THE INFLUENCE OF SELF COMPACTING CONCRETE FABRICATED WITH BOTTOM ASH ON THE EFFECT OF FLY ASH AND PALM OIL FUEL ASH AS PARTIAL CEMENT REPLACEMENT

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ABSTRACT

The self-compacting concrete (SCC) incorporating with supplementary cementitious material has led to development of more environmental-friendly concrete. This paper deals with SCC made of bottom ash as replacement of coarse aggregates and the cementitious materials of fly ash and palm oil fuel ash as a mixture of partial cement replacement in varying percentages of 10-30%. The water binder ratio was fixed at 0.47 for all mixtures. Tests were carried out on all mixtures to obtain the workability of SCC in terms of viscosity by slump flow test and J-ring. Compressive strength tests were conducted at the ages of 3, 7 and 28 days for various mixes. Results showed that the fly ash at 30% replacement level is the optimum result for the workability and compressive strength test.

Keywords: Self-compacting concrete, bottom ash, fly ash, and palm oil fuel ash.

1.0 INTRODUCTION

Compaction of normal concrete in the industry during casting can arise various problems such as honeycomb and void in concrete, especially in congested reinforcement. The concrete that encountered poor compaction contributing to high permeability and porosity. As the results, it can affect the corrosion of steel embedded in concrete which is reduced the strength of concrete itself. The use of self-compacting concrete (SCC) can increase the workability in term of filling and passing ability in the structural element which usually having the compaction problems. Moreover, the SCC used in manufacturing precast and prestressed concrete structures has several benefits such as increased rate of production and safety, reduced labor needs, higher surface quality, and lower noise levels at manufacturing plants (Lee et al. 2016; Phillips et al. 2005; Shaikh 2016).

According to EFNARC (2005), the term powder is defined as materials of particle size fractions of less than 0.125 mm which including fine aggregates, additions (cementitious materials) and cement. Additionally, the manufacturing of Portland cement requires the burning of large quantities of fuel and decomposition of limestone, resulting in significant emissions of carbon dioxide. Besides that, hydration of Portland cement can release greenhouse gases to the environment (Munir, 2015; Park et al., 2009; Jaturapitakkul et al., 2011). In order to reduce the environmental problem, palm oil fuel ash (POFA) and fly ash (FA) are used as partial cement replacement to produce a sustainable concrete (Ranjbar et al., 2014; Mohamed et al., 2016). Several studies have been investigated on the performance of SCC by incorporating by-product waste material (F.A. Sabet et al., 2013; M. Nepomuceno, 2012; M. Najimi et al., 2012; Norwati J. et al., 2016).

Bottom ash (BA) and FA are waste materials from coal combustion thermal power plant while POFA is waste material from palm oil mill. These waste materials usually dispose in landfills. As the disposal area is limited and become serious problem to environment, POFA, FA and BA are suggested to be used in concrete production which the result of utilization positively reduce the particular problem. BA is at the bottom part of the furnace which has not be re-utilized effectively compared to FA (Lee et al., 2016). Although several studies have been reported on the use of BA as fine aggregates in concrete, there is limited studies available on the use of BA as coarse aggregates in SCC (Lee et al., 2016; Phillips et al., 2005). Due to extraction of natural aggregates is affecting the eco system, this has encouraged many researchers to investigate alternative from waste materials in order to reduce the reliance on natural aggregates (Shaikh, 2016). Therefore, by utilizing BA as fully replacement of natural aggregate can solve the depleting of resources at the same time utilizes the waste to solve waste disposal problem. Both BA and FA contain high content of silica and alumina while POFA has high silica oxide content. Because of this, it meets the pozzolanic properties criteria as it can be potentially utilized in concrete (Mohamed et al., 2016; Corradi, 2006; Joo-Hwa, 1990).

The objective of this study is to determine the properties of SCC fabricated with bottom ash as coarse aggregates with the effect of the mixtures of POFA and FA as partial cement replacement. Experimental study was conducted with variation a total up 10% to 30% of the mixtures of POFA and FA. Several tests included slump flow, T50cm, and J-ring were conducted to assess the workability. Furthermore, hardened properties was evaluated by compressive strength.

2.0 METHODOLOGY

2.1 Materials

The proportions of the concrete mixtures are summarized in Table 1. Ordinary Portland Cement (OPC) and partial cement replacement of FA and POFA were used as binder materials in the production of concrete mixtures. The coarse aggregates for granite (normal concrete) and BA size were graded size sieved through 20 mm and retained at 14 mm according to BS 1881 PT 116 (1983) for the mould size of 150 mm × 150 mm × 150 mm. The fine aggregates was natural river sand with 4.75 mm maximum size. The fine aggregates was surface dried for a day before concrete mixing. Polycarboxylic ether based superplasticizer namely Masterglenium ACE 8589 was used to enhance the flowability of the mixtures.
Raw POFA was obtained from Unique Palm Oil, Mukah and oven dried at Concrete Technology Lab, UCTS at 105°C for 24 hours. The POFA used in concrete production was unground POFA. BA and FA were obtained from Sarawak Energy Coal Power Plant, Mukah. The POFA was then sieved in 300 µm sieve which is passed through the sieve.

