PERFORMANCE OF PALM OIL FUEL ASH CEMENT BASED AERATED CONCRETE SUBJECTED TO DIFFERENT CURING REGIME TOWARDS CARBONATION

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ABSTRACT: Since the early days, the never ending effort of researchers in improving and innovating products has lead to vast improvement in the existing human civilization now. In this century which is known as era of information technology, the availability of high-tech telecommunication network system has created an active knowledge sharing culture internationally. Thus, eventually motivating the researchers to be constantly innovating products to fulfill the growing demand of modern human society especially construction industry. The utilization of palm oil fuel ash (POFA) in concrete technology is one of the research areas that has been discovered in past century by Malaysian researchers and continually developed. Now in the 21st century, the Faculty of Civil Engineering of Universiti Teknologi Malaysia again revealed that this problematic waste which constantly produced abundantly by palm oil mill also has the prospect to be integrated as a partial cement replacement in aerated concrete. Therefore, the current objective of this investigation is to study the effect of different curing regime towards the carbonation resistance of POFA cement based aerated concrete. All specimens were cast in the prisms of (40x40x160mm) and then subjected to various curing regimes namely, natural weather curing, water curing, air curing and initial water curing followed by air curing. Then, carbonation test was conducted to the prisms aging 28 days in accordance to RILEM CPC 18 (1988). Based on the early studies, it was found that both specimen either consisting POFA or 100% cement subjected to natural weather curing exposed to higher carbonation as compared to any other types of curing regime. Conclusively, POFA cement based aerated concrete is exposed to higher carbonation in all types of curing regime as compared to normal aerated concrete due to its lower density.

Keywords: Palm Oil Fuel Ash, Partial Cement Replacement, Aerated Concrete, Different Curing Regime, Carbonation

1. INNOVATION OF AERATED CONCRETE

Aerated concrete which came to be known in construction project since last century in a country somewhere around the globe has gone through endless research and development process in order to fulfill the end user requirement. At the same time, the availability of telecommunication system and transportation network which has supported the process of knowledge dissemination globally which enable this material to be introduced to the construction industry in other region. As a result, at present aerated concrete that can be found in many countries not only being used for various functions in construction work and method of production but also varied and has been revolutionized continuously. At the same time, innovative researchers (Hauser et.al, 1999; Narayanan & Ramamurthy, 2000a; Holt & Raivio, 2005) whom always seem to be concern with issues such as industrial wastage problem has attempted to incorporate by-product of local industry in producing this material as means of reducing amount of waste ending up at landfill. In Malaysia, Faculty of Civil Engineering from Universiti Teknologi Malaysia has become the pioneer attempting to integrate waste in gas concrete production in early of 21st century which started off with Arreshvhina (2002), Mat Yahaya (2003) and currently Abdullah (2006). The present research findings of Abdullah (2006a) discovered that palm oil fuel ash has the potential to be used as partial cement replacement material in formation of aerated concrete.

In general, Malaysia as the biggest producer of palm oil in the world facing difficulties in managing the by-product of palm oil mill without jeopardizing the environment. Moreover, the continuously growing industry has lead to production of palm oil fuel ash abundantly which then dumped without being put for any use. The necessity for utilizing this waste material in order to promote nature friendly palm oil industry has lead to attempt of incorporating POFA as partial cement replacement in aerated concrete. Early findings by Abdullah (2006b) highlighted that replacement from 10 to 35% of POFA as partial cement replacement is still able to produce aerated concrete. Basically, accomplishment in incorporating POFA as partial cement replacement material in producing new type of lightweight concrete could lessen amount of cement used as compared to ordinary aerated concrete. Thus, this definitely could reduce the contractors or the manufacturers' high dependency on cement supply. Furthermore, success in producing the product consisting POFA as partial element in this material could also offer another solution to palm oil industry to convert their abundantly produced by-product into profit contributing means. Moreover, this accomplishment will be able to aid this industry from causing extensive pollution towards environment and community surrounding besides becoming more environmental friendly. In fact this achievement will have the double advantage towards palm oil mill whereby development of this material could increase the palm oil industry earnings and also a means of disposal of waste.

2. EXPERIMENT DETAILS

2.1 Preparation of Materials

POFA, for the purpose of this research was obtained from a local palm oil mill. The potential ashes were ground in a Los Angeles Abrasion Machine in order to reduce the particle size as shown in Figure 1. The fineness was checked using the wet sieve method with No.325 sieve. Coarser ash found retained in a larger amount in the sieve as compared to finer one. The ashes used are very fine whereby 99% of it passes this particular sieve. A single batch of Ordinary Portland Cement (OPC) which is produced by HOLCIM under the brand name of "SELADANG" was used throughout the experiments. Meanwhile, sand was dried for 24 hours and sieved passing 600µm. Gas producing agent and superplasticizer packed in a different packet according to required amount. Mould for producing the prism is specially made in Faculty of Mechanical as shown in Figure 2.

