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Experimental Analysis of Self Compacting Concrete Incorporating Pofa and Eggshell Powder as Cement Replacement

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Abstract: The rapid development of urbanization generate the ample amount of agricultural waste name as Palm oil fuel ash (POFA) and eggshells. As the POFA and eggshells posseses the pozzolanic characteristics due to that these wastes could be potentially utilized as the supplementary cementing material in concrete. This research investigated the potential utilization of POFA and eggshell powder (ESP) as supplementary cementing material in self compacting concrete (SCC). The main objective of this research is to examine the material chemical and fresh properties of SCC. The chemical property name as chemical compostion of material was determined on POFA, ESP and cement. The fresh state properties of SCC includes the slump flow, passing ability and segregation resistance were investigated by utilizing various percentage of POFA and ESP replaced by cement in SCC. The 5% to 15% POFA, 0% to 5% ESP were used as supplementary cementing material. The results shows that the chemical characteristics of POFA and ESP have the pozzolanic materials. The OPC and ESP has high content of Calcium Oxide (CaO) with 70.3% and 93.4%. Meanwhile, POFA has high content of Silicon dioxide (SiO_2). Which shows that SiO_2 and CaO will produce the pozzalnic gel to enhance the mechanical properties of SCC. The fresh state properties such as slump flow (T_{500} test), passing ability (J-ring test) and segregation test showed that the all the mixes satisfied the EFNARC specifications. The specimen 5P5E has better fresh state properties compare to all other nmixes.

Keywords: *self compacting concrete, palm oil fuel ash, eggshell powder*

1.0 Introduction

Self-compacting concrete (SCC) is a highly workable type of concrete that can flow by its own weight and completely fill into the formwork without external efforts such as vibrators and compaction. Innovation of SCC make the concrete more durable and feasible. In addition, the benefits of SCC is supreme to be utilized in drilled shafts and dense reinforcement. These benefits play an important role in improvement of conventional construction, saves the time for casting, reduces the noise, reduces the man power, easy placement during the casting and less segregation in concrete mix (Abdalhmid *et al.*, 2019; Herrmann *et al.*, 2019; Ren *et al.*,2019; Mohamad *et al.*, 2019).

In Malaysia, palm oil is important agricultural product which has great significance in the economy. The large amount of production produces the huge amount of waste which create a lot of disposal and environmental pollution. Beside that the municipal agricultural waste name as egg shells waste is also growing rapidly which affects the environment and producing pollution to public health. Regarding to this problems, Malaysian scholars start to explore and study utilizing POFA and ESP as a building material to produce new material in construction. Therefore, the application of such waste materials into construction can help to resolve these problems. Because of its pozzolanic characteristics of ESP and POFA could be significance in production of SCC (Tangchirapat *et al.*, 2007); (Khalid *et al.*, 2016); (Hussin *et al.*, 2009);(G. De Schutter *et al.*, 2008). Utilization of POFA and ESP as supplementary cementing material replacement will reduce the cement consumption, saves the natural resources of lime and protect the environment from pollution (Okamura *et al.*, 2000); (Jhatial *et al.*, 2018).

This research focusses on the physical properties and chemical composition of POFA and ESP and the fresh properties of SCC incorporating POFA and ESP as supplementary cementing material.

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2.0 Materials

The materials which was used in SCC was binding material (cement, POFA and ESP) fine aggregate, course aggregate, water and superplasticizer. Ordinary Portland Cement was utilized throughout experimental work. The Tasek brand was used which satisfied the Malaysian standard for OPC. Fine aggregate was passed from the 4.75mm sieve. The river sand was used as fine aggregate. The potable water was utilized to made the concrete mix and achieve the adequate workability. The crushing aggregate was utilized as coarse aggregate and passing from 12mm sieve.

The palm oil fuel ash (POFA) was utilized as partially cementing material that was together from Ban Dung P.O Ind. Sdn. Bhd, Seri Medan, Batu Pahat, Johor. POFA was oven dried at 110 °C for 24 hours as shown in Figure 1. Next, dried POFA was grinded about 3 hours in the grinder machine and finally sieved POFA with size 75µm to increase the fineness as cement replacement.

Figure 1: POFA

The Egg shell powder (ESP) also utilized as partially cementing material. The eggshell was cleaned to remove the liquid with normal water then dried in open air for 24 hours, and next is put those eggshells in the oven at constant temperature at 110 °C for another 24 hours. Figure 2 shows the dry eggshells were grinded into powder form and sieved passed through 75µm.

Figure 2: ESP

Super Plasticizer was utilized as admixtures in SCC to achieve the flowability, passing abiliyty and seggregation resistance to concrete. In this study the Conplast SP430 brand SCC was used the 2% by weight of cement was used in SCC mix.

Figure 3: Conplast SP430

3.0 Results and Discussions

3.1 Chemical Properties

XRF test was conducted to analyse the chemical composition on cement, POFA and ESP. Chemical composition of these three materials are shown in Table 1.

From Table 1 it can be seen that POFA and ESP possess the pozzolanic material such as SiO_2, Al_2O_3 and Fe_2O_3. According to ASTM C618 if the material possesses the pozzolanic material it will contribute either to improve the strength or not depends upon the whole chemical composition. From Table 3 it is also seen that the POFA contains the high amount of SiO_2 whereas ESP has the CaO in huge amount. Which shows that when POFA and ESP will be utilized as partially cementing material will develop pozzolanic gel which will enhance the mechanical properties of SCC.

