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PROPERTIES OF MULTI-BLENDED CEMENT MORTARS USING AGRO-INDUSTRIAL WASTES

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Abstract: This study is conducted to investigate the performance of multi-blended pozzolan admixtures as partial cement replacement in cement mortars. Eight types of mixtures were prepared using various agro-industrial wastes as admixtures such as pulverized fuel ash, rice husk ash, slag, and palm oil fuel ash, of which four mixtures have different percentages of admixtures (Multi Blended Cement, MBC), and the others four are single mix (Binary Blended Cement, BBC). The experimental work initially deals with workability, compressive strength development, water absorption, and total porosity of MBC and BBC mortars cured at different curing conditions. The effects of different percentages of MBC and BBC mortars with different water-cement ratios were examined in terms of workability and compressive strength to achieve optimum mix proportions for MBC and BBC mortars. MBC system produced low permeability mortar compared to control, and BBC mortars. The strength properties of MBC mortars were more significant than control and BBC mortars when provided with appropriate curing.

Keywords: *Multi-blended pozzolanic admixtures; multi-blended cement; binary blended cement; workability, strength properties*

1.0 Introduction

Pozzolanic materials are widely used in concrete and mortars for various reasons, particularly for reducing the amount of cement required for making concrete and mortar which leads to a reduction in construction cost. Moreover, most pozzolanic materials are by-products and their use leads to reduction in waste and saving of energy consumed to produce cement. Most recently, blended and multi-blended cement, incorporating industrial by-products/pozzolanic materials, are becoming an active area of research because of their improved properties such as workability, long-term strength and durability. The common blending agents used are fly ash (PFA), rice husk ash (RHA), palm oil fuel ash (POFA), Slag, silica fume (SF), calcined clay etc. The improved properties such as rheology and cohesiveness, lower heat of hydration, lower

permeability and higher resistance to chemical attack are reported in the literature (Khan, 2000 and Mehta, 1989&1994).

In recent times, there has been a growing trend towards the use of supplementary cementitious materials, whether natural, waste or by-products, in the production of blended cements because of ecological, economical and diversified product quality reasons. One of the major options adopted for economic reason is to utilize local resources especially waste materials that would provide cost effectiveness, moreover, the potential utilization of hazardous waste which could reduce environmental pollution. Malaysia being largest producer of Palm Oil in the world and having large milling paddy capacity, has agricultural fly ash in abundance as waste material. This has led to the idea to investigate the suitability of these materials to be incorporated in multi-blended cement as partial cement replacement. Also this may lead to resolving the burning issue of disposal of these waste materials which have hazardous effects on the country's environment.

In this study the effects of different percentages of multi-blended cement (MBC) and binary- blended cement (BBC), with different mix proportions, on physical and mechanical properties of mortars are examined. Evaluation is made by comparing the water absorption, porosity and compressive strength of different mix mortars, up to the age of 90 days. Consequently, MBC and BBC produced low porosity and high strength mortars compared to control.

2.0 Materials

Ordinary Portland Cement was used as specified in ASTM C150 (1994). Agro-industrial waste such as ground granulated blast furnace slag (GGBFS) was used complying with the specifications of ASTM C989 (1993). The pulverized fuel ash (PFA) was a by-product and used as class F according to ASTM C 618-84 (1992). The rice husk ash (RHA) used was grinded to achieve its fineness according to ASTM C 618-84 specifications. Palm oil fuel ash (POFA) is also a by-product of palm oil industry and produced as a result of the burning palm oil shell and husk as fuel in palm oil mill boiler to produce steam for electricity. Crushed granite sand was used as fine aggregate. Tap water and commercially available high water reducing agent (super plasticizer) were employed to mix mortars. The chemical and physical compositions of the cement and other agro-industrial wastes used are presented in Table 1 while Table 2 represents the physical properties.

