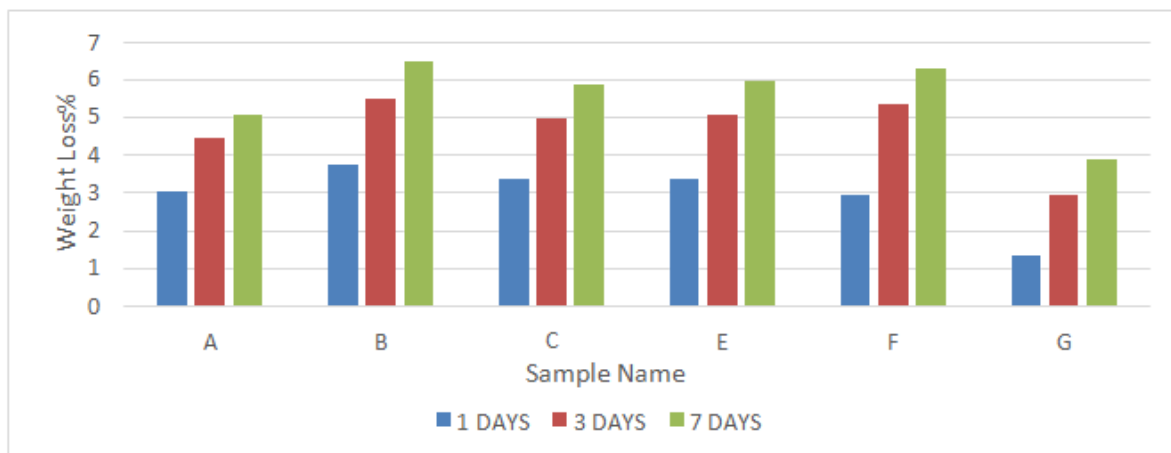


Figure 2. Acid resistance test result

4.2. Water Absorption Test

Table 3 and Figure 3 show the results on water absorption of concrete samples contain POCP & CSP with respect to 7 and 28 days of curing period. According to the water absorption test that been done, the results stated that the control samples with 0% POCP& CSP showed the lowest water absorption among the samples that contain POCP& CSP. The percentage of weight loss that recorded at 7 days for the control mix was 9.49. On the other hand, the samples B with 10% POCP and 0% CSP recorded the highest water absorption compared to other samples with 10.22%. The different between the highest and lowest water absorption percentage at 7 days is 0.73%. Next, at 28 days, the highest percentage of water absorption comes from sample F which contains 13% POCP and 7% CSP with 9.99%. Meanwhile, the

control samples recorded percentage of water absorption is 9.26%. The different between the highest and lowest water absorption percentage at 28 days is 0.73% like the difference at 7 days. In the previous study of [1] prove that the water permeability of the concrete mixtures with cockle shell ash was higher than normal concrete in the age of 28 days of curing. Despite that, at the age of 120 days of curing the water permeability of the concrete mix with cockle shell ash was lower than a normal concrete. Therefore, the age of curing periods is an important factor for the strength of the concrete contained cockleshell which is proved that is impermeable (waterproof) which mean the quantity of water that been absorbed less than conventional concrete.

Table 3. Result of Water Absorption Test at 7 and 28 Days

PERCENTAGE OF POCP: CSP	WATER ABSORPTION %	
	7 DAYS	28 DAYS
A 0:0	9.49	9.26
B 10:0	10.22	9.55
C 5:5	10.01	9.5
E 15:5	10.1	9.68
F 13:7	10.2	9.99
G 0:10	9.82	9.9

To sum up, it can be said that concrete samples containing POCP & CSP produce higher percentage of water that been absorbed than control sample. All the samples that contain POCP show increases ratio of weight loss. This may be due to the size of particles and chemical composition of POCP & CSP as partial cement replacement. POCP & CSP can act as filler and fill the void during the mixing. All the results produced by the mixes showed decrease in weight loss with the increment of curing period. In addition, all the concrete samples contain POCP & CSP did not meet the specific requirements of water absorption test and it is more permeable comparing to control mix.

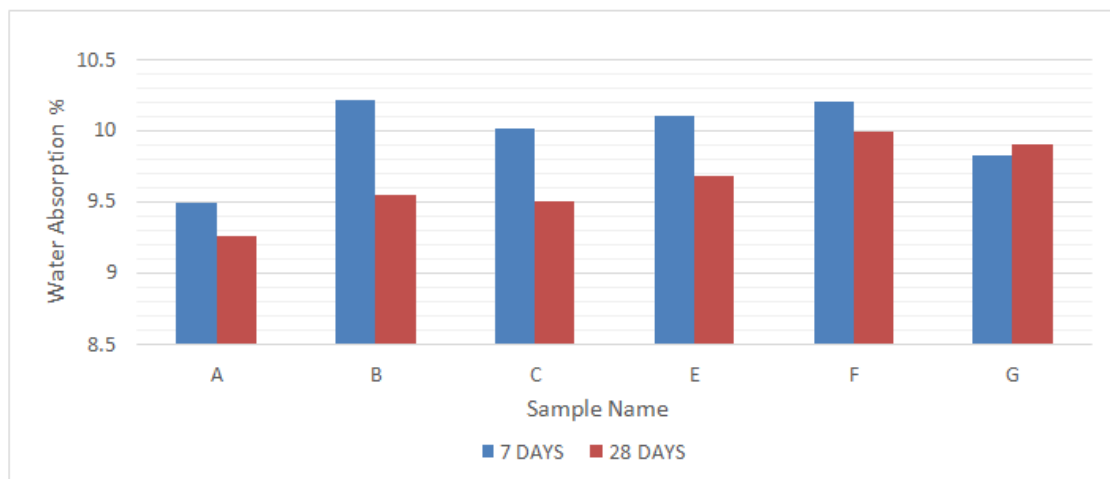


Figure 3. Water absorption test result

Based on the above results, it can be seen that using CSP acted as a filler to avoid in the concrete mix which eventually make a dense mix that can resist acid attack. Moreover, using a POCP & CSP produce a light weight and a friendly environment product compared to the mix with cement. However, a mix with POCP & CSP shows more permeable mix compared to the mix with cement. Thus, POCP & CSP are not enough to replace cement in the concrete mix.

5. Conclusion

The following conclusions can be drawn from the results obtained.

- POCP & CSP as partial cement replacement in concrete production would affect the water

absorption value. The percentage of water absorption of the concrete sample would therefore increase with the increment of the POCP & CSP in the concrete. This study proved that concrete containing POCP & CSP as partial cement replacement would have the highest percentage water absorption.

- The presence of POCP & CSP in concrete would affect the acid resistance. This study proved that concrete containing 10% of POCP as partial cement replacement would have the lowest acid resistant. While the highest acid resistant was obtained in sample G which contained 10% of CSP.

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