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Utilisation of Mussel Shell Ash and Palm Oil Leaves Ash as Admixture in Concrete

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Abstract: Mussel shell and palm oil leaves is a type of waste that generally undergo disposal process due to less-valuable materials. However, this waste is potentially to be used in concrete designing due to its cementing properties. Thus, this paper presenting the incorporation of mussel shell ash (MSA) and palm oil leaves ash (POLA) as an admixture in concrete. MSA and POLA were obtained through grounding, burning and sieving process. As total, 84 concrete samples were mixed with different proportions of POLA (0.5%, 1% and 1.5%), MSA (1% and 2%) and K for control samples. All the samples were cured for 7 days and 28 days. The study was carried out to measure its physical and mechanical properties such as compressive, split tensile and capillary absorption analysis. While, its materials properties (MSA and POLA) were identified through its specific gravity test. The results demonstrated that B5 (1.5% POLA + 1% MSA) gave a good performance in concrete compressive strength on 7 and 28 days. Besides that, B5 also indicates a lower capillary water absorption compared to other specimens. Whereas B6 indicates a higher value for density analysis. Overall, the experimental result indicates that B5 does not giving any adverse effect on the concrete performance. Thus, it is proved that the utilisation of MSA and POLA as cementing materials are applicable in improving concrete strength and its durability accordingly to the selected percentages.

Keywords: mussel shell ash, palm oil leaves ash, admixture, physical and durability

1. Introduction

Rapid urbanisation has the potential in improving of economical through its developments in various sector. This companion phenomena had contributed to the economy development and generates more income prospects. However, this has linked to environmental concerns which led to the increment of wastes being disposed from various sector. Thus, a significant action needs to be implemented in order to manage and control waste generated from the urbanisation activities in industrial or agricultural sector which could cause an environmental issue related to landfill and waste [1]. Regarding to this situation, this had drawn the attention among researcher in dispensing a research on the utilization waste generated from various sector as an eco-friendly material for new products.

Mussels or *Perna viridis* is a type of mollusc from fishery sector that were widely cultivated in Malaysia. This industry has a high demand and well received by the government in industry development. Department of Fisheries

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Malaysia issues statistics that mussel farmers were increases in every year and it had become one of country's economic resources. In year 2016, the quantity of mussel production had increased to 1,827.27 tonnes compared in year 2015 which are 1,673.27 tonnes [2]. The used of mussel shell in concrete to make concrete environmentally friendly by using natural waste material. The chemical composition of mussel shell makes it the same as the content contained in the limestone used ordinary Portland cement. It also plays a role as a filler in concrete and cement replacement materials [3].

There is other waste appeal among researchers such as palm trees or its scientific name, *Elaeis guineensis* is the most popular plants and the main economic resource of the country. Generally, Malaysia currently the world's second-largest producer of palm oil [4]. In year 2017 the number of palm oil fruit production increased by 7,115,150 tonnes compared to 6,069,588 tonnes in 2016 [5]. According to this statistic, it shows that Malaysia produces many wastes and not well utilized.

Palm oil fuel ash was produced from combustion of palm oil husk and palm oil shell. Palm oil fuel ash was dried in oven with a temperature of 110˚C for 24 hours. The dried palm oil palm has facing a sieve process that passes over 300 m to ensure the removal of impurities and large particle size [6]. Table 1 shows the chemical composition on the mussel's shell, palm oil ash (POFA) and ordinary Portland cement.

Table 1 - Chemical composition of mussel shells, palm oil fuel ash (POFA) and ordinary Portland cement

Chemical composition (%)	Mussel shells ash [3]	Palm oil fuel ash (POFA) [6]	Ordinary Portland cement [3]
$CaCO_3$	95.6	-	-
SiO_2	0.73	49.20	21.20
Al_2O_3	0.13	5.45	5.47
Fe_2O_3	0.05	5.73	3.31
CaO	53.38	7.50	65.52
MgO	0.03	3.93	1.97
K_2O	0.02	5.30	1.71
Na_2O	0.44	0.90	0.46
SO_3	0.34	1.73	1.90
Cl	0.02	-	-
SO_4	0.11	-	-
LoI	-	13.85	-
P_2O_5	-	6.41	-

Various materials have been used to improve the properties of concrete with the change's technology. There are also many of kind waste materials such as shells, oyster shells, mussel shell and others waste which are used in concrete. Based on previous studies, palm oil fuel ash is a good material as a reactive as a pozzolan materials in concrete [7]. This shows that both admixtures have a lower weight of characteristic physical compared with ordinary Portland cement. The use of refined palm oil fuel ash will increase the concrete properties as well as potentially improve concrete performance [8]. Table 2 shows the use of various seashells and palm oil fuel ash (POFA) in the concrete.