Table 1: Chemical compositions of pozzolanic admixtures (%)

Material	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	SO_3	K_2O	P_2O_5	LOI
OPC	20.1	4.9	2.5	65.0	3.1	0.2	2.3	0.4	< 0.9	2.4
PFA	91.2	5.84	0.76	0.34	-	0.24	0.35	1.21	-	-
POFA	53.1	1.9	1.18	1.66	-	0.16	1.11	3.47	-	-
SLAG	28.2	10.0	1.8	50.0	4.6	0.1	2.2	0.6	-	0.2
RHA	97.5	0.02	0.13	0.18	-	0.1	0.49	1.39	-	-

Table 2: Physical properties of pozzolanic admixtures

Property	PFA	SLAG	RHA	POFA
% retained on 45µm sieve	8.0	-	4.0	6.0
Specific surface (m^2/g)	1.4	2.5	11.8	34.0
Specific gravity	1.18	1.3	0.90	1.18

3.0 Experimental Works

3.1 Mix Proportions

Nine types of mixes including one control mix without replacement of cement were casted for this study. Two series of the mortar mixes were considered. Four mixes were designed with the binary blended cement as binder material during first series. Binary blended cement (BBC) was prepared by replacing partially Slag, PFA, RHA and POFA. Whereas the percentages of partial replacement applied for each blending constituent is the optimum value as reported by various researchers (Abdul Awal and Hussin, 1996a, 1996b and 1997 and Chindaprasit *et al.*, 2007&2008). The details of the BBC mortars are given in Table 3. The second series of the mortars was designed by replacing cement with a combination of all the four blending constituents and the mortars developed are known as Multi-Blended Cement (MBC) mortars. Four mixes were prepared for this series. The replacement level of OPC was fixed at 50% of total binder by weight. Whereas, the content of Slag, and POFA was also fixed at 20% and 5% of the total binder by weight respectively. The remaining 25% replacement of cement was adjusted between the various percentages of RHA and PFA. The details of the MBC mortars are shown in Table 4. Due to large variation in water absorption of agro-industrial admixtures, the flow of all mortars was fixed to 170±5 at super plasticizer (SP) content of 0.1%, however, only the compressive strength of blended mortars was determined with and without SP.

Table 3: Mix proportions (%) for BBC mortars

Mix	OPC	Replacement	W/C	SP
Control	100	0	0.52	0.1
SLAG	50	50	0.53	
PFA	70	30	0.43	
RHA	80	20	0.52	
POFA	90	10	0.51	

Table 4: Mix proportions (%) for MBC mortars

Mix	OPC	Slag	PFA	RHA	POFA	W/C	SP
Control	100	-	-	-	-	0.52	0.1
MA	50	20	5	20	5	0.54	
MB	50	20	10	15	5	0.49	
MC	50	20	15	10	5	0.48	
MD	50	20	20	5	5	0.46	

3.2 Preparation of Specimens and Curing

Cube specimens of standard size (70×70×70mm) were casted. Three specimens for each type of mix were prepared. The specimens were cured in water at room temperature (28℃) for 7, 28, 60 and 90 days.

3.3 Tests

To examine the effects of various pozzolanic admixtures on physical and mechanical properties of cement mortars, water absorption (BS 1881: Part 122; 1983), porosity (Vanisha, 2003) and compressive strength (BS 1881: Part 116; 1983) tests were conducted. Three specimens for each type of mortar were tested to calculate the mean value.

4.0 Test Results and Discussion

4.1 Effect of Pozzolanic Admixtures on Water Absorption

The fine pore structure of MBC and BBC mortars improves its transport properties and consequently increases its resistance to water absorption. As seen in Figure 1, the water absorption of MBC mortars was lower than BBC and control mortars, whereas RHA mortar showed higher water absorption after 7 to 90 days age both in MBC and BBC mortars. PFA mortars exhibit lower water absorption at all ages in both MBC and BBC mortars. This is attributed to pores in the bulk paste or in the interfaces between aggregate and cement paste which are filled by pozzolanic admixtures; hence, the capillary pores are reduced. As mentioned above, the beneficial role of binary and

tertiary blended pozzolanic admixtures causes an increase in the strength and reduction in the capillary sorption of mortars as well.

