

Utilisation of Oil Palm Ash in Foamed Concrete

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Abstract. This study is a part of an on-going research examining the properties of foam concrete when replacing the cement with semi-processed Oil Palm Ash (OPA). Replacements range from 25% to 65% were used for a mix having the mix ratio of (1:2:0.45) and having the target density of 1300kg/m³. All mixes were tested for their strength using the compressive, splitting tensile and flexural strengths up to the age of 28 days. Results show that a 25% replacement level exhibited higher compressive and splitting tensile strength than that of the control mix at the age of 28 days. However, the same replacement level exhibited a close strength to that of the control mix when tested for the flexural strength at the same age.

1 Introduction

Foam concrete, is a type of lightweight concrete. This type of concrete is a homogeneous material due to the absence of large aggregates when compared to conventional concrete. The most attractive properties that this type of concrete has are its self-compacting and self-levelling nature, flow-ability, its ability to be produced with very low densities [1] and its low weight leading to designing more economical supporting structures such as foundations, walls and floors [2]. Furthermore, foam concrete is considered to be an environmentally friendly product because it uses less natural resources and the ability to incorporate larger amounts of waste materials within its mix [3]. Such wastes include fly ash, rice husk ash and blast furnace slag. These by-products can possess pozzolanic properties that can enhance the characteristics of concrete further more. These pozzolanic materials are called Supplementary cementitious materials [4]. Oil palm ash has been introduced recently to be a pozzolanic material.

Oil palm Ash (OPA) or Palm Oil Fuel Ash (POFA) is a by-product produced by countries having a blooming palm oil industry such as Malaysia and Thailand. It is generated by the incineration of oil palm shell and palm oil empty fruit bunch at 800C° to 1000C° as a mean of heating up the mill's boilers instead of using conventional fuels. Due to this incineration process, ash is produced at about 5% by weight of the incinerated solid fuels [5]. The quantity of OPA produced in Malaysia alone is about 4 million tonnes a year [6].

OPA is a throw away product that is produced abundantly. Common practices for disposing of this by-product were either by tipping or dumping. Hence, the waste is either spread over the premises of the mill or dumped to fill in low economic value dumps or selected types of land such as swamplands, abandoned sand quarries [7]. These disposal methods were conducted without taking into consideration the surrounding environment or taking precautions to compact, cover and prevent the spreading of pollutants into the ground water levels [7]. In addition, due to its fine particles, OPA can

be easily carried away by wind by that causing smog on a humid day [8]. Therefore, the utilisation of OPA in concrete production has a number of environmental benefits such as reducing the amount of OPA that is disposed of into landfills, reducing the amount of energy used and the emitted greenhouse gases when OPA is used to replace manufactured cement and the conservation of other natural resources when OPA is used as filler replacement. Therefore, a number of studies focused on the utilisation of OPA in the construction industry as a mean of recycling such a waste. OPA has been used as a binder or filler replacement in normal concrete [8,9,10], high strength concrete [11,12], mortar [10,13] and aerated concrete [14,15,16].

This study is a part of an on-going research studying the effects of semi-processed OPA on the properties of foam concrete when used as a cement replacement. It is common sense to utilise such a by-product into the manufacture of an environmentally friendly concrete in order to make it greener.

2. Materials

The cement used is a Type I cement which can be classified as MS 522 and complies with BS EN 196 of the British Standards. The cement is manufactured in Malaysia under the CIMA group and packed under the name (Blue Lion). Natural sand from a local river bed was used as the fine sand in this study. A sieve analysis was conducted on the sand and it fell into zone 3 according to BS 882: Part 2: 1973.

Oil palm ash was produced by the incineration of oil palm shell and empty fruit bunch by a nearby palm oil mill. The type of ash used has been incinerated at a temperature of 800C°. The OPA used in this study is the passing through a 300µm sieve. Table 1 shows the chemical composition of both the cement and OPA used in this study. The OPA's chemical composition complies with a class F pozzolana according to ASTM C 618 [17].

The foaming agent is a protein based agent called (Noraite PA-1) which is manufactured in Malaysia. The foaming agent was diluted in water at a ratio of (1:30) by volume producing stable foam with a density range of 64kg/m³ to 68kg/m³. A super-plasticiser called (PS-1), also manufactured in Malaysia, is used with mixes containing OPA replacements. This additive is based on soluble salts of Polymeric Sulphonates. Table 2 shows the characteristics of this additive.

