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Effect of Curing Regime on Compressive Strength of Aerated Concrete Containing Palm Oil Fuel Ash as Partial Sand Replacement

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Abstract

Issues on preservation of natural river sand from being used excessively in concrete industry has led to the efforts of utilizing palm oil fuel ash, a by-product from palm oil industry as partial sand replacement in production of aerated concrete. This paper reports the effect of curing regime on compressive strength development of aerated concrete containing palm oil fuel ash as partial cement replacement. Two types of mixes were used in this experimental work namely plain aerated concrete acting as control specimen and aerated concrete containing 30% palm oil fuel ash as partial sand replacement. Concrete cubes were subjected to different types of curing namely initial water curing for 7 days followed by air curing, water curing and air curing until the testing date. The compressive strength test was conducted in accordance to BS EN 12390-3 at 7, 14, 28 and 90 days. Application of water curing is the most suitable method to be applied to ensure better strength development in aerated concrete containing POFA as partial sand replacement. Continuous presence of moisture promotes better hydration and pozzolanic reaction leading to formation of extra C-S-H gel and that subsequently make the concrete denser and compressive strength higher.

Keywords: aerated concrete; palm oil fuel ash; partial sand replacement; curing regime; compressive strength.

1. Introduction

The present research stems out from two factors presented by two different industries in Malaysia that is solid waste disposal by palm oil industry and the increasing demand for natural sand for concrete production. The growing Malaysian palm oil industry has led to generation of the palm oil mill by-product known as palm oil fuel ash (POFA) which dumped in the landfill. The palm oil mill has been facing difficulties in disposing this abundantly generated waste [1]. In future, more dumping site needs to be allocated for this waste disposal and large sum of money is to be spent for the management of this waste unless this material is processed for other applications. So far, researches conducted since the end of 20th century have proposed this solid waste after processed to be used as partial cement replacement in various types of concrete [2-6]. Discovering other potential of this by-product would widen the application of this material and would reduce amount disposed as environmental polluting waste.

At the same time, the developing local construction industry demands for concrete material has become higher which indirectly increases the need for larger quantity of sand supply. Continuous sand mining from the natural environment would pose negative impact to the environment in terms of water pollution, ecological imbalance at river bed environment and also the possibility of this material to deplete in future. The negative impact of excessive sand mining was elaborated by Asyraf *et al*., [7]. This issue has motivated researchers [8 - 10] to investigate the potential of using waste materials as partial sand replacement material in concrete production. Success in integrating waste material as partial sand replacement in concrete would result in a more sustainable concrete product and cleaner environment. In view of environmental sustainability, Mat Yahaya [11] successfully incorporate 30% palm oil fuel ash as partial sand replacement in aerated concrete production. The positive contribution of palm oil fuel ash which manifested through the increment in aerated concrete strength performance has encouraged for more investigation in other aspects for determining the suitable application of modified lightweight concrete. Thus, this paper discusses the strength performance of this modified lightweight concrete upon exposure to different types of curing regimes.

2. Experimental Programme

2.1. Materials

Among the mixing ingredient used in the production of aerated concrete are ordinary Portland cement (OPC), river sand, potable water, aluminium powder, superplasticizer and palm oil fuel ash (POFA). POFA used in this research was obtained from a palm oil mill in the state of Johor, West Malaysia. The ashes were sieved passing 300 μm sieve to remove debris. Then it was oven dried before ground in a Los Angeles Abrasion Machine in order to reduce the particle size. Based on the chemical composition in Table 1, the processed ash is classified as pozzolanic material belonging to Class F as per ASTM C618-05 [12].

TABLE1: CHEMICAL COMPOSITION OF PALM OIL FUEL ASH

Chemical Composition	**POFA**
Silicon dioxide (SiO_2)	82.07
Aluminium oxide (AL_2O_3)	6.04
Ferric oxide (Fe_2O_3)	2.70
Calcium oxide (CaO)	5.11
Magnesium oxide(MgO)	2.28
Sodium oxide (Na_2O)	1.34
Pottasium oxide (K_2O)	2.90
Sulphur oxide (SO_3)	2.20
Loss of ignition (LOI)	5.30

2.2. Mix Proportion and Testing

Specimens were prepared in two sets, a control specimen consisting 100% OPC known as plain aerated concrete and another mix of OPC/POFA consisting the processed ash of 30%. The ash was mixed as a weight-for-weight replacement of sand in a constant quantity. Specimens were produced by adding constant quantity of sand, cement, aluminium powder and adequate water dry mix ratio. The mix proportion used to produce aerated concrete containing palm oil fuel ash as partial sand replacement is tabulated in Table 2.

