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EFFECT OF CERAMIC AGGREGATE ON HIGH STRENGTH MULTI BLENDED ASH GEOPOLYMER MORTAR

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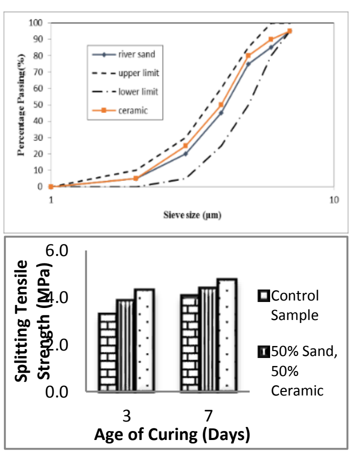
Graphical abstract



Abstract

Geopolymer is a type of amorphous alumino-silicate cementitious material, synthesized by the reaction of an alumina-silicate powder with an alkaline solution. The geopolymer technology has recently attracted increasing attention as a viable solution to reuse and recycle industrial solid wastes and by-products. This paper discusses the performance of geopolymer mortar comprises of multiple blended ash of palm oil fuel ash (POFA), pulverized fuel ash (PFA) and ground granulated blast furnace slag (GGBFS) by replacing ordinary Portland cement. Fine aggregate obtained from the ceramic waste was used to partially replace normal sand in the mixture. The concentration of alkaline solution used was 14 Molar. The fresh mortar was cast in 50x50x50 mm cubes geopolymer mortar specimens and cured at ambient temperature for 24 hours. The effects of mass ratios of alkaline solution to multiple blended ashes and percentage of ceramic aggregate as sand replacement on compressive, flexural and tensile strength of mortar were examined. The results revealed that as the multi blended ash (GGBFS: PFA: POFA) mass ratio increased, the compressive strength of geopolymer mortar is increased with regards to the ceramic aggregate properties.

Keywords: Geopolymer mortar, ceramic aggregate, POFA, GGBS, PFA

1.0 INTRODUCTION

In manufacturing of ordinary Portland cement huge amount of carbon dioxide (CO_2) is released in atmosphere. Geopolymer technology is one of the new technologies attempting to decrease the usage of OPC [1-3]. Geopolymer is a developed technology, where most of research work has been done using class F pulverized fuel ash as filler, because Si-Al minerals present in it reacts with alkaline solutions which consequently produces a three dimensional polymeric structure consisting of Si-O-Al-O [4, 5].

Malaysia is the second biggest producers of palm oil producers in the world. Palm oil by-products, are burnt in the boiler to produce electricity. The ash produced from burnt palm oil by-products in boiler contains huge amount of silicate (SiO_2) which is one of the main components in producing geopolymer. This POFA has pozzolanic properties (proven by previous research) and has been successfully used in the improvement of strength and durability of concrete [6-10].

Although large amount of POFA is dumped in the landfill it is estimated that total volume of solid waste generated in palm oil industry is about 10 million per year. Previous researchers use pulverized fuel ash in producing geopolymer concrete which improve strength and durability performance because ratio of silica to alumina is high [11]. This research is part of an experimental work which focuses on the possible use of ceramic waste from a local ceramic manufacturer.

2.0 METHODOLOGY

2.1 Materials

POFA was originated from burning of palm oil waste (in equal volume) from a mill in Johor. The obtained ashes were greyish and the losses on ignitions (LOI) were 1% for PFA and 18% for POFA [12]. PFA from Kapar power plant, Selangor, Malaysia was used. GGBFS is white in colour obtained from a factory in Johor. The chemical compositions of PFA, GGBFS and POFA are given in Table 1. Multiple blended ash was activated by alkaline solution [13].

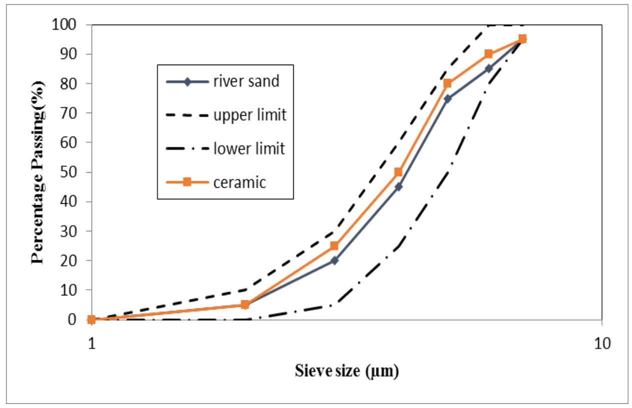


Figure 1 Sieve analysis for river sand ceramic aggregate

2.2 Preparation of Specimens

The multi blended ash, ceramic aggregate and river sand were dry mixed for around two minutes. Then water and a high range water reducing Naphthalene Sulphate based superplasticizer (SP) were added to the mix and continuous mixing for another 6 minutes . The mortar specimens were placed in the mould of 50 x 50 x 50 mm cubes. The samples for splitting tensile strength were cast in the cylinder mould of 100mm in diameter and 200mm height according to ASTM C496-11. Specimens for flexural strength were cast in a prism mould having measurement of 40x40x160 mm.

Table 1 Chemical composition of OPC and Ceramic Powder

	Chemical composition (%)					
	SiO_2	Al_2O_3	Fe_2O_3	CaO	K_2O	LOI
GGBFS	33.80	13.68	0.40	42.56	-	1.81
PFA	46.70	35.90	5.00	3.90	0.50	1.00
POFA	53.50	1.90	1.10	8.30	6.50	18.00

The river sand for casting was modified according to ASTM C33-13. Figure 1 shows the sieve analysis of river sand which is used in this research and the ceramic aggregate. The ceramic waste were crushed in jaw crusher machine and after that sieved by a series of sieves according to ASTM standard C33-13.The fine aggregate shall satisfy the limitation which is mentioned in the standards. After grading, the ceramic aggregate was used as sand replacement [14-16]. The percentage of sand replacement was varied to get the best mix design. The range of Na(OH) concentration used in this research was 14 molar. For improving the workability of mortar, extra water mixed with super plasticizer was added during the mixing process.