Table 1: Chemical composition of cement, POFA and ESP

Chemical Composition	**Cement (%)**	**POFA (%)**	**ESP (%)**
Calcium Oxide (CaO)	70.3	8.96	93.4
Silicon dioxide (SiO_2)	17.0	30.6	0.151
Sulphur oxide (SO_3)	2.96	0.974	0.511
Aluminium Oxide (Al_2O_3)	3.57	0.935	0.0906
Ferric oxide (Fe_2O_3)	2.87	2.97	0.0288
Magnesium oxide (MgO)	1.97	2.60	0.764
Potassium oxide (K_2O)	0.097	16.1	0.0244
Titanium Oxide (TiO_2)	0.135	0.132	-
Phosphorus pentoxide (P_2O_5)	-	1.65	0.155

3.2 Fresh Properties

3.2.1 Slump Flow & T_{500} Test

Slump flow and slump time for T_{500} test were utilized to investigate the workability & filling ability of SCC mixture. Table 2.

The Table 2 shows that the all samples satisfied the EFNARC specification but control sample possesses the highest slump flow highest slump flow compare to other samples. Whereas other specimens which contains the POFA possess the lowest slump flow This is because material POFA and ESP are organic material which absorb the more water in the SCC. From the result, replacement of cement at 15P5E have the lowest slump flow which was 550mm. This might due to the characteristics of both material that absorbs more water. However, for specimens that have POFA and ESP as cement replacement which is 5P5E, 10P5E, and 15P5E gave result with low slump flow among all specimens. Presence of POFA and ESP in concrete could be seen to effect content of water in concrete mixture.

3.2.2 J-Ring Test

J-Ring test methods is to analyses passing ability of SCC under its own weight in combination with a slump mold. Table 6 presents the result for J-ring test.

From Table 3, it can be seen that specimen that has 5% of ESP as cement replacement have the lowest passing ability. Meanwhile, specimen with 0% of ESP gave high passing ability. It shows that the materials have high absorbance in SCC mix. Specimen with 15P0E have the lowest workability due to high percentage of POFA which absorb the water in the concrete mix. Both materials of POFA and ESP might have porous structure of surface area. The all specimen satisfied the requirement from EFNARC (2005) state that passing ability of J-ring flow must less than 10mm.

Table 2: Result for Slump Flow test & T_{500}

Specimen	Slump Flow Test			
	Diameter of Spread (mm)			Time of Spread toT_{500}
	d_1	d_2	d_{avg} = 550 mm ≥ *SF* ≤ 850 mm	Time (s)
Control	680	700	690	3.0
5P 0E	680	675	678	3.3
5P 2.5E	655	650	655	4.0
5P 5E	620	640	630	5.1
10P 0E	630	610	620	5.0
10P 2.5E	610	600	605	5.4
10P 5E	590	590	590	5.5
15P 0E	580	570	570	5.1
15P 2.5E	570	560	560	5.4
15P 5E	550	550	550	5.7

Table 3: Result for J-ring test

Specimen	J-ring Flow						
	Height of Spread (mm)						Passing Ability
	h_{x1}	h_{x2}	h_{y1}	h_{y2}	h_{avg}	h_o	$h_{avg} – h_o \leq 10$ mm
Control	119	118	110	120	116.75	113	3.75
5P 0E	120	110	115	120	116.25	112	4.25
5P 2.5E	120	120	120	120	120	115	5.00
5P 5E	120	110	110	110	122.25	118	4.25
10P 0E	130	130	120	130	127.50	120	7.50
10P 2.5E	120	120	125	120	121.25	115	6.25
10P 5E	118	120	125	120	120.75	117	3.75
15P 0E	110	115	120	120	116.25	107	9.25
15P 2.5E	120	115	115	120	117.50	109	8.50
15P 5E	110	110	110	115	111.25	109	2.25

Table 4: Result for Segregation test

Specimen	Segregation Sieve			
	Mass of sieve receiver + passed concrete, *Wps* (g)	**Mass of the sieve receiver, *Wp* (g)**	**Initial mass of concrete placed onto the sieve, *Wc* (g)**	**Segregated portion, SR (%) ≤ 20%**
Control	1770	1700	3890	1.80
5P 0E	950	850	3470	2.88
5P 2.5E	1000	860	3810	3.67
5P 5E	990	840	3490	4.30
10P 0E	960	850	3690	2.98
10P 2.5E	890	860	3300	0.91
10P 5E	780	710	3440	2.03
15P 0E	900	870	4140	0.72
15P 2.5E	910	850	3100	1.94
15P 5E	870	850	4220	0.47

3.2.3 Segregation test

The Table 4 indicates the outcome of segregation sieve for different percentage of POFA and ESP as cement replacement. From the result, it shows that 15P5E specimen have the lowest percentage of segregation. Concrete that have high workability produces higher percentage of segregation as shown the result for specimen 5P5E. The all samples fulfill the Requirement by EFNARC (2005) for sieve segregation result is the percentage must lower than 20%.

4.0 Conclusions

Based on the experimental result, the chemical composition of POFA and ESP shows that the POFA and ESP possess the pozzolanic material which will contribute to develop a pozzolanic gel and will enhance the strength of SCC. The fresh state properties show that the all specimen of SCC satisfied the EFNARC requirements. The slump of control sample was higher than the specimens which possessed the POFA and ESP this is because the ESP and POFA have high water absorption. The J-ring test and segregation resistance results have sample profile as in slump flow test. The utilization of POFA and ESP in SCC as cementing material develops a sustainable green concrete which decreases the CO_2 emmision and saves the natural resources of lime.

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