Table 1: Chemical composition of cement and OPA

Chemical composition %	Cement	OPA
Silicon Dioxide (SiO ₂)	19.98	66.6411
Aluminium Oxide (Al ₂ O ₃)	5.17	3.8164
Iron Oxide (Fe ₂ O ₃)	3.27	3.6979
Calcium Oxide (CaO)	63.17	5.2290
Magnesium Oxide (MgO)	0.79	2.2866
Sulphur Trioxide (SO ₃)	2.38	0.4278
Loss on Ignition (LOI)	2.5	2.32
SiO ₂ +Al ₂ O ₃ +Fe ₂ O ₃	--	74.155

Table 2: PS-1 Characteristics and typical composition

Chemical content	A mixture of sodium acids and glycol compounds
Appearance	Brown to light brown coloured liquid
Total Solids %	40
PH Solution	7.5 to 8.0
Salt Content	Max. 5%
In-Soluble Materials	Negligible
Chlorides as NACL	Nil

3 Mixing Procedure

A total of six mixes have been conducted in this part of this research. Each mix had the mix ratio of (1:2:0.45), a target density of 1300kg/m^3 and a volume of 0.18m^3 . The difference between target and wet density was fixed at 150kg/m^3 . Cement has been replaced by OPA at levels starting from 25% to 65%. Super- plasticiser (PS-1) was added to the mixes containing OPA at a percentage of 1% by weight of cementation materials. The flow table test was kept at a range between 22cm and 24cm. Table 3 shows the mix proportion for the mixes conducted.

Table 3: Mix proportions

No.	Mix Symbol	Mix Proportions (kg)						Slump (cm)
		OPC	OPA	Sand	Water	PS-1	W/C	
1	CC	74.6	--	149.2	25.07	--	0.45	22.0
2	OPA25	55.95	18.65	149.2	26.44	0.746	0.45	22.0
3	OPA35	48.49	26.11	149.2	26.58	0.746	0.45	22.5
4	OPA45	41.03	33.57	149.2	27.33	0.746	0.45	23.0
5	OPA55	33.57	41.03	149.2	27.47	0.746	0.45	23.5
6	OPA65	26.11	55.95	149.2	32.24	0.746	0.45	23.0

4 Testing Procedures

All specimens were de-moulded after 24hrs + 2hrs from mixing. Afterwards the specimens were wrapped with polythene wrapping and kept until the day of testing [18]. Before 24 hrs of the testing date, specimens were kept in an oven at a temperature of $105\text{C}^{\circ} \pm 2\text{C}^{\circ}$ then they would be taken out, weighed, left to cool down then tested. Tests were conducted at the age of 7, 14 and 28 days. Compressive strength, splitting tensile strength and flexural strength were examined for all mixes. For compressive strength, a 100mm cube is used and the mean of three cubes was taken as the reading for each age. For the splitting tensile strength, a cylinder having a length of 200mm and a diameter of 100mm is used and the reading for each age is taken as the mean of three specimens. On the other hand, prisms having the dimensions of (100×100×500) mm were used and the reading for each age is taken as the mean of the three specimens.

5 Results and Discussion

5.1 Mix Proportions

Due to the porous nature of OPA's particles, it is clear from Table 2 that the amount of water needed to achieve the required slump increases with the increase in replacement level of OPA. The Control mix needed the least amount of water were there was about 8.5kg of extra water. On the other hand, the mix OPA65 with a replacement level of 65% of cement by OPA left out only 1.33kg of water to achieve the desired slump.

5.2 Compressive Strength

The compressive strength results for all six mixes are listed in Table 4 below. All cubes were tested at a pace rate of 2.5KN/s with an ELE testing machine that has a capacity of 3000KN. The results show that two of the replacement levels, namely 25% and 35%, have exhibited higher compressive strengths than that of the control mix at the age of 28 days. The 25% replacement showed

a 9% increase to the control mix's compressive strength. While a 35% replacement exhibited 41% increase than the control mix's strength at 28 days. This can only be explained by the fact the OPA used, despite its large particle size, has a high content of (SiO_2) (66.6411%) enabling it to react with the Calcium Hydroxide ($\text{Ca}(\text{OH})_2$) producing additional Calcium Silicate Hydrates (C-S-H); hence, causing the improvement of the compressive strength [11].