The specimens were prepared by pouring the slurry aerated concrete mix into mould cubes (100 x 100 x 100 mm). The mixture was left to expand like a cake before trimming the excess of concrete. After that, the specimens were covered with wet gunny sack before demoulded after 24 hours. Then, specimens were placed in different curing environment namely water curing and initial water curing for 7 days followed by air curing, continuous water curing and air curing until the testing date. The compressive strength test was carried out in accordance to BS EN 12390-3 [13] at 7, 28 and 90 days.

TABLE 2: MIX PROPORTION OF AERATED CONCRETE CONTAINING PALM OIL FUEL ASH

Binder Sand Ratio	**30 : 70**
Ordinary Portland cement (%)	82.07
Palm oil fuel ash replacement (%)	6.04
River sand (%)	2.70
Water dry mix ratio	0.45
Aluminium powder (%)	0.2

3. Results and Discussions

The curing methods applied do influence the strength development of this lightweight concrete as illustrated in Figs. 1 and 2. Inclusion of palm oil fuel ash as partial sand replacement enhances the strength of aerated concrete. This probably owing to the palm oil fuel ash filling effect which increases the concrete packing density and pozzolanic reaction that contributes towards densification of concrete microstructure. Specimens subjected to water curing exhibit the highest compressive strength and continuous air cured aerated concrete possess lowest strength value. On overall, all specimens exhibit continuous strength development throughout the curing age which indicates the increment in the amount of C-S-H gel.

It is interesting to note, aerated concrete with palm oil fuel ash as partial sand replacement which has been placed in water curing condition for 7 days exhibit higher strength compared with control specimen even at the early age of curing. Integration of palm oil fuel ash as mixing ingredient in aerated concrete and at the same time maintaining the quantity of cement used has resulted in producing concrete with added value in terms of strength. Adding palm oil fuel ash has open the door for occurrence of reaction between silica from the ash and calcium hydroxide, a by-product of cement hydration in the continuous presence of moisture leading to formation of secondary C-S-H gel. The occurrence of hydration and pozzolanic reaction in aerated concrete containing POFA causes the total amount of C-S-H gel to become higher and thus the concrete strength to be better than plain specimen. Furthermore, the fine ash also functions as filler by filling in the existing voids which makes the concrete internal structure more packed and that leads to strength enhancement. Previous researcher, Isaia *et al.* [14] has highlighted that filler effect that takes place as the proper arrangement of small particles fill the voids and contribute to the increment of compressive strength without any chemical reaction. Both the filling effect and pozzolanic reaction initiated by palm oil fuel ash has contributed to positive strength achievement of aerated concrete.

Looking at the effect of curing regime on the concrete strength, it is evident that the strength development of concrete becomes varied when placed in different curing regime depending on the duration of water supplied to the specimens. Continuous supply of moisture allows undisturbed pozzolanic reaction to take place thus generating larger amount of C-S-H gel filling in the concrete pores. This helps the water cured concrete possess the most dense internal structure and thus being able to exhibit the highest strength compared to other specimens. Aerated concrete subjected to initial water curing for 7 days and then air curing for the rest of curing age, has provided conducive environment for formation of C-S-H gel during early stage whereby the specimens were immersed in water. After 7 days, when left in the open air, the reactions in the concrete were disrupted due to absence of water causing it to exhibit lower strength value compared to water cured specimen. The non-availability of water for air cured specimen retards the hydration and pozzolanic reaction leading to the least amount of total C-S-H gel and this caused the concrete to possess the lowest strength value.

