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Research paper

Strength of Blended Cement Mortar Containing Palm Oil Fuel and Eggshell Ashes

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Abstract

This study investigated characteristics strength of blended cement mortar containing palm oil fuel ash (POFA) and eggshell powder (ESP). POFA and ESP were easily sourced from palm mills and bakeries. POFA was dried in the oven at 105-110 °C for 24 hours while ESP was sun-dried. Cement in mortar partially substitute 20% by weight of cement by both ashes to form their cement blends. POFA is divided into two groups which is unground POFA (UPOFA) and ground POFA (GPOFA). A total of 36 mortar cube of 100mm x 100mm x 100 mm was tested at curing ages of 28 days for determination of compressive strength. The recommended mix design of 1: 3 and the 0.5 water / cement ratio was adopted referred to the BS EN 196-1: 2015 standard specification. Then, the XRD testing was conducted for the highest compressive strength value of blended mortar and control mortar. The results show that the blended mortar C80GP16E4 gives the highest compressive strength of 21.3 MPa which increases by 6.5% compared to the control mortar, 20 MPa. For mortars containing only 20% replacement of UPOFA or GPOFA, they give 17.4 MPa and 14.3 MPa compressive strength respectively. An increase of 21% for GPOFA. This is due to the high fineness of POFA providing more surface area that filled the voids between cement and aggregate. The paper concludes that POFA and ESP separately or as a binary blends can be adopted as a partial substitute for cement in mortar production but must not exceed 20% cement weight.

Keywords: *Palm Oil Fuel Ash; Eggshell Powder; Compressive Strength; X-ray Diffraction; X-ray Fluorescence*

1. Introduction

Affordable products with advanced properties are necessary towards the higher human development and sustainable economic growth. Therefore, reusing the abundant waste materials has become necessary.

The use of these waste material products like palm oil fuel ash (POFA), egg shell powder (ESP), fly ash (FA), rice husk ash (RHA) and silica fume (SF) is not only one of the solutions to environmental and ecological problems. Some of this product is already shown very effectively in improving the microstructure and consequently the durability properties of concrete which is difficult to achieve by the use of pure ordinary Portland cement (OPC) [1], [2].

POFA is one of the waste materials that can be used as replacement for cement in mortar. Substituting POFA as cementing materials in construction industry will reduce the environmental problems without disposing it in landfills [3]–[5]. Many studies have been done on the partial replacement of cement by POFA. POFA has low pozzolanic reaction due to its large particle size and porous structure. But it can be improved by grinding process [6]–[9].

Eggshells are known to have good strength characteristics when mixed with concrete. Most of the eggshell waste is commonly disposed in landfills without any pretreatment because it is traditionally useless. The use of eggshell ash in mortar production reduced the cost of raw material and contributes to the construction industry.

Eggshell contains a very pure form of calcium carbonate or limestone which is called as calcium carbonate (CaCO3). The substitution of ESP into the OPC also can be used to decrease the setting time in cement [10].

2. The Aim of Research

Investigations were systematically conducted on performance of POFA and ESP mortar on compressive strength. The control and replacement spesimen were tested for 28 days. Based on the test results, the effect of POFA fineness and ESP substitution on mortar properties was discussed. The proper utilization of waste by integrating it into mortar production and possibly reducing construction cost.

3. Materials and Test Methods

3.1 Collection and Preparation of Palm Oil Fuel Ash and Eggshell Waste Powder.

In this study, POFA was obtained from a factory in Johor, the southern state of Malaysia. After collection, POFA is dried in oven at 105-110 °C for 24 hours. POFA is divided into two groups namely unground POFA (UPOFA) as in Figure 1(a) and ground POFA (GPOFA) as illustrated in Figure 1(b). To increase fineness, POFA are then ground to ensure 1-3% retained on sieve 325 (45 μm) complying the requirement of ASTM C618.

Eggshell as demonstrated in Figure 2(a) that has been used in this study is obtained from bakeries, restaurants and stalls. Collected eggshells are cleaned with tap water and then dried to remove egg, egg yolks and others. It is then ground to ensure 1-3% is retained on sieve 325 (45 μm) to comply with ASTM C618 requirements as shown in Figure 2(b).

(a) (b)

Figure 1: (a) Unground POFA and (b) Gound POFA

(a) (b)

Figure 2: (a) Egg shells and (b) egg shell powder after ground

3.2 Concrete Materials and Mixes

In this study, three group mortar mixes were made identified as A, B and C. The groups and relative proportions of mixtures are shown in Table 1.

Group A is 100% OPC and acted as the control mortar. Group B is a replacement of 20% OPC by weight with a combination of UPOFA and ESP. Meanwhile, the third group, C is OPC which is replaced by 20% GPOFA and ESP.

Ordinary Portland cement (Type 1) was used in the study. Fine aggregates with dry conditions are used to ensure that they do not affect the water cement ratio during mixing. The water source used is regular treated water coming directly from the laboratory pipes.