Table 1. Mix Proportion of Control and Self Compacting Concrete

Sample	OPC(kg/m^3)	Sand (kg/m^3)	Coarse aggregates (kg/m^3)	BA (kg/m^3)	Fly ash (kg/m^3)	POFA (kg/m^3)	w/p	SP %
SCCN	420	768	630	-	180	-	0.47	0.2
SCCBA1	420	768	-	630	180	-	0.47	0.2
SCCBA2	420	768	-	630	120	60	0.47	0.5
SCCBA3	420	768	-	630	60	120	0.47	0.5
SCCBA4	420	768	-	630	180	0	0.47	0.5

2.2 Mixture proportion

A total number of forty-five (45) specimens were casted for five (5) different mixture proportions including SCC normal concrete (using granite) as control. Each mixture proportions was casted at 3, 7, and 28 days. OPC, FA, and POFA were mixed in dry state, and that of coarse and fine aggregates were mixed dry separately. All the materials were mixed together by adding about half of water while mixing goes on for 1 min. The remaining water was added to the mixture and continue mixing it for 3 minutes. After concrete specimen hardened, the specimens were cured under ambient temperature and tested on specific day.

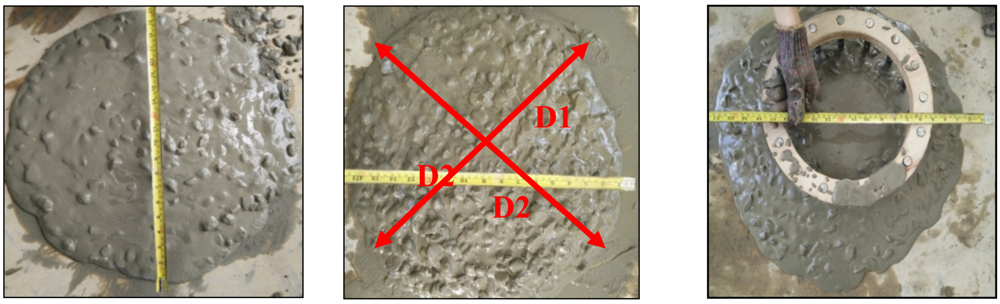
2.3 Fresh concrete tests

In order to ensure the concrete mixture in SCC classification, fresh properties of the concrete mixture was tested. The T50cm, slump flow and J-ring were executed to determine the fresh properties of the mixtures. As shown in Fig. 1, the T50cm, slump flow and J-ring were performed according to the procedure recommended by (EFNARC, 2005).

Slump flow test has been proposed to assess filling ability of concrete in the absence of obstructions. Concrete was filled into the slump cone without tamping and trowel was applied onto the surface to provide a flat top surface. The slump cone was lifted steadily to allow the concrete to flow and deform. The acceptance criteria are within 550 – 850 mm from lightly to heavily reinforced concrete structure.

T50cm test was carried out to determine the filling ability and viscosity of fresh properties of self compacting concrete. The test was conducted when the slump cone of self compacting concrete was being lifted. The time taken for the fresh concrete to flow through 500 mm diameter was being recorded and the corresponding result is known as T50cm.

J-ring test was used to determine the passing ability of the fresh concrete especially in the congested reinforcement and with tight opening. The procedure executed by placing the J-ring outside the slump. After that, concrete was filled inside the slump cone and lifted vertically to allow the fresh concrete to free flow and deform. The height distance between inside the J ring and concrete outside the J Ring was measured. The acceptance criteria for the J Ring for height differences should not be more than 10 mm.



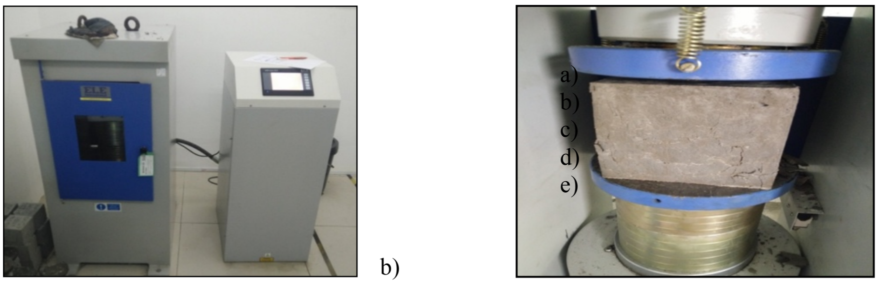
a) b) c)

Fig. 1. Fresh concrete test; a)T50cm b) Slump flow and c) J-ring

2.4 Compressive strength tests

The compressive strength of concrete for SCC specimens were tested on 3, 7, and 28 days. The specimens were cured under ambient temperature and tested on specific day. The compressive strength test was tested on the specimens according to BS1881 PT 108, (1983).