However, mixes that exceeded a replacement level of 35% showed lower compressive strengths. This phenomenon is interrelated to the fact that lower cement content will reduce the amount of Calcium Oxide (CaO). For that reason, smaller amounts of Calcium Hydroxide ($\text{Ca}(\text{OH})_2$) are produced which in turn are insufficient for all the silica to take part in the pozzolanic reaction creating Calcium Silicate Hydrates (C-S-H) which are responsible for the development of strength. This result agrees with findings of [16].

Table 4: Compressive strength results

Mix	7days (MPa)	14days (MPa)	28days (MPa)
CC	5.92	6.00	5.58
OPA25	5.51	6.51	6.09
OPA35	6.66	5.75	7.89
OPA45	4.59	6.19	4.49
OPA55	3.81	4.42	4.43
OPA65	2.46	2.70	3.28

5.3 Splitting Tensile Strength

The results for the splitting tensile strength for all six mixes are presented in Table 5. The cylinder specimens were tested at a pace rate of 0.94KN/s with the same machine used for the compression test. The findings show a different trend than the compressive strength. The highest tensile strength is recorded at the age of 28 days for OPA25 exhibiting a tensile strength of 0.720MPa higher than that of the control mix by 8.3%.

Table 5: Splitting tensile strength results

Mix	7 days (MPa)	14 days (MPa)	28 days (MPa)
CC	0.75	0.77	0.67
OPA25	0.70	0.72	0.72
OPA35	0.69	0.69	0.59
OPA45	0.42	0.29	0.39
OPA55	0.22	0.28	0.34
OPA65	0.29	0.29	0.31

5.4 Flexural Strength

Flexural strength specimens were tested using the same machine used for the prior tests. Prisms were tested at a pace rate of 0.200KN/s using a 4 point flexural test. The results show that all replacement mixes suffer from lower flexural strengths when compared to the control mix. The nearest flexural reading was recorded for OPA25 having a reading of 1.802MPa by that obtaining 96% of the flexural strength exhibited by the control mix. Table 6 lists the results for the flexural strength of all mixes.

Table 6: Flexural strength results

Mix	7 days (MPa)	14 days (MPa)	28 days (MPa)
CC	1.62	2.12	1.87
OPA25	1.45	1.29	1.80
OPA35	1.87	1.61	0.98
OPA45	0.74	0.92	0.78
OPA55	0.56	0.56	0.68
OPA65	0.52	0.67	0.52

6 Strength to Replacement Level Relationship

The previous tests show that OPA when semi-processed (sieved through a 300µm sieve) with the help of a super-plasticizer can be a good pozzolanic material. Replacements of cement by the sieved only OPA can be done until 35%. It is evident that both the 25% and 35% replacement levels excelled with its compressive strength. However, only the 25% replacement level showed higher splitting tensile strength than that of the control mix. On the other hand, flexural strength results showed that even at a 25% replacement flexural strength of about 96% of the control mix’s flexural strength can be achieved. Fig.1 shows the results for all mixes at the age of 28 days for the tests.

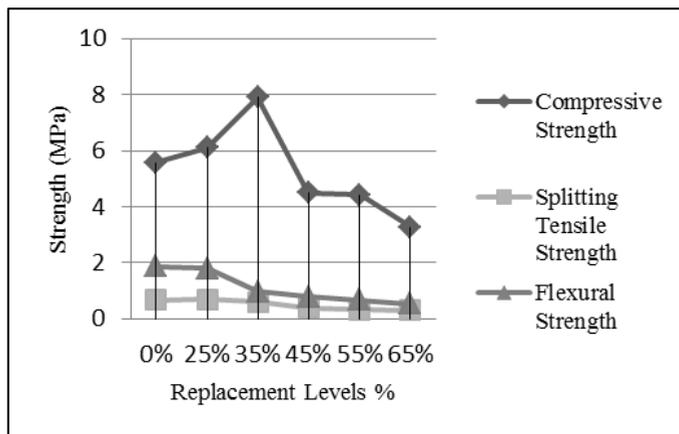


Figure 1: Results for all mixes at the age of 28 days for the tests.

7 Conclusions

- 1) When sieved OPA is used as a cement replacement, the increasing replacement levels will need more water to achieve the desired slump.
- 2) Replacement level of 25% showed good results in compressive strength, splitting tensile strength and flexural strength at the age of 28 days by obtaining a 109%, 108% and 96% of the control mix strengths, respectively.
- 3) When only Compressive strength is concerned, a 35% replacement has shown good results by obtaining 141% of the control mix’s compressive strength at the age of 28 days.
- 4) Increasing the replacement levels will decrease the strength of foam concrete.

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