Table 1: Mix design proportions of OPC, POFA and ESP

No	Group	Mix design	OPC (%)	UPOFA (%)	GPOFA (%)	ESP (%)
1	A	C100	100	-	-	-
2	B	C80UP0E20	80	-	-	20
3		C80UP4E16	80	4	-	16
4		C80UP8E12	80	8	-	12
5		C80UP12E8	80	12	-	8
6		C80UP16E4	80	16	-	4
7		C80UP20E0	80	20	-	-
8	C	C80GP0E20	80	-	-	20
9		C80GP4E16	80	-	4	16
10		C80GP8E12	80	-	8	12
11		C80GP12E8	80	-	12	8
12		C80GP16E4	80	-	16	4
13		C80GP20E0	80	-	20	-

3.3 Determination of Compressive Strength

The mortar proportions by mass shall be one part of the cement, three parts of sand (1:3) and one half part of water (water/cement ratio 0.50) was adopted accordance to BS EN 196-1:2015.

The moulds with size 100 x 100 x 100 mm were cleaned and oiled to ease demoulding. The specimens were left in the open air for 24 hours before demoulding and cured by complete immersion in water. Three cube specimens were cast for each of the each mix proportion making a total of 39 specimens. The cube specimens were tested for compressive strength at 28 days.

3.1 Determination of X-ray Diffraction

The silica content of OPC, POFA and ESP is determined by X-Ray Diffraction (XRD) analysis using the Bruker AXS D8 Advance Equipment. The XRD was conducted to determine whether the materials are in crystalline or amorphous state.

The mortar mix design selected for this test is the highest compressive strength value and the control mortar. The small amount of mortar powder was placed on the XRD plate. Then, the sample was compacted using the thin glass plate and ready to be tested under the XRD testing is as shown in Figure 3.

Figure 3: Mortar sample of mix C80GP16E4 for XRD testing

4. Analysis and Discussion

4.1 Compressive Strength of Mortar

The results of partial replacement of the cementing the mortar with UPOFA and ESP gave a compressive strength between 14% and 20% as illustrated in Figure 4. The highest compressive strength blended mortar for group B is 16.9 MPa which is C80UP12E8 mixture containing 80% OPC, 12% UPOFA and 8% ESP. However, it can't overcome the compressive strength of the control mortar with 20 MPa. The lowest compressive strength is 14.3 MPa which is replaced by 20% UPOFA only.

The compressive strength for the group C which is GPOFA and ESP blended mortar are presented in Figure 5. The figure showed that the compressive strength of blended mortar with GPOFA and ESP typically greater than group B with the same mix design proportion. It is only distinguished by POFA fineness. Furthermore, OPC mortar mix containing 80% OPC, 16% GPOFA and ESP 4% gave a higher compressive strength of 21.3 MPa compared with control mortar. The lowest compressive strength is 14.6 MPa with the replacement of only 20% ESP.

The higher compressive strength that contains only 20% replacement of UPOFA or GPOFA are 17.4 MPa and 14.3 MPa, respectively. An increase of 21% for GPOFA. This is due to the high fineness of POFA gives more surface area which filled the voids between the cement and aggregates. [11], [12].

The replacement of 20% ESP resulted in lower compressive strength range of 14.6%.The fine particle size of POFA is the main cause of pozzolanic reaction and calcium content of ESP enhancement in compressive strength.

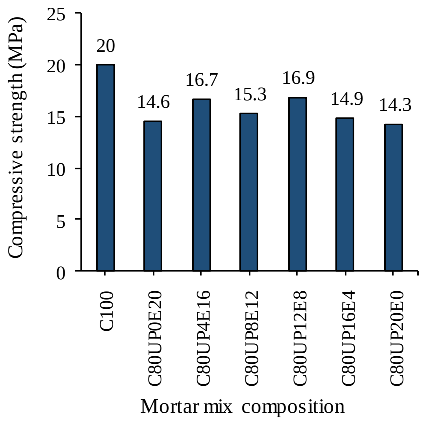

Figure 4: Compressive strength or mortars containing UPOFA and ESP at 28 days

4.2 X-ray Diffraction

X-ray Diffraction testing was conducted to determine the crystal structure of OPC 100% and the design mix that obtained the maximum strength in compressive strength test which is C80GP16E4. Figure 6 shows the XRD analysis for the presence of quartz and calcium silicate. The presence of quartz in C80GP16E4 was higher than C100 while for the presence of calcium silicate, C100 was higher than the C80GP16E4. Quartz is a chemical compound consisting silica and oxygen.