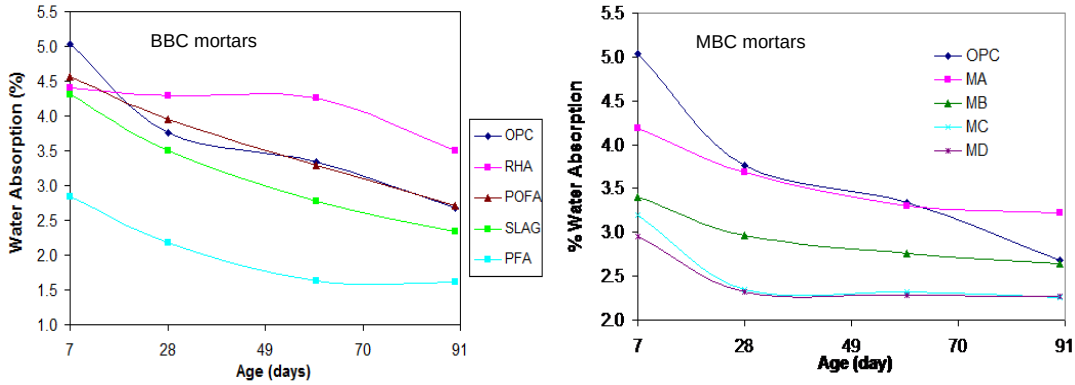

Figure 1: Water absorption of BBC and MBC mortars

4.2 Effect of Pozzolanic Admixtures on Porosity

The porosity results are illustrated in Figure 2. The values of both BBC and MBC mortars varied between 15% and 25%, at different ages tested (7 to 90 days). These relatively low porosity values indicate the effect of mix proportions and pozzolanic admixtures on reducing the porosity of mortars. The results also indicate that more reduction in porosity at prolonged age was achieved by the use of binary and tertiary blended pozzolanic admixtures in MBC mortars. The fine PFA particles, in addition to being highly pozzolanic material, improve the packing of the mortar matrix and at the interfaces with aggregate, resulting in a denser mortar matrix with finer pore structure. In this study, PFA in BBC and in MBC mortars with other pozzolanic admixtures exhibited lower porosity values (less than 15%) when compared to OPC control mortar. It has been reported that with each 10% replacement of OPC by PFA in concrete mix, the water content reduced by 3 to 4%, that eventually improved the packing capacity of the concrete ingredients and reduced its porosity [Hassan *et al*., 1997]. Figure 2 shows that PFA in BBC and MBC (MD) mortars gave the low porosity values at early age and became lower at the age of 90 days.

