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The Effects of POFA and SF as TBC Binder on the Heat of Hydration and Compressive Strength of Mortar

Nor Umairah Abd Rahim[1]* and Mohd Fadzil bin Arshad[2]

[1]Linton University College, 71700 Mantin, Negeri Sembilan, Malaysia
[2]FKA UiTM Shah Alam, 40450 Shah Alam, Selangor, Malaysia

ABSTRACT

Ordinary Portland Cement (OPC) is widely used by the construction industry. Research to find the precise proportion of cement replacement material which can be used to produce a product called Ternary Blended Cement (TBC) is not new. The objective of this study is to determine the effect of POFA and SF as TBC on the heat of hydration and compressive strength of mortar. Before producing TBC, specimens using BBC is required. Mix design proportion for POFA and SF are 5%, 10%, 15%, and 20%. Mix design proportion TBC are chose from the highest compressive strength value achieved at 7 days of curing. This research found the heat of hydration of TBC containing 20% POFA and 5% SF is high in the beginning to drop at the end of hydration process in addition to producing lower compressive strength.

Keywords: BBC, compressive strength, heat of hydration, OPC, POFA, SF, TBC

INTRODUCTION

Background of Study

Excessive carbon dioxide (CO_2) emissions need to be reduced in the interest of ensuring sustainability. The use of cement replacement material is to replace the excessive usage of Ordinary Portland cement (OPC) can reduce CO_2 emission. Among the cement replacement materials examined in this study are Palm Oil Fuel Ash (POFA) and Silica Fume (SF). These two wastes have been selected to produce Ternary Blended Cement (TBC) binder.

Scope of Study

This study examines the effect of POFA and SF as cement replacement material in TBC binder on the heat of hydration and

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E-mail addresses:
umairah@ktgeducation.edu.my (Nor Umairah Abd Rahim),
fadiil2013@yahoo.com (Mohd Fadzil bin Arshad)
*Corresponding Author

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compressive strength of mortar. Presently pozzolans are used only in BBC binder and the optimum replacement of pozzolan to OPC to be not more than 20% (Fadzil, Azmi, Hisyam, & Azizi, 2008). The percentage of cement replacement chosen for this study are 5%, 10%, 15% and 20% respectively. The water cement ratio was set at 0.50, and the experiments conducted at the Faculty of Civil Engineering, UiTM, Shah Alam Concrete and Non-Destructive Test Laboratory. The main materials used are OPC collected from Tasek Cement Berhad, POFA from palm oil mill factory Jengka Pahang, SF from SIKA Berhad, river sand from a local supplier, tap water from Syarikat Bekalan Air Selangor (SYABAS) Sdn Bhd, and distilled water. The SF used in this study is unclassified. 72 hours was needed for the cement hydration test equipment to complete the heat of hydration test. Total specimen for the test was 10. The specimen containing mortar weighed 10 g of control mortar with different percentage of POFA and also SF. Data from this experiment was collected and graph showing degree of hydration versus time was obtained. Reference and standard documents used for the test are ASTM C1679-14. For the compressive strength test, 120 mortar mould sized 50 mm x 50 mm x 50 mm was prepared. All TBC binder specimens can be tested for 1, 3, 7 and 28 days of curing, following which they were placed inside the curing tank and tested using compressive strength machine. British Standard BS EN196-1: 2005 served as the reference and standard document.

Significant of Study

There is still some gap in knowledge on the effect of POFA and SF as TBC binder on the heat of hydration and compressive strength of mortar. The findings should be useful in encouraging the usage of TBC binder and reduce the usage of OPC for construction and contribute to greater sustainability.

MATERIALS AND METHODS

Materials

The cement is OPC and complies with ASTM Type 1 and Malaysian Standard MS522. Tasek Cement Berhad is the company supplier of this OPC. The sand that had been used is river sand and came from a local supplier. During the mixing of mortar specimen for Compressive Strength Test tap water from Syarikat Bekalan Air Selangor (SYABAS) Sdn Bhd is added gradually. The water cement ratio used in this study is 0.50. POFA was collected from palm oil mill factory Jengka Pahang, while unclassified silica fume (SF) came in the form of a 20 kg bag from SIKA Berhad. Distilled water was used when preparing mortar paste specimen for heat of hydration test. The water cement ratio of distilled water is same as water cement ratio used in mortar specimen in compressive strength test that is 0.50.