Figure 1: Los Angeles Abrasion Machine For Grinding Ash To Finer Particles

Figure 2: Prisms (40 x 40 x 160mm)

2.2 Manufacturing And Carbonation Test

Specimens were prepared in 2 sets, a control specimen consisting 100% OPC known as normal aerated concrete and another mix of OPC/POFA consisting the processed ash. The ash was mixed as a weight-for-weight replacement of cement in a constant quantity. All specimens were produced by adding constant quantity of sand, cement, gas producing agent, superplasticizer and adequate water dry mix ratio. The specimens were mixed and cast in the prism of (40x40x160mm) then demoulded after 24 hours before being subjected to initial water curing for 7 days as shown in Figure 3, 4, 5 and 6.

After 7 days, each set consisting 3 control prism and 3 OPC/POFA specimens were subjected to different types of curing that is water curing, air curing, natural weather curing and wet dry cycle curing as shown in Figure 7, 8, 9 and 10. All specimens cured for 28 days. Finally, at 28 days, each series of specimens was subjected to carbonation test in accordance to RILEM CPC 18 (1988). Three test samples from each set were split to obtain a break without wet sawing. Then the broken surface was immediately cleaned of dust and loose particles. The carbonated depth is then measured 24 hours after application of phenolphthalein to the free surface obtained by splitting as shown in Figure 12 and 13.

Figure 3 : Mixing Process

Figure 4 : Slurry Mix In The Mould

Figure 5 : Slurry Mix After Expansion

Figure 6 : Specimens After Demoulded

Figure 7 : Natural Weather Curing

Figure 8 : Air Curing

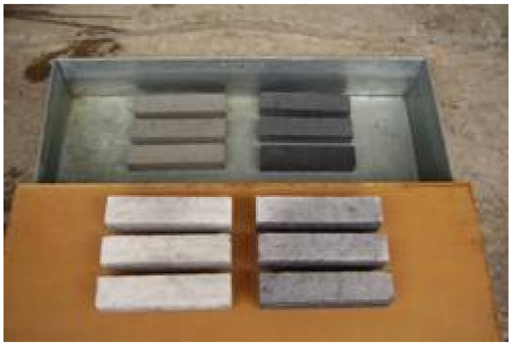

Figure 9 : Wet Dry Cycle Curing

Figure 10 : Water Curing

Figure 11 : OPC Aerated Concrete Soon After Phenolphtalein Sprayed

Figure 12 : POFA Cement Based Aerated Concrete 24hrs After Phenolphtalein Reacted

3. RESULTS AND DISCUSSION

3.1 Chemical And Physical Properties of Palm Oil Fuel Ash

Originally, the POFA brought from the factory, consist various size of ash and little amount of the particle managed to pass No.325 sieve during wet sieve process. It should be noted, after POFA being ground the quantity of ash retained on No.325 sieve changed from 98.5% to 1%. Chemical analysis that have been conducted proved that this ash can be classified as pozzolanic material belongs to Class F as was described in previous published paper by Abdullah (2006b) .

3.2 Effect of Different Curing Regime Towards Carbonation

It is mentioned earlier that specimens for carbonation test has been cast in form of prism with OPC and OPC with 20% POFA added as partial cement replacement. Here, all the specimens were subjected for carbonation test at 28 days. Table 1 presents data on carbonation of both OPC and POFA Cement Based Aerated Concrete subjected to different curing for 28 days. The depth of carbonation as indicated by the change in colour boundary either for normal aerated concrete or POFA Cement Based Aerated Concrete is illustrated in Figure 13 below. Basically, both types of aerated concrete are exposed to carbonation except specimens cured in the water show no traces of carbonation as presented in Figure 14. This is because penetration of carbon dioxide into the saturated concrete under a condition of high humidity is difficult (Lee & Lo, 2002). Lee & Lo (2002) also added that the optimum condition for the carbonation reaction process is in the humidity range of 50 – 70 %. However, carbonation nearly disappears at RH below 25 percent or near saturation (Somayaji, 2001).

