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Properties of Unground OPA Foamed Concrete

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ABSTRACT

This study investigated the effects of partially replacing OPC by unground OPA in foamed concrete. Six foamed concrete mixes were prepared with OPA replacing OPC at replacement levels of 0, 25, 35, 45, 55, and 65%. The mix ratio used in producing the mixes was 1 part of binder, 1.5 parts of filler and W/C ratio of 0.45 for design purposes. A 1% dose by weight of binder of super-plasticiser has been used in the mixes containing unground OPA replacements. The properties investigated were compressive strength, water absorption and porosity of the foamed concrete mixes at the ages of 7, 28 and 90 days. Results show that the optimum replacement was 25% by weight of binder due to the enhanced properties exhibited, thus, producing a cheaper and a more environmental friendly foamed concrete.

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INTRODUCTION

In recent years, the attention to the utilisation of light weight concrete has risen. This increased attention was due to its properties of low self-weight, low thermal conductivity, self-compacting and high heat resistance. Numerous advantageous can be seen when using low density materials such as lower dead loads, a faster building rate and decreased transport costs [1]. However, the cost of a foamed concrete mix is dependent on the amount of cement content and by the amount of foam dose [2]. Therefore, many studies have endeavored on using supplementary cementing materials as cement replacements for the sake of cost saving, property enhancement and incorporating large volumes of waste materials.Oil palm Ash (OPA) or Palm Oil Fuel Ash (POFA) is a by-product generated by the incineration of oil palm shell and palm oil empty fruit bunch at 800Cº to 1000Cº 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[3]. The annual amount of produced OPA in Malaysia alone is about 4 million tonnes [4]. This number is expected to rise due to the increased attention to the use of palm oil as biofuel and to the encouragement of the Malaysian government in using bio-waste (oil palm fibres and empty fruit bunch) as fuel in electricity production. The common practices for disposing of OPA were either by spreading the waste 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[4].OPA has already been used as a cement replacement in concrete, high-strength concrete, mortar, aerated concrete and pastes [5, 6]. However, all these studies have processed the OPA either by grinding to increase its fineness or by heat treatment to reduce its carbon content. Although these further processing procedures enhance the properties of OPA, they do add a considerable cost. Hence, hindering the practicality of such incorporation and making it only achievable in laboratory conditions.This paper aims on investigating the potential of using sieved only OPA in the production of foamed concrete when used as a partial cement replacement. In addition, it will study how such incorporation would affect the properties of foamed concrete and to study the possibility of producing a greener and cheaper foamed concrete used for semi-structural applications.

Method:

The materials used in this study are ordinary Portland cement, fine sand as filler, potable water, protein based foaming agent which was diluted in water at a ratio of 1:30 then aerated to produce pre-formed foam having a density of 68kg/m^3, and a naphthalene based super-plasticiser having a PH of 7.5. The OPA was

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collected from a nearby palm oil mill which was heated at 105 ±3ºC for 24 hours then sieved through a 300µm sieve. The passing through the 300µm sieve will be used as a partial cement replacement. Table 1 shows the physical properties of both cement and sieved OPA. Binder and filler materials are mixed using an inclined rotary drum mixer until a homogeneous dry mix is obtained. Water is added gradually until the required consistency is achieved; in this case 220-240mm. the density of the base mix is determined by weighing a 1litre cup of the mortar then the amount of foam is calculated then added until the required design density is obtained (1450kg/m^3 ±3%). Specimens are removed from the moulds after 24 hours the sealed cured until the testing date.A total of six mixes were conducted for this study. These mixes had a mix ratio of 1 part of binder to 1.5 of filler. A water to cement ratio (W/C) of 0.45 was chosen for design purposes. OPA is used to replace cement at replacement levels of 25-65% with 10% increments. A pure cement foamed concrete mix is prepared for the sake of comparison with OPA foamed concrete. Table 2 shows the mix composition of these mixes. Properties to be tested are compressive strength, water absorption and porosity. These properties were tested at the ages of 7, 28 and 90 days. Each recorded reading is the average of three samples.

Table 1: Physical properties of cement and sieved OPA.

Property	cement	OPA
Median particle size d_{50} [µm]	5.73	18.63
Specific gravity	2.85	1.65
Loose bulk density [kg/m^3]	1180	833.6
Blaine surface area [cm^2/g]	3924	1952

Table 2: Mix composition.