Methods

The ratio that had been used in this study is 1:3 and aimed at achieving Grade 60 mortar. For the BBC binder test specimen, the design mix proportion used was 5%, 10%, 15% and also 20%. For TBC binder test specimen, design mix proportion was s OPC 75%, POFA 20% and SF 5%

and based on the highest compressive strength value achieved at 7 days of curing in BBC test specimen. A summary of the design mix proportion of mortar specimen is presented in Table 1.

Table 1
Design mix proportion of mortar specimen

Control (%)	POFA (%)	SF (%)	Water Cement Ratio
100	-	-	0.5
95	5	-	0.5
90	10	-	0.5
85	15	-	0.5
80	20	-	0.5
95	-	5	0.5
90	-	10	0.5
85	-	15	0.5
80	-	20	0.5
75	20	5	0.5

The first step is the weighting of the material according to the chosen proportion, and mixed using a standard BS EN 196-1:2005 mechanical mixer. Sand is added into the bowl mixer following which OPC, POFA and SF was added together with water. In this study, the mould size 50mm x 50mm x 50mm was used and the poured in 3 layers. Each specimen is labelled according to date of casting and type of pozzolonic material used. After 24 hours, the mould were removed and cured by submerging them in a curing water tank for 1, 3, 7, 28 days before they are dried and weighed and recorded before being subjected to compressive test. For heat of hydration test the selected material is poured onto paper on the weighting machine. The mortars need to be exactly 10 g and are mixed and poured into a test tube and compacted A syringe is used to take distilled water based on the ratio described in BS EN 196-1:2005. Figure 1 shows the mortar specimen casting process.

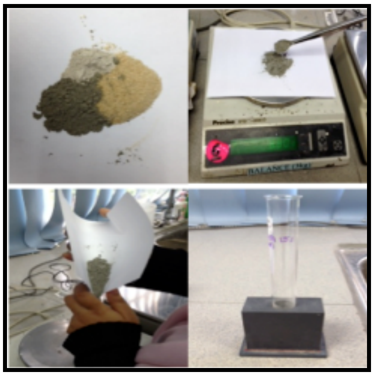

Figure 1. Casting process of mortar specimen

Heat of Hydration and Compressive Strength Test for TBC Binder

For heat of hydration test, 3 tests cube specimens were tested and called Cell 1, Cell 2, and Cell 3. Before turning the cover of each cell holders clockwise, it is important to ensure that the display monitor is at zero. The compressive strength testing is conducted at 1, 3, 7 and 28 days following the curing process. The mortar specimen is tested to evaluate its performance according to BS 1881-16:1983. Before the compressive strength test is begun, the mortar specimen is dried and weighted. The machine is operated at pace rate of 0.9 kN/sec.

RESULTS AND DISCUSSION

Heat of Hydration of Tbc Binder

Figure 2 shows the heat of hydration of TBC binder and the controlled specimen. It shows the control specimen achieves the highest degree of hydration value compared to TBC binder. When mixing cement with water, a rapid heat evolution of a few minutes from 0 to 0.03 hours occurs. The graph shows that the heat of the aluminium and sulphates solution of TBC binder is higher than the control specimen.

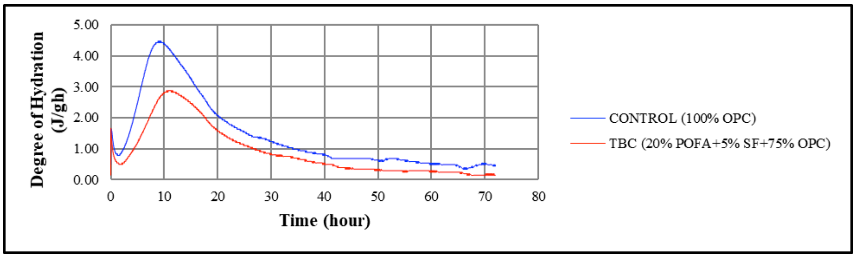

Figure 2. Heat of hydration of TBC binder (OPC+POFA+SF)

The graph shows hydration peak takes place at 8 to 11 hours. The highest value for hydration is 4.49 J/gh which is at 8.83 hour for the control specimen and 2.87 J/gh in 10.68 hour when TBC binder is used. Percentage difference between control specimens and TBC binder is more than 20%, which is 36.08% and considered significant. These difference in values of hydration maybe due to the different of pozzolanic reaction between TBC binder and the control specimen. The high degree of hydration for the control specimen might due to reactivity of 100% OPC caused the energy released at this point is higher as compared to TBC binder. At 0 to 10 hours, there is a huge difference in the projection of degree of hydration value for TBC binder and the control specimen, and be caused by initial thermal power by dissolution of cement and initial cement hydration occurs is differing between TBC binder and control specimen. From 20 to 72 hours the hydration value for both TBC binder and control specimen continues to decrease. From the discussion, it can be concluded that the degree of hydration value for TBC binder is higher than the control specimen in the early stage of the hydration process. TBC binder is finer r than OPC and therefore affect the rate of heat development for concrete or mortar mixture. Based on the finding obtained from this experiment, the hydration value of TBC binder containing 75% OPC, 20% POFA and 5% SF is high in the early stage; that is at 0.03 hours and continues to decline compared to the control specimen.