This is because at that condition, all existing pores is filled with water and this makes the carbon dioxide faces difficulties to absorb into the specimen (Mat Yahaya, 2003). Meanwhile, in a very low humidity condition, the carbonation process would be delayed because the dissolved carbon dioxide is very low to start this process. However, a combination of wet and dry condition would assist the carbonation process to be faster (Mat Yahaya, 2003). This facts clearly explains the reason natural weather cured aerated concrete become the specimens with highest value of carbonation depth as compared to other curing conditions. Besides, this result is justifiable due to the fact that Malaysia is a tropical climate country which has continuously wet and dry climate with high humidity throughout the year. Meanwhile, specimen consist of POFA and normal aerated concrete that has been subjected to air curing faces higher rate of carbonation as compared to wet dry cycle. This is because the constant changing of curing medium from water to air every 7 days has able to slower the carbonation rate due to longer period of immersion in water as compared to air cured specimen. However, the continuous air curing specimen has been subjected to constant rate of carbonation without any changes towards the curing medium within the 28 days as compared to wet dry cycle curing specimen.

In the case of aerated concrete and specimens consisting POFA, carbonation that occurs on specimen consisting POFA is higher as compared to normal aerated concrete. According to Horiguchi et al (1994) who observed in binary and ternary blended cement stated that when the blending ratio of blast furnace slag and fly ash increased, the carbonation constant was also increased. In this study it is justifiable due to the fact that POFA cement based aerated concrete consist palm oil fuel ash as a partial cement replacement which is not only very fine but also has a big surface area, thus requiring more water to be added to improve workability as compared to normal aerated concrete. Addition of more water and fine ash has lead to creation of more voids which not only successfully decrease the density of POFA cement based aerated concrete compared to OPC aerated concrete as shown in Figure 15 but also inadvertently lead to higher depth of carbonation. Previous researcher Mat Yahaya (2003) stated that the internal structure of concrete with POFA has high volume of macro and micro capillary which makes the absorption of carbon dioxide easier. Mat Yahaya (2003) also added aerated concrete having lower density has volume of micro capillary which facilitate the dispersion of carbon dioxide. However, effect of density towards carbonation has been highlighted by Orchard (1979) whom mentioned that carbonation takes place more readily in low density concrete than in high density concrete.

Overall in this study, it can be observed that, specimens consisting POFA as partial cement replacement with lower density exhibit higher carbonation in all curing conditions. However, it is strongly believed that the rate of carbonation will decrease as the curing period increase. This is because denser concrete in the surface layer formed as a result of the carbonation process and consequently, the rate of carbonation was reduced with time (Fattuhi, 1986). Another researcher Parrot (1996) also added that cement type and curing seem to influence carbonation mainly through their effects upon the pore structure and gas transport properties of cover concrete, the more reactive the cement and the longer the period of curing, the lower are the permeability and the rate of carbonation. However, further conclusion on the performance of POFA Cement Based Aerated Concrete towards carbonation when it was subjected to longer curing age will yet to be reserved.

Table 1 : Depth Of Carbonation For OPC and POFA Cement Based Aerated Concrete Subjected To Various Curing Regime At The Age of 28 days

Curing Regime	**Type of Aerated Concrete**	**Density (kg/m^3)**	**Average Depth of Carbonation (mm)**
Water	OPC	1367	0
	POFA	1340	0
Air	OPC	1113	0.75
	POFA	1015	2
Wet Dry Cycle	OPC	1168	0.5
	POFA	1054	1.5
Natural Weather	OPC	1211	1.75
	POFA	1016	3

Figure 13 : OPC and POFA Cement Based Aerated Concrete Before And After 24 Hours Of Carbonation Test