Realizing that calcium silicate hydrate is a major strength-providing reaction product of cement hydration, which also acts as a porosity reducer resulting in a dense microstructure in concrete [15], it is justified that continuous water curing which able to produce largest amount of C-S-H gel is the most suitable curing method. Similarly, previous researchers [16, 17] has highlighted the suitability of continuous water curing for better strength performance of concrete containing palm oil fuel ash. On overall, all the three curing regimes applied in this experimental work can be applied to produce aerated concrete specimens containing palm oil fuel ash as partial sand replacement having adequate strength enabling it to be used for non-structural purpose.

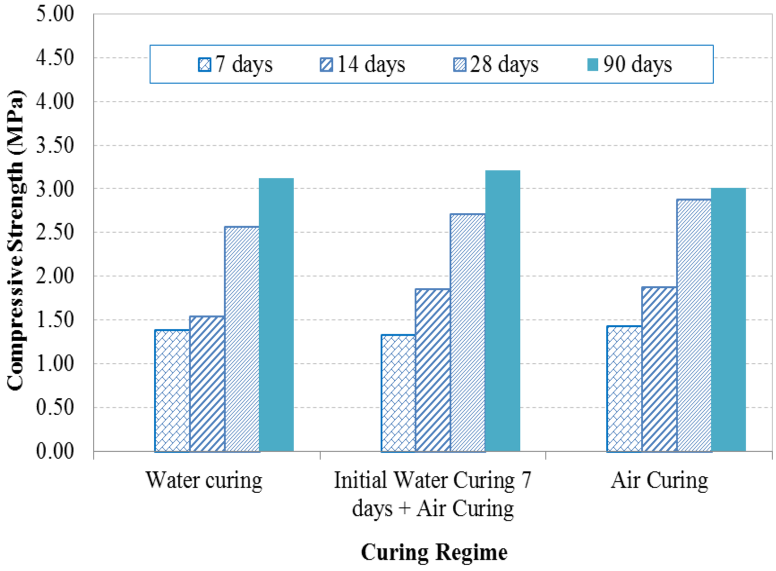

Figure 1. Effect of curing regime on compressive strength of plain aerated concrete without palm oil fuel ash as partial sand replacement up to 90 days.

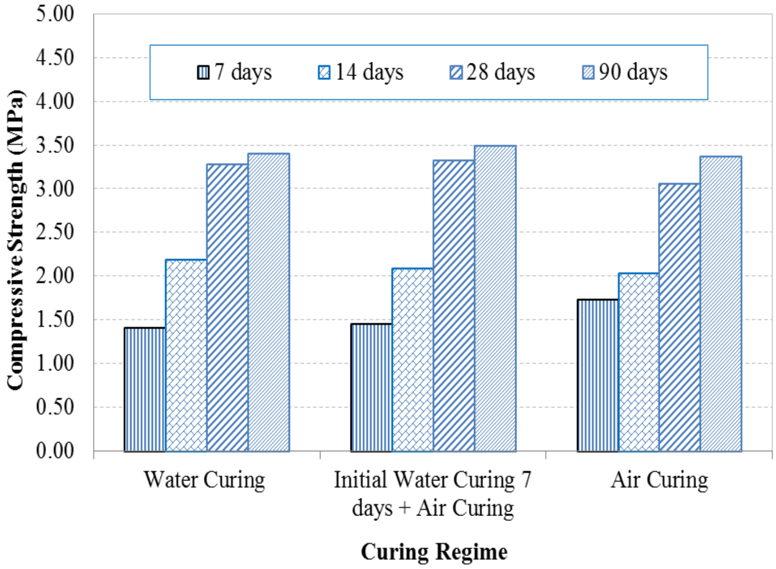

Figure 2. Effect of curing regime on compressive strength of aerated concrete containing palm oil fuel ash as partial sand replacement up to 90 days.

4. Conclusions

On overall, curing methods influence the strength performance of aerated concrete containing palm oil fuel ash. Continuous presence of moisture through water curing enables aerated concrete with POFA to exhibit higher strength through the generation of larger amount of C-S-H gel from hydration and pozzolanic reactions. Being added as partial sand replacement material, palm oil fuel ash contributes towards strength enhancement of lightweight concrete, offers solution to palm oil mills to manage their waste and reduce the dependency of concrete industry on natural sand supply. Success in identifying alternative material derived from locally generated waste to be used as mixing ingredient is expected to encourage production of aerated concrete by local manufacturer which would be more economic.