The cube mould size used was 150 × 150 × 150 mm. The concrete cube sample was tested by using compressive machine with capacity 3000 kN of compression load and the applied load rate is 13.50 kN/s. The compressive strength test is shown in Fig. 2.



b) a)

Fig. 2. Compressive Strength Test a) Overview of test machine b) Specimen under applied load

3.0 RESULTS AND DISCUSSION

3.1 Fresh properties of concrete

In order to determine the self-compact ability of the concrete specimen, the fresh properties was tested on slump flow test, J Ring, T50cm for filling and passing ability of the concrete. The fresh properties of self compacting concrete is obtained in Table 2.

Table 2 Filling and Passing Ability of Self Compacting Concrete

Specimens	Filling ability		Passing ability
	Slump Flow(mm)	**T50cm (s)**	**J Ring Height Differences (mm)**
SCCN(30%FA)	550	4	9
SCCBA1(30%FA:0%POFA)	630	4.2	6
SCCBA2(20%FA:10%POFA)	550	4.6	6
SCCBA3(10%FA:20%POFA)	400	3.2	12
SCCBA4(0%FA:30%POFA)	390	2.9	12
Acceptance Criteria EFNARC 2005	550 – 800 mm	2 – 5s	0 – 10 mm

According to Table 2, the time required for the concrete to flow to the 500 mm circle as in T50cm test shows that the specimens of SCCN, SCCBA1 and SCCBA2 are in acceptance criteria of slump flow, T50cm and J-ring tests according to EFNARC (2005). Contrary to specimens of SCCBA3 and SCCBA4, both filling ability and passing ability did not fulfill the requirement of EFNARC (2005).

Based on the results, the amount of POFA incorporated in concrete is limited to 10% of cement replacement to be passed with the filling and passing abilities. The further increased would reduce the filling and passing abilities results. According to Ranjbar et al., (2015), the POFA concrete is more porous than the OPC concrete which causing the water absorption is higher compared to OPC concrete. Therefore, the water demand for POFA concrete mixing is essential in order to roll the particles with each other.

3.2 Compressive strength test results

The compressive strength of concrete for normal concrete and self compacting concrete was tested on 3, 7, and 28 days. The compressive strength results for specimens concrete are presented in Table 3 and Fig. 3.

Table 3 Compressive Strength Results of SCC

Specimen	Cement Replacement		Coarse Aggregates		Compressive strength N/mm^2		
	FA (%)	POFA (%)	Granite (%)	Bottom Ash (%)	3	7	28
SCCN (30%FA)	30	0	100	-	24.8	29.6	35
SCCBA1 (30%FA 0%POFA)	30	0	-	100	27.9	31.9	50
SCCBA2 (20%FA 10%POFA)	20	10	-	100	18.1	19.7	29.2
SCCBA3 (10%FA 20%POFA)	10	20	-	100	7.5	9.5	11.2
SCCBA4 (0%FA 30%POFA)	0	30	-	100	4.9	6.6	8.8

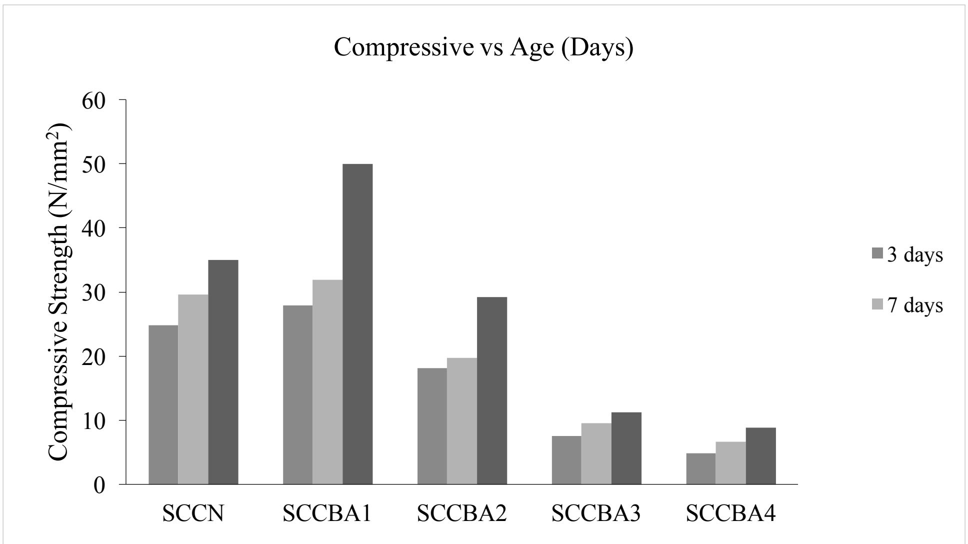


Fig. 3. Compressive strength against age of concrete at 7, 14 and 28 days.

