

Effect of Palm Oil Fuel Ash as Partial Cement Replacement on Strength of Foamed Palm Oil Clinker Concrete

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Abstract—Malaysia, being one of the largest palm oil producer in the world generates increasing amount of by-products namely palm oil clinker and palm oil fuel ash which usually dumped as environmental polluting waste. At the same time, increasing sand mining activities to meet the need of construction industry has arisen the concern of researchers on the negative impact of the activity towards environment when it is carried excessively. With the aiming these problems, researcher has looked into the possibilities of producing foamed palm oil clinker concrete containing palm oil fuel ash as a supplementary admixture. The present research investigates the strength performance of foamed palm oil clinker concrete when palm oil fuel ash is added as partial cement replacement. All specimens were cast in form of cubes and then subjected to continuous water curing. The compressive strength test was carried out at 7 and 28 days. The findings show that the strength performance of foamed palm oil clinker concrete is influenced by amount of palm oil fuel ash integrated in the mix. Addition of palm oil fuel ash at 10% successfully enhances the compressive strength of the lightweight concrete. Integration of solid wastes from palm oil industry in foamed concrete production would contribute towards a more environmental friendly palm oil industry and able to provide the contractors with locally made sustainable lightweight construction material.

Keywords—palm oil clinker; palm oil fuel ash; foamed concrete; sand replacement; density; compressive strength

1. INTRODUCTION

Concrete is one of the widely used construction material globally. Throughout the years, the growing construction industry has led to production of concrete continue to increase which also directly causes more natural aggregate harvested from the environment. This results in negative impact to environment and serious depletion of aggregate for the use of future generation. Previous researcher [1] has pointed out that high demand for concrete supply has drastically reduced natural stone deposits and irreparable damages to environment. There are countries facing the shortage of natural fine aggregate suitable for construction [2]. Unless action taken to reduce the high dependency of the concrete industry on natural coarse aggregate and fine supply, more wildlife habitats would be destroyed leading to their extinction in future. Approach of integrating waste from industries as replacement of aggregate totally or partially would be able to reduce quantity of natural resources taken from the environment and also reduces the waste disposed as landfill. At the same time, palm oil industry which contributes to the prosperity of the country's economy is also producing a large amount of solid wastes that creates environmental pollution. Both palm oil clinker (POC) and palm oil fuel ash (POFA) is the by-product obtained after the pressed palm oil fibres, shells and empty fruit bunches is incinerated to generate electricity for the palm oil mill to operate. Palm oil clinker is pieces of solid material appearing like porous rock collected at the burning chamber. Abutaha et al. [3] stated that this material is generated in large quantities. Palm oil fuel ash is greyish form of ash which can easily be carried by the wind. It is normally dumped at the vicinity of the palm oil mill. Approximately 2 million tonnes of palm oil fuel ash were produced annually [4]. The negative impact of this waste towards the environment has been highlighted by [5, 6, 7, 8]. The practice of

dumping these wastes is seen as less effective practice since it leads to more landfill to be opened and also contributes towards increasing of environmental pollution issues in future. An alternative approach of utilizing these by-products as a raw in construction product would reduce amount of wastes ending at landfill and contributes towards cleaner environment. In order to solve of the problems related to natural sand issues and palm oil industry wastes, the current research investigates the possibility of integrating palm oil fuel ash as partial cement replacement in foamed palm oil clinker concrete production. The paper discusses the effect of palm oil fuel ash content as partial cement replacement towards workability and strength performance of foamed concrete.

2. EXPERIMENTAL PROCEDURE

A. Materials

Ordinary Portland cement (OPC) from a single source was used throughout the experimental work. Tap water was used for the process of mixing the concrete and curing. Foaming agent was used to produce foamed concrete. Both solid wastes, palm palm oil clinker (POC) and palm oil fuel ash were collected from a palm oil fruit processing factory located in a district of Pahang, West Malaysia. Fig. 1 and 2 illustrated the dumping area of palm oil clinker and palm oil fuel ash respectively. Both materials were transported from the mill to the laboratory using a four wheel drive transport. All the wastes were cleaned and processed before used in the foamed concrete production. The big chunks of palm oil clinker was crushed to be smaller size so that it is suitable to be used as fine aggregate replacement as shown in Fig.3. Palm oil fuel ashes (POFA) were ground to be fine enough fulfilling the requirement in [9] enabling to be used as partial cement replacement. Fig. 4 shows the finely ground palm oil fuel ash ready to be used. Based on the chemical composition tabulated in Table 1, the collected POFA is classified as pozzolanic material. It can be observed that POFA being a pozzolanic material contains higher amount of silicon dioxide and lower content of calcium oxide compared to ordinary Portland cement (OPC).