Compressive Strength for Tbc Binder

Compressive strength test was successfully done on 120 samples. The compressive strength result for control specimen, different percentages of BBC binder and TBC binder contains POFA and SF at 1, 3, 7, and 28 days of curing as shown in Table 2. The purpose of preparing BBC binder specimen at different percentages of POFA or SF is to obtain the highest compressive strength value at 7 days of curing in order to choose the design mix proportion for the following TBC binder specimen.

Table 2
Design mix proportion of mortar specimen

Control %	POFA %	SF %	Compressive Strength (N/mm^2)			
			1 day	3 day	7 day	28 day
100	-	-	17.24	29.14	40.60	58.62
95	5	-	7.67	14.03	19.63	26.98
09	10	-	5.88	9.81	13.00	21.30
85	15	-	8.17	14.53	19.02	38.74
80	20	-	9.94	15.81	21.71	39.03
95	-	5	11.30	18.83	26.82	38.45
90	-	10	10.08	16.41	22.22	32.83
85	-	15	11.38	19.83	26.18	36.88
80	-	20	9.58	15.84	22.31	32.17
75	20	5	8.99	17.30	22.84	33.43

Based on Figure 3, the compressive strength value between TBC binders containing 20% POFA, 5%SF and 75% OPC and the control specimen is shown. From the figure, the control specimen still achieves the highest compressive strength value compared to TBC binder, which is 17.24 N/mm^2, 29.14 N/mm^2, 40.60 N/mm^2 and 58.62 N/mm^2 at 1, 3, 7 and 28 days of curing. TBC binder only achieved compressive strengths of 8.99 N/mm^2, 17.30 N/mm^2, 22.84 N/mm^2 and 33.43 N/mm^2 at 1, 3, 7 and 28 days of curing. The percentage difference between the control specimens and TBC binder at 28 days of curing was more than 20%, or 42.97% and is considered significant.

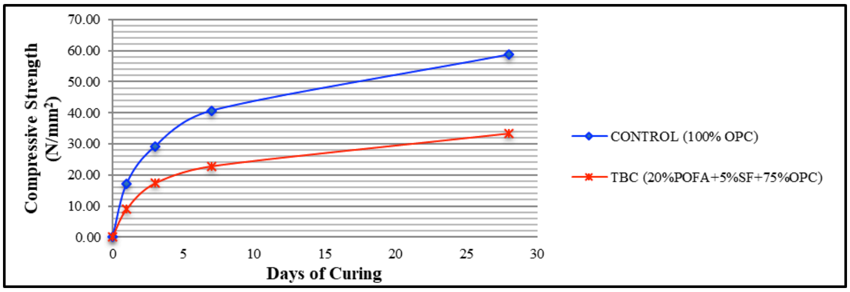

Figure 3. Graph compressive strength versus days of curing for control and TBC Binder (OPC+POFA+SF)

As seen from the graph, the compressive strength of the control specimen is increased drastically when cured from 1 to 7 days. For the TBC binder, strength is moderately increased until curing of 3 days. The high compressive strength of the control specimen compared to the TBC binder may be due to the high rate of hydration of OPC particles. Due to the effect of hydration process, the porosity of OPC decreases daily. The compressive strength of TBC binder at 3 days of curing is 17.30 N/mm^2 similar to that of 7 day of BBC binder containing 10% POFA. It can be concluded that TBC binder containing POFA and SF as cement replacement material improves the strength development of mortar. The result also shows that by using both cement replacement material like POFA and SF to create a new TBC binder can further strengthen the product. Research done by Rukzon and Chindaprasit (2009), stated that the blend of fine pozzolans is responsible for improving the strength of concrete due to the synergic effect. These findings are also supported by Bleszynski et al. (2002) which showed TBC binder has better overall durability compared to BBC binder.

CONCLUSION

The heat of hydration of TBC binder containing 75% OPC, 20% POFA and 5% SF produces a high value of degree of hydration only in the early period and decreases towards the end of hydration process. The compressive strength of TBC binder with 75% OPC, 20% POFA and 5% SF produces a lower compressive strength value compared to the control specimen.

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