The SCCBA1 specimen incorporating with a mixture of 30% FA:0% POFA and bottom ash as coarse aggregates shows the highest compressive strength of 50 N/mm^2 at days 28. Meanwhile, the lowest strength is SCCBA4 which incorporating with 30%POFA:0%FA at compressive strength of 8.8 N/mm^2 at aged 28 days. Muthusamy et al. (2015), mentioned that due to the pozzolanic properties of POFA, it can react with lime or calcium hydroxide ($CaOH_2$) from the cement hydration process to form additional calcium silicate hydrate (CeSeH) with binding properties which is known to reduce the concrete strength.

When the amount of POFA increases, the early strength is reduced. From Fig. 3, the compressive strength of POFA in SCC drop from 29.8 to 8.8 N/mm^2 when incorporating with 10%, 20% and 30% of POFA. This can be due to the hydration process of cement that is initially required by the cement is now being absorbed by the POFA due to its large particles, thus the pozzolanic reaction of POFA is delayed and consequently reduce the bonding between the aggregates. In addition, the POFA fineness at 300 µm which is unground POFA contributing to the lower strength. According to Jaturapitakkul et al. (2011), the specific gravity of ground POFA increased with the particle fineness since the grinding process reduced the porosisties as well as the voids in the POFA particles.

From the experiment, when the amount of POFA is increased, the workability reduced and it does not fulfill EFNARC [4] standard which is the POFA in SCCBA3 and SCCBA4 increased from 20% to 30%. Poor workability for the compacting of concrete under its own weight due to low filling ability. The low w/p ratio of 0.47 for 20% and 30% replacement with POFA can resulting in insufficient of water demand for the pozzolanic reaction take place.

Furthermore, the fineness of POFA improves the strength of concrete by filling the gaps between cement particles (M. A. Ismail et al., 2010). The POFA used in this study was unground POFA and was sieved passing through fineness of 300µm affect the inter-bonding between the aggregates as it reduces the strength of concrete. According to Tangchirapat et al. (2007), POFA received directly from the palm oil mill was unsuitable as a pozzolan due to its large particle size and high porosity. In order to improve its reactivity, POFA has to be thoroughly pre-processed by grounding by ball mill (Tangchirapat et al., 2007; Bakar, B.H.A., Ramadhansyah, P.J. and Azmi, 2011) or modified Los Angeles machine (Awal & Shehu, 2013) before being used and sieved to get homogeneous size of POFA.

Different dosage of superplasticizer was added to SCCBA due to different content of cementitious material of FA and POFA. The SCCBA1 with 30% FA:0% POFA used 0.2% superplasticizer compared to 0.5% superplasticiser used when incorporating SCC with 20% and 30% POFA. Higher amount of POFA due to its large particle size requires higher dosage of superplasticiser in order to maintain the workability. The dosage of superplasticizer was determined from trial mixes and measured by percentage of cement weight.

4.0 CONCLUSION

In order to produce environmental friendly concrete by utilizing POFA, FA, and BA in self compacting concrete, the conclusions can be drawn to fulfill the research objectives are as follows:

i. SCCBA1 with mix proportion 0%POFA:30%FA as partial cement replacement and 100% BA as coarse aggregate replacement has higher workability (slump flow, T50cm and J-ring) with increasing in compressive strength compared to normal SCC (30%FA) specimens. There is significant effect of BA as coarse aggregates replacement in SCC to the workability and compressive strength of the concrete.

ii. SCCBA1 with mix proportion 0%POFA: 30%FA has the highest compressive strength among SCCBA. In contrast, by incorporating POFA in SCCBA it decreased the workability of concrete due to high water absorption from unground POFA.

iii. The fineness of POFA which is unground POFA with the size of 300µm affect the inter-bonding between the aggregates as it reduces the strength of concrete. The incorporation of unground POFA due to its large particle size is not effective in improving the workability and strength of SCC. POFA has to be thoroughly grounded by ball mill or modified Los Angeles machine before being used and sieved to get homogeneous size of POFA so that can be incorporated in concrete.

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