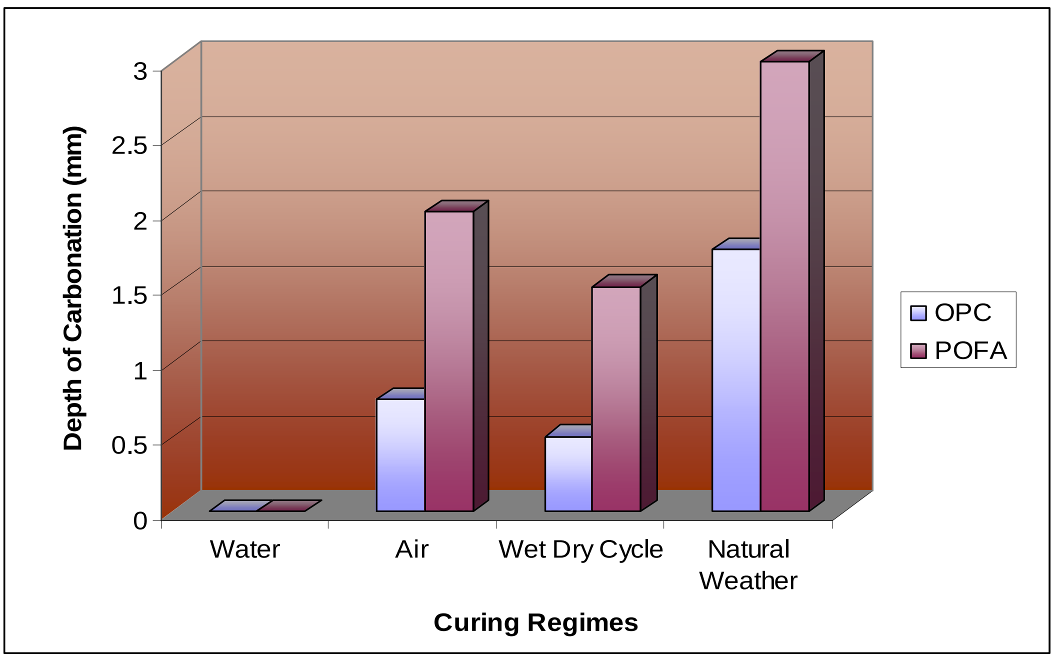

Figure 14 : Depth Of Carbonation For OPC and POFA Cement Based Aerated Concrete Subjected To Various Curing Regime At The Age of 28 days

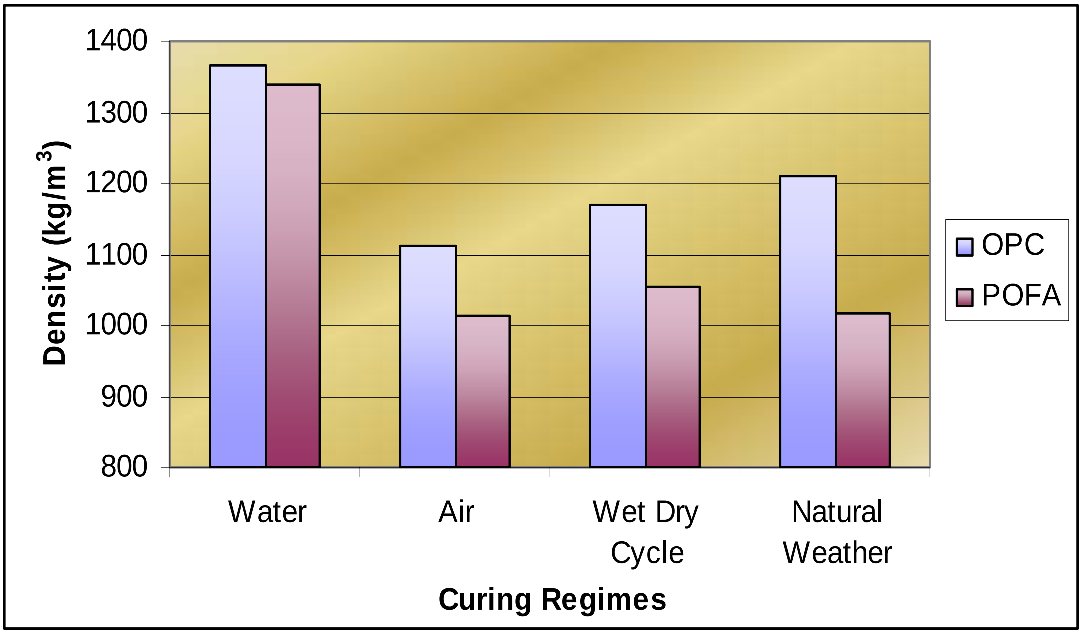

Figure 15 : Density Of OPC and POFA Cement Based Aerated Concrete Subjected To Various Curing Regime At The Age of 28 days

4. CONCLUSION

From the experimental results and discussion, the following conclusion can be drawn.

i. Method of curing have substantial influence on the carbonation of either OPC aerated concrete or POFA cement based aerated concrete.

ii. Specimen consisting POFA exposed to higher carbonation as compared to ordinary aerated concrete due to its higher amount of water added and inclusion of POFA as partial cement replacement material which causes the specimen consisting POFA to be lower density than normal aerated concrete.

iii. Both specimen either ordinary aerated concrete or POFA cement based aerated concrete subjected to natural weather has presented highest value of carbonation depth as compared to specimens subjected to other curing regimes.

iv. All specimens cured in water did not expose to carbonation.

v. Both specimen POFA cement based aerated concrete and normal aerated concrete that been subjected to air curing faces higher carbonation as compared to wet dry cycle which able to slower the carbonation rate due to longer period of immersion in water.

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