The specimens were demoulded 4 hours after casting and left at ambient temperature until testing. The mix proportions of the geopolymer mortar is shown in Table 2.

Table 2 Mix proportions of mortar

Materials	Mortar mix		
	Control (Sample1)	50% (Sample 2)	100% (Sample 3)
MBA* (kg/m^3)	1150	1150	1150
Ceramic (kg/m^3)	-	575	1150
Sand (kg/m^3)	1150	575	-
A/C ratio**	0.2	0.2	0.2
SP (%)	2	2	2

*Multi blended ash
**Alkaline solution/ cement ratio

3.0 RESULTS AND DISCUSSION

3.1 Compressive Strength

The compressive strength of mortar with different percentage of ceramic aggregate as river sand replacement is shown in Figure 2. At one day curing period, all specimens have reached the strength of 40MPa. The control sample shows an increment of 10 to 32% from 3 days to 7 days of age. While, the cubes containing 50% and 100% ceramic content as sand replacement have shown an increment of 44% to 63% respectively. The specimen with 100% ceramic content has achieved 80MPa compressive strength at 7 days. This is may be due to high amount of SiO_2, CaO and Al_2O_3 in multiple blended ash and ceramic aggregate which give high reaction of N-A-S-H and C-A-S-H of multiple blended ash combined with the alkaline solution in producing a high strength of geopolymer mortar characteristic.

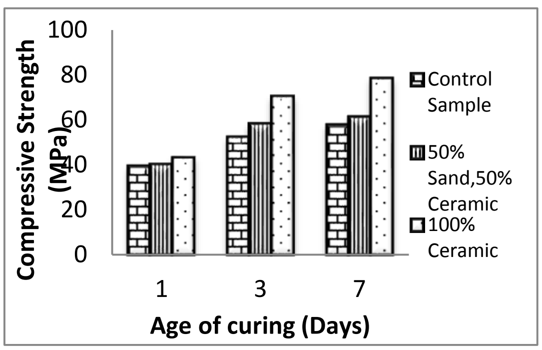


Figure 2 Compressive strength of mortar with river sand and ceramic aggregates

3.2 Splitting Tensile Strength

The splitting tensile strength of all specimens shown in Figure 3 displayed a similar pattern to compressive strength. At the age of 3 days, the specimens with 50% and 100% ceramic aggregate as sand replacement, the tensile strength increased about 18% and 31% respectively compared to the control samples. The increment of strength at 7days curing slightly increased for about 8% and 17% more than the control samples.

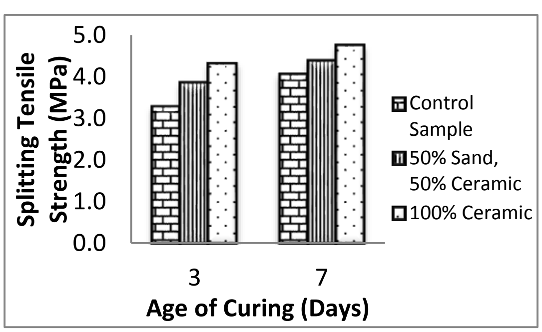


Figure 3 Splitting tensile strength of mortar with river sand and ceramic aggregates

3.3 Flexural Strength

Figure 4 shows the flexural strength containing different percentages of ceramic aggregate as river sand replacement. The results show that the age of curing has quite significant effect on flexural strength of the samples. The strength increment after 7days of 100% ceramic aggregate replacement is almost double. The strength increment of the control sample for 3days and 7days is 3.28 MPa and 7.22MPa respectively compared to 4.27MPa and 9.06 MPa of the samples with 100% ceramic aggregate after 3days and 7days curing period.

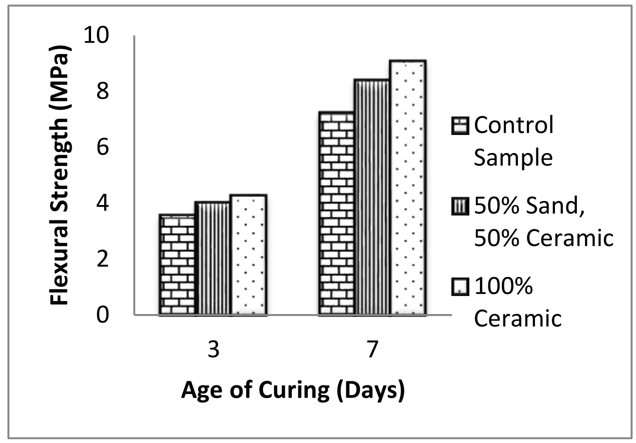


Figure 4 Flexural strength of mortar with river sand and ceramic aggregates

4.0 CONCLUSIONS

The use of ceramic aggregate as replacement of river sand has positive effect by producing high compressive strength, splitting tensile strength and flexural strength at all curing ages. Gaining strength in the samples containing ceramic aggregate as river sand replacement is faster than control samples. In all testing of compressive, splitting tensile and flexural strengths, the 100% ceramic aggregate as river sand replacement displayed better results than control speciments. The strength of samples with 100% ceramic aggregate as river sand replacement showed a significant increment at 7 days, it was 35% more than the control samples. Thus, by totally replacing river sand with ceramic aggregate can protect natural recourse as well as produce high strength geopolymer mortar.

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