Figure 1: Palm oil clinker dumping site



Figure 2: Palm oil fuel ash disposal area



Figure 3: Palm oil clinker ready to be used



Figure 4: Finely ground palm oil fuel ash

Table 1: Chemical composition of ordinary Portland cement and POFA

Constituents	OPC	POFA
Silicon dioxide (SiO_2)	16.05	51.55
Aluminium oxide (Al_2O_3)	3.41	4.64
Iron (III) oxide (Fe_2O_3)	3.41	8.64
Calcium oxide (CaO)	62.28	5.91
Magnesium oxide (MgO)	0.56	2.44
Sodium oxide (Na_2O)	0.06	0.07
Potassium oxide (K_2O)	0.82	5.50
Sulfur trioxide (SO_3)	4.10	0.61
Loss of ignition (LOI)	1.2	5
BET Surface Area (m^2/g)	1.29	2.54

B. Mix Proportioning and Testing Procedure

Three types of mixes foamed palm oil clinker concrete containing different content of palm oil fuel ash as cement replacement have been used in this experimental work. The amount of cement, palm oil clinker and water used were kept constant for all mixes. Only the amount of palm oil fuel ash used is varied that is 0%, 10% and 20% by the weight of total cementitious material. All the mixes were casted in form of cubes and then covered with wet gunny sack overnight. After 24 hours, the hardened concrete specimens were removed from the mould and immersed in tank filled with tap water until the testing age. The casting process beginning from the process of mixing, casting, demoulding and curing is presented in Fig. 5, 6, 7 and 8 respectively. The compressive strength test is conducted on the specimen following the procedure in [10] at 7 and 28 days.



Figure 5: Foamed concrete mixing



Figure 6: Foamed concrete casting



Figure 7: Foamed concrete demoulding process



Figure 8: Foamed concrete curing process

3. RESULTS

Figure 9 shows that the compressive strength performance of foamed palm oil clinker concrete containing various percentage of palm oil fuel ash. Generally, all mixes exhibit continuous strength development as the curing age become longer. The application of continuous water curing has ensured the process for generation of calcium silicate hydrate (C-S-H) gel is uninterrupted. Plain specimen containing 100% OPC depends wholly on hydration process for strength increment. In contrast, specimens containing palm oil fuel ash undergoes another chemical reaction other than hydration process that is pozzolanic reaction. The available silica of palm oil fuel ash reacts with calcium hydroxide which is a by-product of hydration process to produce secondary C-S-H gel. The undisturbed reactions in the specimen's results in continuous strength gain along with age. The influence of curing method towards strength has been confirmed by [11] who stated that continuously water supply able to enhance the strength of concrete.

From the study, it is found that integration of suitable content of POFA as partial cement replacement can increase the strength of foamed palm oil clinker concrete. Addition of POFA at 10% exhibits the highest compressive strength that is 17.58 MPa as compared to all mixes. SiO_2 of ground POFA reacts with the Ca(OH)_2 released from cement hydration in the presence of water and forms secondary calcium silicate hydrate (C-S-H) gel. The formation of the C-S-H gel gives away more homogeneous densely packed microstructure with reduced micropores in concrete. This finding is in good agreement with [12] who suggests that fine pozzolanic material can increase the packing density of the cement matrix thus better strength were obtained. Similar trend of result has been reported by [13] whom incorporated pozzolanic ash as partial cement replacement in concrete. However, strength of concrete begins to drop to 6.9 MPa for compressive strength at 28 days respectively when 20% of POFA is used. Conclusively, inclusion of suitable content of palm oil fuel ash successfully enhanced the compressive strength of palm oil clinker concrete.

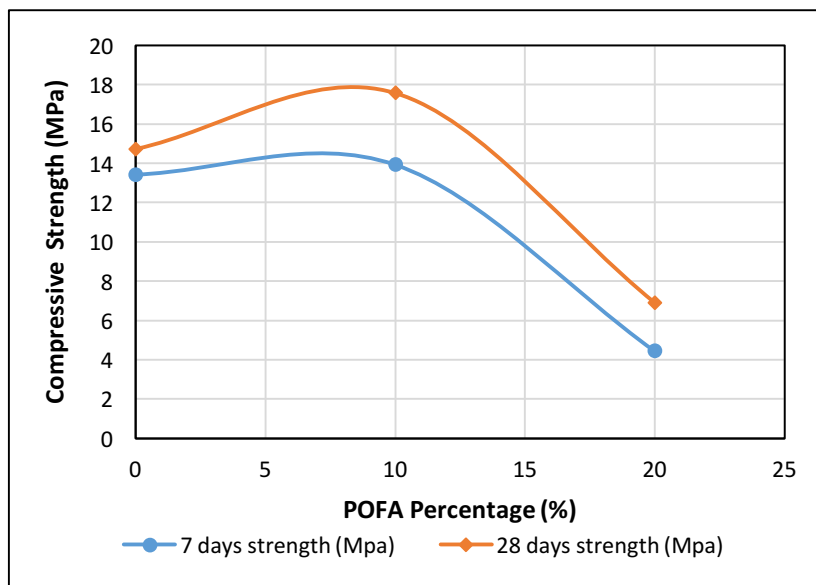


Figure 9: Compressive strength of foamed palm oil clinker concrete containing various percentage of palm oil fuel ash

4. CONCLUSION

The used of palm oil fuel ash as partial cement replacement influence the compressive strength and density of foamed palm oil clinker concrete. Inclusion of suitable content of palm oil fuel ash increases the compressive strength of foamed palm oil clinker concrete. Production of foamed concrete containing zero natural river sand with palm oil clinker functioning as fine aggregate and palm oil fuel ash as partial cement replacement able to save the use of river sand, decrease amount of palm oil industry wastes thrown as waste and also promotes towards lesser use of cement.

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