References

[1] Hussin, M.W., Abdullah, K., and Zakaria, F. *Effect of mixing constituent toward engineering properties of POFA cement-based aerated concrete.* Journal of Materials in Civil Engineering, 2010, **22**: p. 287-295.

[2] Abdul Awal, A.S.M, and Hussin, M.W. *The effectiveness of palm oil fuel ash in preventing expansion due to alkali-silica reaction.* Cement and Concrete Composites, 1997, **19** (4): p. 367-372.

[3] Hussin, M.W., Abdullah, K. and Zakaria, F. *Utilization of palm oil fuel ash for optimum strength of aerated concrete*. In *2008 Proceedings of 1st International Conference on Civil Engineering, ICCE 2008*. 2008. Kuantan, Malaysia.

[4] Budiea, A., Hussin, M.W., Muthusamy, K., and Ismail, M.E. *Performance of high strength POFA concrete in acidic environment.* Cement Research Letters, 2010, **1**(1): p. 14-18.

[5] Aldahdooh, M.A., Muhammad Bunnori, N., and Megat Johari, M.A. *Influence of palm oil fuel ash on ultimate flexural and uniaxial tensile strength of green ultra-high performance fiber reinforced cementitious composites.* Materials and Design, 2014, **54**: p. 694-701.

[6] Muthusamy, K., and Nur Azzimah, *Z. Exploratory study of palm oil fuel ash as partial cement replacement in oil palm shell lightweight aggregate concrete.* Research Journal of Applied Sciences, Engineering and Technology, 2015, **8** (2): p. 150-152.

[7] Asyraf, M.A., Maah, M.J., Yusoff, I., Wajid, A., and Mahmud, K. *Sand mining, effects causes and concerns: A case study from Bestari Jaya Selangor peninsular Malaysia.* Scientific Research and Essays, 2011, **6** (5): p. 1216-1231

[8] Yang. E.I., Myung, Y.K., Park, H.G., and Seong, T.Y. *Effect of partial replacement of sand with dry oyster shell on the long-term performance of concrete*. Construction and Building Materials, 2010, **24** (5), pp.758-765.

[9] Muthusamy, K., Zulkepli, N.A., and Mat Yahaya, F. *Exploratory study of oil palm shell as partial sand replacement in concrete*. Research Journal of Applied Sciences, Engineering and Technology, 2013. **5**(7), p.2372-2375.

[10] Aggarwal, Y., and Siddique, R. *Microstructure and properties of concrete using bottom ash and waste foundry sand as partial replacement of fine aggregates*. Construction and Building Materials, 2014, **54**, p. 210-223.

[11] Mat Yahaya, F. *Pengaruh abu terbang kelapa sawit terhadap kekuatan mampatan dan ketahanlasakan konkrit berudara.* Master Thesis, Universiti Teknologi Malaysia, Malaysia 2003[In Malay Language].

[12] ASTM C618. 2005. *Standard specification for fly ash and raw material or calcined natural pozzolan for use as a mineral admixture in Portland cement concrete*. Part 5. ASTM Internationals, West Conshohocken, PA.

[13] British Standard. 2003. *Testing hardened concrete. Compressive strength of test specimens*. London. BS EN 12390-3.

[14] Isaia, G.C., Gistaldini, A.L., and Morraes, R. *Physical ad pozzolanic action of mineral additions on the mechanical strength of high – performance concrete.* Cement and Concrete Composites, 2003, **25**, p. 69-76.

[15] Safiuddin, Md., Raman, S.N., and M. Zain, M.F. *Effect of different curing methods on the properties of micro silica concrete.* Australian Journal of Basic and Applied Science, 2007, **54**, p. 87-95.

[16] Abdul Awal A.S.M., *A study of strength and durability performances of concrete containing palm oil fuel ash*. PhD Thesis. Universiti Teknologi Malaysia, Malaysia, 1998.

[17] Abdullah, K., Hussin, M.W., and Abdul Awal, A.S.M. *Effect of curing regime on properties of lightweight concrete containing palm oil fuel ash*, in 2009, *Proceeding of International. Conference on Building Science and Engineering*, ICON BSE 2009, Johor Bahru, Malaysia