Influence of Eco Process Pozzolan on the properties of Foamed Concrete

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Abstract. Present research studies the effect of Eco Process Pozzolan (EPP) on the properties of foamed concrete as replacement for cement. Uses of EPP replace cement in the proportions of 10, 20, 30, and 40 percent by weight of binder. The influences of EPP as partial cement replacement on workability, density, compressive strength, and water absorption of foamed concrete have been reported. Results indicate that EPP significantly improved the compressive strength of foamed concrete and other properties also performed well which behaviours are comparable to normal concrete.

Introduction

Today, the world is moving to a new direction by looking for lighter, durable, practical, economic and environmentally sustainable materials to answer the demand of modern construction. Foamed concrete is the combination of cement paste and preformed foams that causes the foam concrete to be lighter than normal concrete. In recent years, foamed concrete has shown the potential to fulfil all the requirements as the new alternative material. Scores of research [1],[2],[3],[4],[5] have shown that the unique properties of low density, flowing and self compacting, excellent sound and thermal insulation can greatly benefit the construction industry. More useful characteristics of the foamed concrete are presented in other studies [6],[7],[8],[9],[10].

Moving forward, McCarthy & Jones[11] have reported a number of innovative research done on foamed concrete. All are good except that it is hard to achieved high strength. Although there are many uses of foamed concrete related to the construction industry, unfortunately engineers and designers are not highly supportive or not giving serious attention to such ability for structural application due to the lower strength. Presently, its density is within the low range of 240-1900 kg/m^3 and the 28 days compressive strength is between 0.3 to 15 MPa which could be used to fill in void and trench reinstatement. Unless the strengths of at least 25 MPa can be achieved, then and only then, it can be used for structural application.

For the past few years, studies on the high strength of foamed concrete have been undertaken and researchers have investigated several ways to resolve the problems (low strength, high permeability, easily cracking). Kearsley and Wainwright [12],[13],[14],[15] concluded that although porosity affects compressive strength, it does not affect the fly ash or cement content. Porosity was found to be mainly dependant on the dry density of foamed concrete. On the other hand, the optimum ash content resulted in the highest compressive strength for a given porosity and the strength increases with age. Increasing numbers of researches on foamed concrete used for structural lightweight concrete are focusing on the effect of the minerals admixtures and fibres reinforcement [16],[17],[18],[19],[20]. The high strength lightweight concrete can be achieved with or without mineral admixtures but the use of chemical admixtures is mandatory to get the appropriate strength. In this study, the aim is to assess the influence of EPP as the partial cement replacement in the foamed concrete properties.

Methodology

Materials. The type of cement used is gred 32.5 MPa Ordinary Portland cement Type I (OPC) produce by Lafarge Cement Sdn. Bhd. Fine sand used is manufactured by Johor Silica Industries Sdn. Bhd. Hydrolyzed protein foaming agent and foam machine are locally manufactured by LCM Technology Sdn. Bhd Kuantan, Pahang. Eco Process Pozzolan (EPP) used in this study was provided by Eco Innovation Sdn. Bhd. The chemical composition of OPC and EPP used in this study are presented in Table 1. EPP was classified as Class N Natural Pozzolan in accordance with ASTM C618-12 (2012)

Table 1 : Chemical composition of EPP and OPC

Parameters	CaO %	SiO_2%	Al_2O_3%	Fe_2O_3%	MgO%	SO_3%	Loss on Ignition %
OPC	55.49	26.49	9.81	3.9	0.8	4.72	0.88
EPP	6.6	55.82	13.48	8.24	5.94	1.05	0.18

Mix Proportion. In this study, the mix proportion has been summarized in Table 2 which are the properties of foamed concrete containing different percentages of EPP were compared to control mixture M (100% OPC without foam) and FC (100% OPC with foam).

Table 2 : Mix proportion of foamed concrete

Mixture	kg/m^3	s/c	w/c	Cement	EPP	Sand	Foam
M	2143	1.5	0.5	714.5	-	1072	-
FC	1600	1.5	0.5	535.9	-	803.8	250
10EPPFC	1600	1.5	0.5	482.3	53.6	803.8	250
20EPPFC	1600	1.5	0.5	428.7	107.2	803.8	250
30EPPFC	1600	1.5	0.5	375.1	160.8	803.8	250
40EPPFC	1600	1.5	0.5	321.5	214.4	803.8	250

Preparation process. Foamed concrete is the combination of cement, fine sand, water and preformed foams. In this study, preformed foam has been prepared by diluting 1 liter of foaming agent with 25 liters of water into the foam machine where the density of foam should be in the range of 50 to 60 kg/m^3. Then foam is added into the cement paste and mixed continuously until there was no sign of foam during the mixing and the slurry become homogenously mixed as shown in Figure 1. Filled the fresh mix into the cube specimens size 100x100x100 mm and removed from the mould after 24 hours. All the equipment, materials and procedures in producing foamed concrete have been implemented according to ASTM C796 [21].