Mix	Cement [kg/m^3]	OPA [kg/m^3]	Sand [kg/m^3]	Water-solids ratio	SP [kg/m^3]	Foam [litre]	Mortar spread [mm]
CM	484.7	-	727.1	0.14	-	372.0	230
OPA25	363.5	121.2	727.1	0.13	4.85	326.0	225
OPA35	315.1	169.7	727.1	0.16	4.85	303.0	230
OPA45	266.6	218.1	727.1	0.18	4.85	270.0	225
OPA55	218.1	266.6	727.1	0.21	4.85	244.0	225
OPA65	169.7	315.1	727.1	0.23	4.85	202.0	220

RESULTS AND DISCUSSION

Table 3 illustrates the results for the properties tested in this study. Compressive strength was conducted on 100mm cubes according to BS EN 12390-3. It is obvious that the OPA25 achieved higher compressive strength than that of the control mix at all ages.

Table 3: Results for the foamed concrete mixes.

Mix	Compressive strength [MPa]			Water Absorption [%]			Porosity [%]		
	7	28	90	7	28	90	7	28	90
CM	7.29	8.46	8.63	11.19	9.62	7.34	43.49	37.05	22.92
OPA25	7.16	9.05	10.72	10.67	9.08	5.75	40.92	34.13	21.43
OPA35	5.7	7.25	8.04	13.32	10.24	7.97	47.88	45.47	38.64
OPA45	5.31	6.55	6.9	16.63	11.34	8.47	50.84	47.97	42.24
OPA55	3.05	4.45	5.61	17.53	13.19	11.49	51.30	48.48	43.80
OPA65	2.8	3.89	4.6	24.77	17.93	12.24	53.09	49.48	45.55

This is reasoned to the reduced amount of artificial pores (macro-pores) within the paste of the mix due to the reduced amount of foamed needed to achieve the required design density. In addition, the existence of a sufficient amount of cement and reduced water-solids ratio due to the addition of 1% by weight of binder super plasticiser. However, exceeding the replacement level beyond 25% has a negative effect on the compressive strength. Compressive strength decreases with increasing replacement levels. As a general observation, all the foamed concrete mixes with an OPA content showed strength development through the ages hinting the existence of a pozzolanic reaction.

Water absorption was tested according to BS 1881:122. Mix OPA25 showed less water absorption readings than that of the control mix. This is due to the decreased water-solids ratio which resulting in decreasing the pores inside the matrix. The decreased water solids ratio was achieved as a result of the addition of the super-plasticiser dose. However, the increase in OPA content in the foamed concrete mix increases the water absorption. Increasing the content of OPA in the foamed concrete mix will reduce the amount of foam required and as a result increases the paste phase volume. Increasing the paste phase volume will lead to the increase of the number micro-pores inside the mix's matrix, hence, increasing water absorption [7]. All mixes illustrated a decrease in water absorption with increasing age due to a type of pore refinement due to a pozzolanic reaction occurring between the cement and OPA.

Porosity was tested using the method prescribed byKearsley and Wainwright[8]. The porosity readings were on par with the absorption readings. OPA25 is less porous than the control mix hinting a more refined pore structure within the matrix of the foamed concrete mix. This came as a result of the sufficient amount of cement and to the reduced water-solids ratio due to the addition of super-plasticiser. Porosity increased with increasing replacement levels. Increasing the paste phase volume clearly increases the amount of micro-pores within the matrix of the foamed concrete mix hence increasing the porosity.

The increase of OPA content beyond 25% clearly had a negative impact on compressive strength, water absorption and porosity of foamed concrete. The reduction in compressive strength was accompanied by an increase in water absorption and porosity, clearly indicating a strong relationship between these three parameters.

It can be concluded that sieved only OPA can be used as a cement replacement at an optimum level of 25% by weight of cement. Even a 35% replacement can be used in producing semi-structural components since it exhibited properties near to that of the control mix. Hence, due to the decreased amount of cement, decreased amount of foam and the utilisation of a cheap waste, a greener and cheaper foamed concrete mix is produced.

Summary:

OPA, a waste produced by the palm oil industry, is used as a partial cement replacement. OPA has been sieved through a 300µm sieve and the passing was used to partially replace cement at levels of 25, 35, 45, 55 and 65%. Results show, that the addition of OPA to the foamed concrete mix reduces foam quantity and increases the water-solids ratio. A foamed concrete mix with a replacement level of 25% of sieved only OPA exhibited higher compressive strengths than that of the control mix. In addition, the same mix exhibited lower water absorption and lower porosity readings than those exhibited by the control mix. Increasing the OPA replacement level beyond 25% decreased the compressive strength, increased water absorption readings and increased porosity. However, all foamed concrete mixes with OPA content showed compressive strength development, and decreased water absorption and porosity readings with age. Hence, hinting a pozzolanic reaction occurring with the matrix of the OPA foamed concrete mix. The incorporation of sieved only OPA in the production of foamed concrete not only produced a greener mix because of its waste utilisation but also a cheaper mix due to the decreased amounts of both cement and foam.

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