Table 2 - The use of various shell and palm oil fuel ash (POFA) in concrete

Researcher	Materials	Results and Analysis
Bin-yang et al. [9]	Oyster shell	Compressive strength: The optimum percentages use of oyster shells in the mortar reaches 49.2MPa and the control mortar reaches 46.9Mpa
Gadgihalli et al. [10]	Seashell	Compressive strength: Concrete grade 20 and 30 achieved strength of 20.3MPa and 28.24MPa and grade control concrete 20 and 30 reached 19.71MPa and 27.72MPa.
Lertwattanaruk et al. [11]	Mussel shell	Specific gravity: The ordinary Portland cement is 3.11 and the mussel shells is 2.86.
Othman et al. [12]	Shells	Permeability of water: 5% mixture of shells ash 11.30 × (10^{-11}) m^2 while for normal concrete mixture 28.50 × (10^{-11}) m^2.
Namdar et al. [13]	Seashell	Compressive strength: The use of 1% ocean shell has the same compressive strength as the control concrete of 35MPa.

Awal & Shehu [14]	POFA	Specific gravity: The specific gravity of ordinary Portland cement is 3.28 and the specific gravity of oil palm husk ash is 2.42.
Awal & Nguong [7]	POFA	Compressive strength: The efficiency of POFA (45µm) increases twice the compressive strength of 39.5 N/mm^2 and the crude POFA reaches the compressive strength of 19.5 N/mm^2.
Shakir et al., [4]	POFA	Compressive strength: The use of 1%, 1.5%, 2%, and 2.5% as mortar additive for palm leaves reached 16MPa compressive strength.
Rani & Tejaanvesh [15]	POFA	Compressive strength: 15% POFA use as cement replacement material in concrete increases compression strength of 53.22 N/mm^2 compared to control concrete 45.07 N/mm^2.

2. Experimental Work

2.1 Materials

2.1.1 Palm oil leaves ash (POLA)

Palm oil leaves that in this study was taken at Parit Hj. Rais, Parit Raja, Johor. Palm leaves were dried in temperature around 35ºC and burned until turn as ash. After burned, sieve process will be done using a passing sieve 75µm. Fig. 1 shows the POLA that used as admixture in concrete.

Fig. 1 - Palm oil leaves ash

2.1.2 Mussel shell ash (MSA)

Mussel shell used in this study was obtained from Pontian, Johor. Johor is the largest mussel's production with 1821.79 tonnes in 2016 [11]. The mussel has to be cleaned and dried at a temperature 35ºC for one week. Next, mussel shells were blended using crusher machine (milling crusher machine) that passing sieve 5 mm and then continued crushing using ball mill (Los Angeles abrasion machine) to obtain the ash form that are passing 75µm sieve size. Fig. 2 shows the MSA that has passed through 75µm sieve.

Fig. 2 - Mussel shells ash

2.1.3 Mix proportion

Concrete mix was design according to DoE method with target concrete strength 30 MPa at 28 days. Mixture of concrete with different mixtures of POLA (0.5%, 1%, 1.5%) and MSA (1%, 2%) were used as admixture in this study. The test samples were mixed from 7 different batches with the total number of 84 concrete cubes with size of 100mm x 100mm x 100mm. After that the samples were through the process of curing for 7 and 28 days to get the data and results of study. The results of control sample will be comparing with concrete sample with admixtures. Mix proportion as show in Table 3.

Table 3 - Mix proportion for specimen

Sample	POLA (%)	MSA (%)	Cement (kg/m^3)	Fine aggregate (kg/m^3)	Coarse aggregate (kg/m^3)
K	0	0	360	630	1280
B1	0.5	1	360	630	1280
B2	0.5	2	360	630	1280
B3	1	1	360	630	1280
B4	1	2	360	630	1280
B5	1.5	1	360	630	1280
B6	1.5	2	360	630	1280

2.2 Testing Parameter

2.2.1 Specific gravity

Specific gravity test is carried out to obtain its physical characteristics of POLA and MSA. The specific gravity is the mass ratio of the sample volume unit at a temperature specified with the same volume of distilled water at room temperature. POLA and MSA were tested according to BS EN 15326: 2007 + A1: 2009 BS 2000-549: 2007 [17].

2.2.1 Slump

Workability of concrete can be identified by concrete slump test and depends on cement-water ratio used in the concrete mix which is in this study value of cement-water ratio is 0.55. However, excessive quantity of water could lead to bleeding which effecting the concrete strength [16]. The slump test was conducted in accordance with BS EN 12350-2: 2000 [18]. The ready-mix concrete was put into mould in 3 layers and each layer needs to be compacted using rods 25 times.

2.2.2 Density

Density test was conducted on wet concrete and dry concrete. Where wet concrete after the concrete curing process and dry concrete are put into the oven for one day at 105˚C. The data obtained in this test will be recorded for analysis. The standards used for this experiment are BS EN 12390-7: 2009 [19].