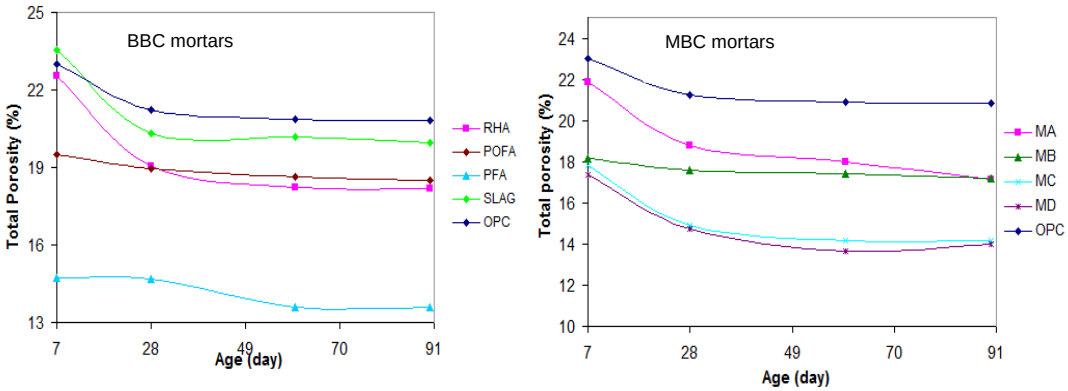

Figure 2: Total porosity of BBC and MBC

4.3 Effect of Pozzolanic Admixtures on Strength of BBC Mortars

Figure 3 shows the compressive strength of BBC mortars using different pozolanic admixtures. The results show the general trend of increasing strength with age for all mixes. It is evident from the Figure 3, that the strength of BBC mortars was significantly influenced by the degree of hydration due to the type of pozzolanic admixtures. The early strength development in all mixes is attributed to superplasticizer (SP). However, PFA mortar with and without SP tends to produce higher early strength compared to the OPC control and other BBC mortars. The strength of SLAG mortars with and without SP was lower than control mortar and other mortars at all ages. Low reactivity crystalline silica type RHA was used; therefore, the strength of mortar was lower than POFA and PFA mortars but higher than SLAG mortar. RHA control mortar with addition of SP showed higher early strength development than PFA and OPC control mortars but the strength was not progressively increased at the final age of 90 days and was comparable with SLAG and OPC control mortars. Minimum strength values of 52 MPa at 28 days and 70 MPa at 90 days were achieved for PFA mortars with and without SP.

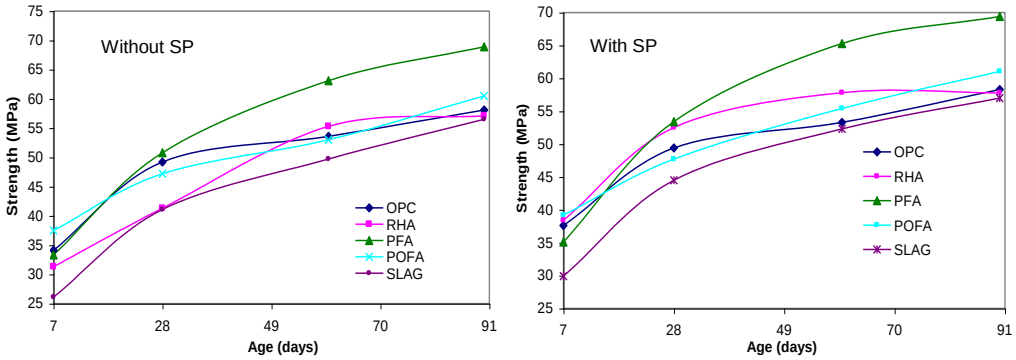

Figure 3: Compressive strength of BBC mortars at different age

Strengths of MBC mortars (ternary blended cement) are lower than that of OPC mortar at same curing condition while BBC mortars (binary blended cement) contributed to higher compressive strength than that of OPC control mortar. However, an increase in compressive strength of MD mortar can be obtained when using high ratio of PFA replacement in MBC mortars. Thus, having PFA in blended cement has a beneficial effect on the compressive strength development of MBC and BBC blended cement mortars. This is due to the higher pozzolanic reaction and higher fineness than SLAG, RHA and POFA particles. It is known that PFA contains much more amorphous SiO2 than SLAG, RHA and POFA and higher fineness making it more reactive (pozzolanic reaction). Amorphous SiO2 in PFA reacted with calcium hydroxide from hydration to C-S-H formation, thus giving strength at an early age and improved compressive strength of MBC and BBC blended cement mortars [Erdem, 2008 and Elahi, 2010].