Figure 1: Production of foamed concrete

Testing procedure. The flow table test used to measure workability of foamed concrete has been followed by the procedure of ASTM C1437 [22]. The fresh density and oven dry density of foamed concrete were determined as per ASTM C796-12 and C513-11[23]. The water absorption of foamed concrete was performed according to ASTM C642-13 [24]. The compressive strength of foamed concrete was carried out following the ASTM C513-11.

Data Analysis

Workability. Figure 2 illustrated the workability of mixture M, FC and four different percentages of EPP. The flow diameter values, a measure of workability decreased as the increased percentage of EPP in the foamed concrete. The results show 10%, 20%, 30% and 40% EPPFC mixture have 215mm, 205mm, 200mm and 150 mm flow diameter respectively. The reduction in the workability of mix when EPP is added is probably due to increased particle surface of fine EPP compare to cement. This fact has been highlighted by a researcher [27] who stated that due to the small particle size and relatively higher surface area of pozzolan particles. Similarly previous researchers [25],[26] reported that concrete made with pozzolan materials has less workability than control specimen produced of 100% cement.

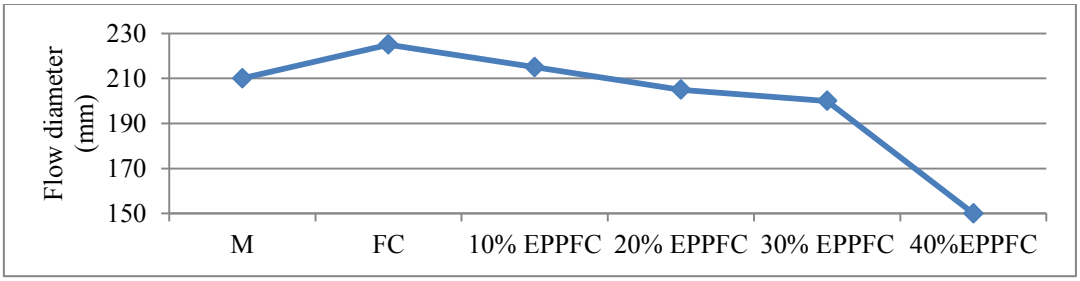

Figure 2: Workability of foamed concrete

Density. Figure 3 shows the oven dry density of foamed concrete mixture. It can be observed that density of control mixture M and FC were higher than density of EPP content for both curing method. The higher the EPP content in the mixture the lower is the density due to specific gravity of the cement which is more than EPP. It can be concluded that for the concrete or mortar made with pozzolan materials which has lower density than the control specimen produced of 100% of cement has similar agreement with available study on pozzolan materials[25][26].

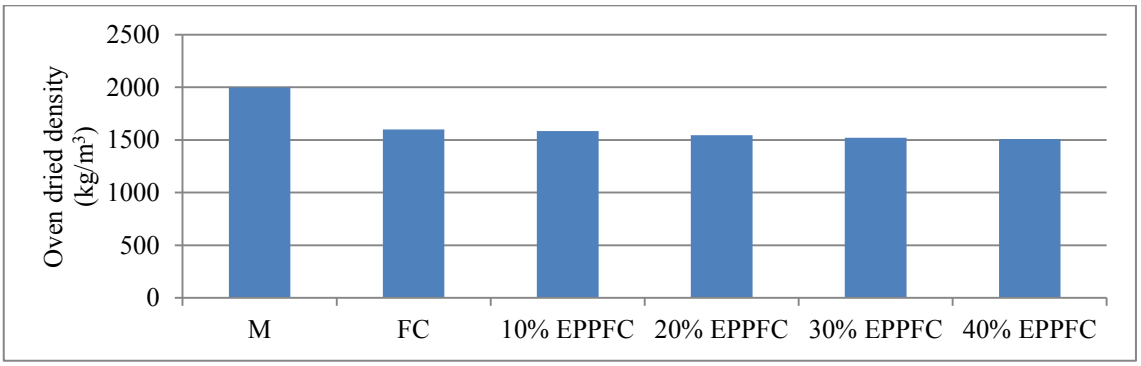

Figure 3: Oven dried density of foamed concrete

Water absorption. Figure 4 shows the water absorption of foamed concrete mixture. For all mixes, the water absorption decreased as the curing period increased from 3 to 28 days for both curing method. It is also can be observed that water absorption decreased with the increase in the percentage of EPP as cement replacement. Among all the different percentage of replacement, 30% EPPFC mixture performed the best result when compared to control sample M. The reduction in the water absorption of mix when EPP was added is probably due to the particle size of EPP which is less than that of cement therefore it can pack the binder phase. Secondly, the decrease was due to the fact that chemical reaction between natural pozzolan and calcium hydroxide of hydrated cement paste was lime consuming instead of lime producing as similarly observed by others [25]. Also [26] reported that water absorption decreased with the pozzolan materials substitution up to 30% thus testifying the results.