2.2.3 Compressive strength test

Concrete strength is one of important aspect and requirement that should well monitor in construction industry. One of common analysis to identified concrete strength are by compression test. In addition, the strength of concrete is affected when the preparation of concrete does not according to the standard testing. Size of samples for compressive strength test in this study are 100mm x 100mm x 100mm. Thus, the standard was used for this test is BS EN 12390-3: 2009 [20] to obtain the analysis.

2.24 Capillary water absorption test

The capillary absorption test was carried out to determine the absorption rate of the water into the concrete by measuring the weight of the concrete. This test is conducted according to the RILEM standards of CPC 11.2: 1982 [21]. The sample size of 100mm x 100mm x 100mm are heated at 105˚C in an oven for one day and let stand at room temperature for 6 hours. Only one surface of sample is exposed to water and before the samples put into water, it should be weighed first. In the last 5, 10, 20, 30, 60, 180, 360 and 1440 minutes need to be weighed as well as the rate of water absorption through its capillary absorption. Each admixture percentage is provided with 3 samples and the reading is taken on average.

3. Results and Discussion

3.1 Specific Gravity

Based on the analysis, it shown that the specific gravity of OPC was higher comparing with POLA and MSA. Specific gravity of ordinary Portland cement is 3.33, meanwhile POLA is 2.05 and MSA is 2.49. Previous researcher found a similarity value were 2.52 [22,23]. While Garcia *et al.* [24] found that the value of MSA specific gravity was 2.62 and it showed slightly higher value compare in this study. However, the difference between previous researcher values of MSA and POLA are quite significant, those ash were still show it is lighter than ordinary Portland cement. Admixture material that are finer and lightweight will give advantage in concrete in terms of workability, density, capillaries and segregation [25]. Hence, specific gravity of POLA and MSA indicates that it is light and have potential as admixture and filler in concretes.

3.2 Slump

Result on slump test of concrete was presented as in Table 4. According to data collected in this study, control mix concrete has high workability compared to concrete containing admixtures. The slump value of control mix sample, K obtained slump value 55mm. While, sample concrete mixture B5 give a higher slump between other mixtures. However, it shows that B1 and B2 indicates similar slump value compared to other specimens. It is due less quantity of MSA and POLA that incorporated with cementing materials that causing almost the similar value for both mixes. According to Wen-Ten [26], utilisation of seashells in concrete potentially accelerates the cements hydration process due to high water absorption rates. The present of MSA and POLA might be the main causes that effecting to the slump value. Therefore, it is resulting low workability value compared to control sample.

Table 4 - Slump values from test

Mixes	Percent of admixtures (%)		Slump
	POLA	MSA	(mm)
Control sample (K)	0	0	55
B1	0.5	1	3
B2	0.5	2	3
B3	1	1	5
B4	1	2	4
B5	1.5	1	8
B6	1.5	2	7

3.3 Density

Density of concrete mixtures is indicated in Fig. 3. Overall, the density of concrete mixes is increased at 28 days curing compared to 7 days. Density of control concrete, K at the age of 28 days was 2310 kg/m^3 while the higher density of concrete containing admixture, B6 was is 2317 kg/m^3. This demonstrate that the more content of admixtures (POLA and MSA) give higher density. In the other words, it does not effects on the physical properties of concrete containing POLA and MSA.

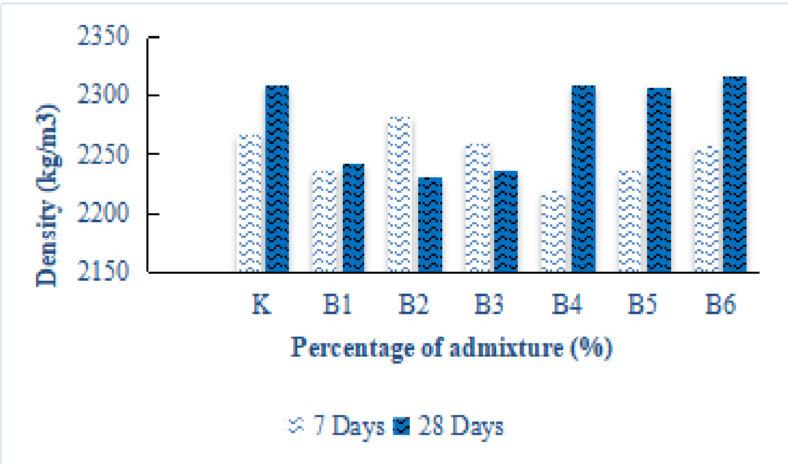

Fig. 3 - Density of concrete

3.4 Compressive Strength

Fig. 4 shows the outcome in compressive strength for each specimen. Test results were determined based on average value of compressive strength to get on accurate reading. However, the compressive strength value all concrete with MSA and POLA mixture had exceeded the design target for specimens which is 30 MPa at the age of 28 days. According to data obtained, the highest value noted by 1% MSA and 1.5% POLA replacement namely B5 (50 MPa). In short, this case happened due to the formation of four special minerals of chemical composition in cement namely *alite*, *belite*, *trikalsium aluminat* and *tetrakalsium aluminoferat*. When cement replaced with material like mussel shell ash and palm oil leaves ash, the total of *alite* with *belite* will brought out and cause CSH gel formed resultant the reduction both minerals in paste. This cause declination of concrete strength. Therefore, most researchers applied small replacement percentage so that product produced achieving goals without prepossess concrete strength worthless.