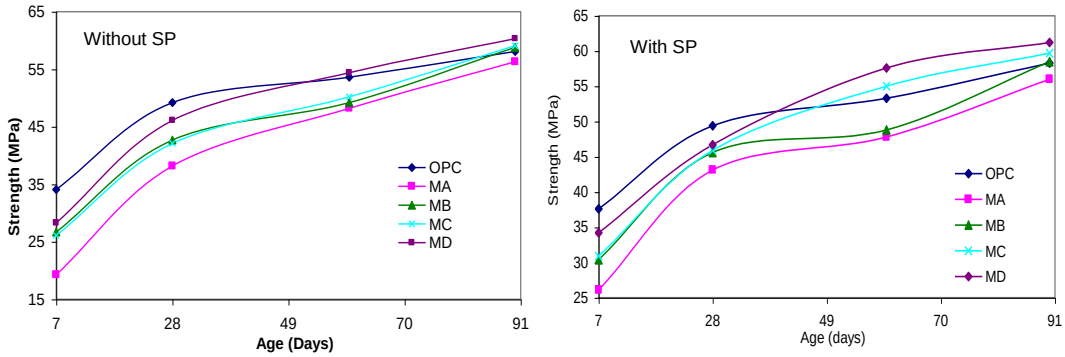

Figure 4: Compressive strength of MBC mortars at different age

4.4 X-Ray Diffraction Analysis (XRD)

XRD patterns for MBC, BBC and OPC mortars are given in Figure 5. All mortar mixes were analysed by XRD to determine the reaction with calcium hydroxide (CH), where the decreased amount of CH indicates the existence of the pozzolanic reactivity. The pozzolanic reaction depends on the CH released by the cement hydration reaction. The analysis is based on the intensity of the peak corresponding to CH in the samples from BBC, MBC and control mortars. From Figure 5, it can be said that cement containing multi-blended pozolanic admixtures has better properties due to its low alkalinity and lesser amount of CH rather than binary blended cements, mainly POFA and RHA, as well as cement containing 100% Portland cement.

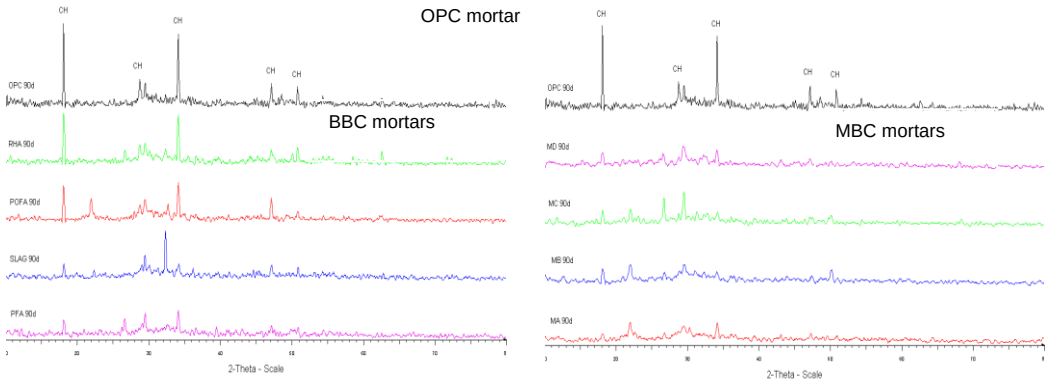

Figure 5: XRD patterns for OPC, BBC and MBC mortars

5.0 Conclusions

Based on the results obtained in this study, the following conclusions are offered:

1) The fine pore structure of MBC and BBC mortars improves its transport properties and consequently increases its resistance to water absorption.
2) It is evident that the strength of BBC and MBC mortars is significantly influenced by the degree of hydration due to the incorporation of pozzolanic admixtures. The compressive strengths of BBC (PFA) and MBC (MD) mortars are higher than that of OPC mortar at same curing condition while BBC mortars with SLAG exhibited same or lower compressive strength than that of OPC control mortar.
3) The cement containing multi-blended pozzolanic admixtures showed better properties due to its low alkalinity and lesser amount of CH rather than binary blended cements, mainly POFA and RHA, as well as cement containing 100% Ordinary Portland cement.

6.0 Acknowledgments

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