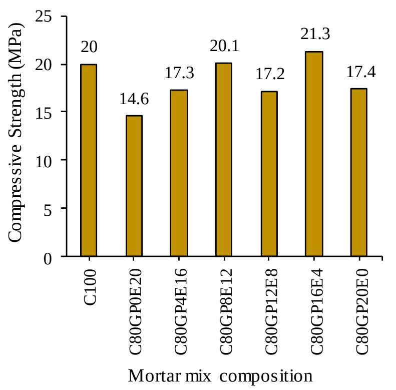

Figure 5: Compressive strength or mortars containing GPOFA and ESP at 28 days

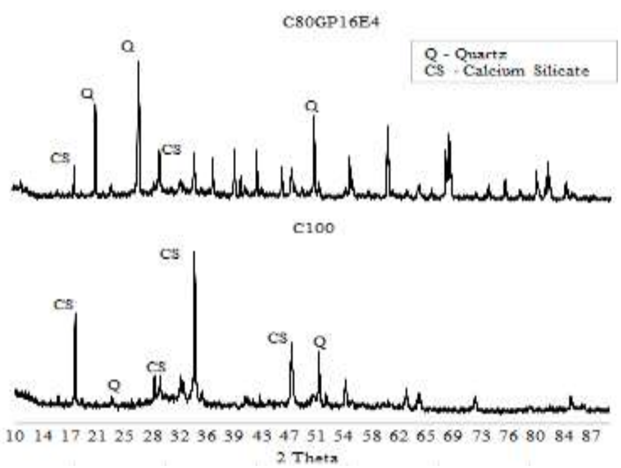

Figure 6: XRD analysis of OPC 100% and mix C80GP16E4 mortars at 28 days.

5. Conclusion

Palm oil fuel ash can be used in mortar production as a retarder. However, egg shell powder can be used as an accelerator in mortar. POFA and ESP separately or as binary blends can be adopted as partial substitute material for cement in mortar production but should not exceed 20%. The fine POFA provides more silica for pozzolanic reaction because it has a larger surface area.

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References

[1] W. Kroehong, T. Sinsiri, C. Jaturapitakkul, and P. Chindaprasirt, “Effect of palm oil fuel ash fineness on the microstructure of blended cement paste,” *Constr. Build. Mater.*, vol. 25, no. 11, pp. 4095–4104, Nov. 2011.
[2] W. Tangchirapat, C. Jaturapitakkul, and K. Kiattikomol, “Compressive strength and expansion of blended cement mortar containing palm oil fuel ash,” *J. Mater. Civ. Eng.*, no. August, pp. 426–431, 2009.
[3] N. K. Vasoya and H. R. Varia, “Utilization of various waste materials in concrete a literature review,” *Int. J. Eng. Res. Technol.*, vol. 4, no. 04, pp. 1122–1126, 2015.
[4] R. Karim, M. Hossain, M. Nabi, N. Khan, M. Fauzi, M. Zain, M. Jamil, and F. C. Lai, “On the Utilization of Pozzolanic Wastes as an Alternative Resource of Cement,” pp. 7809–7827, 2014.
[5] A. J. Patel, S. P. Patel, D. Prajapati, and H. Patel, “Literature review on different waste materials use in concrete,” *J. Emerg. Technol. Innov. Res.*, vol. 1, no. 7, pp. 899–902, 2014.
[6] O. U. Orie and O. J. Omokhiboria, “Mechanical properties of eggshell and palm oil fuel ashes cement blended concrete,” *Res. J. Eng. Appl. Sci.*, vol. 3, no. 6, pp. 401–405, 2014.
[7] W. Y. W. Yusof, S. H. Adnan, Z. Jamellodin, and N. S. Mohammad, “Strength Development of Fine Grained Mortar Containing Palm Oil Fuel Ash as a Partial Cement Replacement,” *Appl. Mech. Mater.*, vol. 774, pp. 964–968, 2015.
[8] M. R. Karim, M. F. M. Zain, M. Jamil, and F. C. Lai, “Significance of Waste Materials in Sustainable Concrete and Sustainable Development,” in *International Journal of Biotechnology and Environmental Management*, 2011, vol. 18, pp. 43–47.
[9] N. H. Abdul Shukor Lim, M. A. Ismail, H. S. Lee, M. W. Hussin, A. R. Mohd Sam, and M. Somadi, “The effects of high volume nano palm oil fuel ash on microstructure properties and hydration temperature of mortar,” *Constr. Build. Mater.*, vol. 93, pp. 29–34, 2015.
[10] D. Gowsika, S. Sarankokila, and K. Sargunan, “Experimental investigation of egg shell powder as partial replacement with cement in concrete,” *Int. J. Eng. Trends Technol.*, vol. 14 (2), no. August, pp. 65–68, 2014.
[11] W. Tangchirapat, C. Jaturapitakkul, and P. Chindaprasirt, “Use of palm oil fuel ash as a supplementary cementitious material for producing high-strength concrete,” *Constr. Build. Mater.*, vol. 23, no. 7, pp. 2641–2646, Jul. 2009.
[12] A. S. M. Abdul Awal and S. I. Abubakar, “Properties of Cocrete Containing High Volume Oil Fuel Ash: A Short Term Investigation,” *Malaysian J. Civ. Eng.*, vol. 23, no. 2, pp. 54–66, 2011.