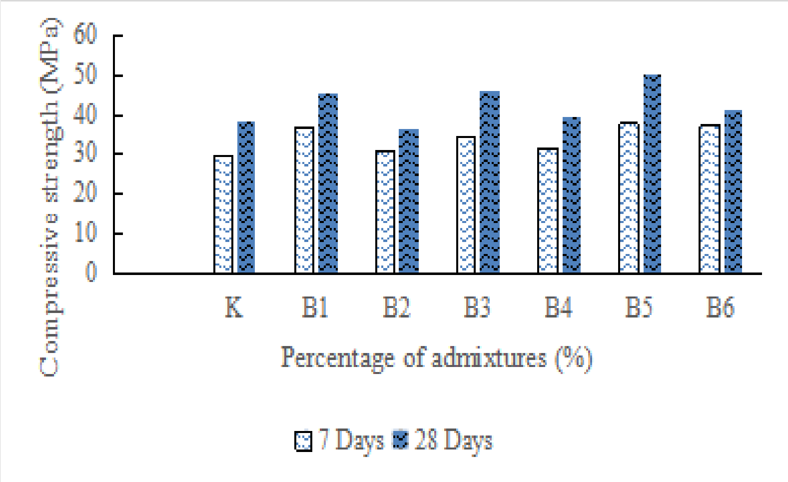

Fig. 4 - Compressive strength

3.5 Capillary Water Absorption

Fig. 5 shown the water capillary absorption against different percentage of admixtures for 42 samples. Overall, control sample, K has a high absorption rate (3.50×10^{-3} cm/s) compared another mixture. According to the data obtained, concrete containing admixture provide low water absorption than control concrete, K at 28 days.

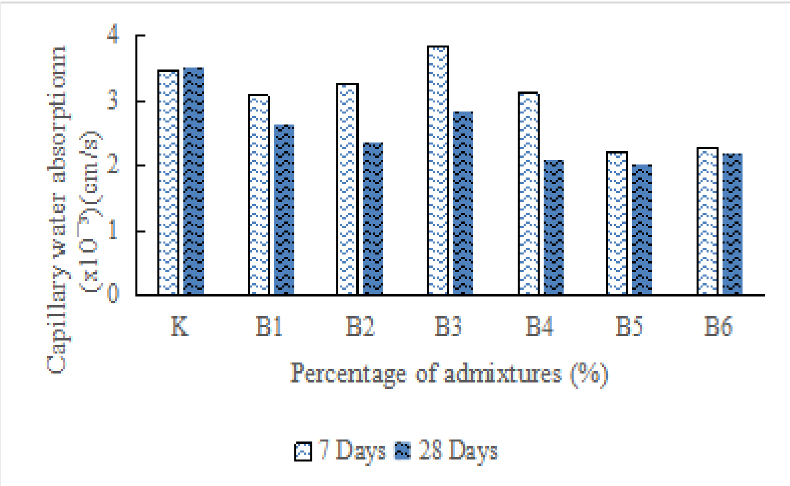

Fig. 5 - Capillary water values from various analysis

4. Conclusion

Based on experimental results, both admixtures of POLA and MSA have a lower water absorption through it capillary compared to control samples. These two admixtures potentially act as filler between cement and aggregate which causing less pores and void existing in internal concrete microstructure. Besides that, this experimental result also obtained that POLA and MSA are lighter compared to cement. Thus, a plenty of water is needed to moisten the entire surface particles of the POLA and MSA since the specific gravity lower than ordinary Portland cement because it will assist higher rate of hydration when both admixtures react with water.

According to compressive analysis, it shows the increment percentages of POLA improved concrete compressive strength compared to others samples. Whereas concrete on 28 days, specimens B5 had higher value of compressive compared to B6. It can clearly obtain that the increments of MSA percentages does not affecting on concrete mechanical properties. In other word, the utilisation of MSA are much less-effective compared to POLA materials. Overall, it was confirmed that the optimum percentage of admixtures selected was B5 with a mixture of 1.5% POLA and 1% of MSA. According to this percentages, it was significantly improving concrete performance in term of its strength and also permeability.

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