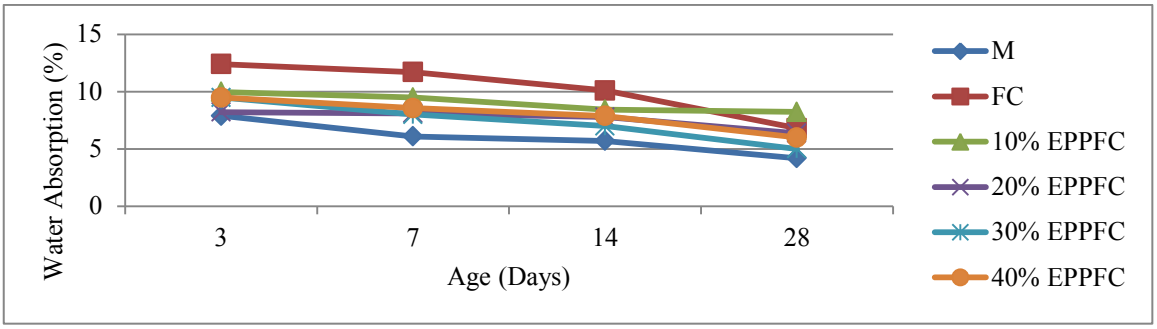

Figure 4: Water absorption of foamed concrete

Compressive strength. Figure 5 shows the compressive strength of foamed concrete. For all mixes, the compressive strength increased as the curing period increased from 3 to 28 days for both curing method. The compressive strength of control mixture M produced of 100% cement was higher than FC and EPP mixture. However, the compressive strength of foamed concrete containing EPP was higher than control FC. It can be observed that at all the ages of testing, the compressive strength increased with the increase in the percentage of EPP as cement replacement. Among different percentage of replacement, 30% and 40% EPPFC mixture performed the best where the value resulted in 20% lesser than control sample M. The reduction in the compressive strength of mix when EPP was added is probably due to the strength gain for pozzolan materials is slow at early ages. Similar trend of compressive strength development of foamed concrete due to pozzolanic effect broadly followed the patterns of concrete or mortar made with pozzolan materials as reported by others [25][26] that the strength gain for pozzolanic reaction takes place at slower rate than the hydration of cement.

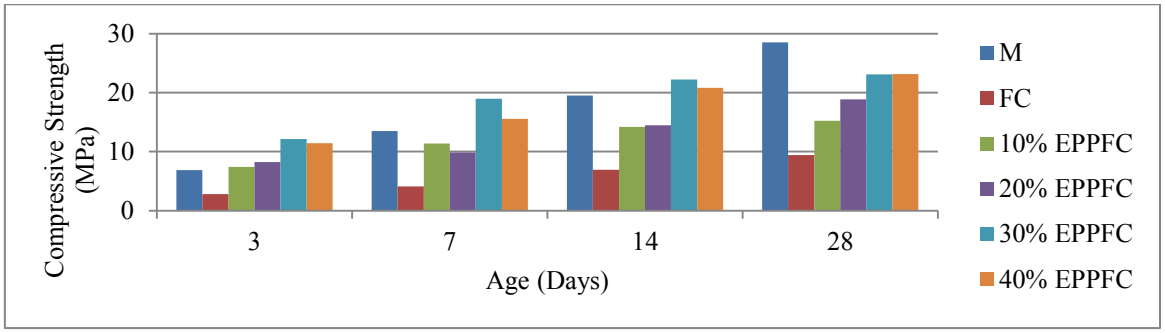

Figure 5: Compressive strength of foamed concrete

Conclusion

Based on the experimental results, it can be concluded that EPP has a significant impact on the foamed concrete properties. It was found that 30% EPP partial replacement for cement provided greater compressive strength and performed better result in foamed concrete properties compared to control FC mixture. Increasing EPP replacement decreases the density of the specimen and water absorption. In practical, the partial replacement of cements by pozzolan is known to improve the mechanical strength because chemical reactions of pozzolanic occurred when the Al_2O_3 and SiO_2 react with calcium hydroxide $(Ca(OH))_2$ to create additional Calcium Silicate Hydrates (C-S-H) and Calcium Aluminate.These conclusions point out that the use of EPP as a replacement for cement is highly useful in developing the compressive strength of foamed concrete.

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