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STUDY THE EFFECTIVENESS OF THE DIFFERENT POZZOLANIC MATERIAL ON SELF-COMPACTING CONCRETE

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ABSTRACT

This paper presents the study on the effect of fly ash (FA), silica fume (SF) and microwave incinerated rice husk ash (MIRHA) as cement replacement material (CRM) on the mechanical and fresh properties of self-compacting Concrete (SCC). Some of the CRM materials are supposed to enhance the properties of SCC by avoiding the Bleeding at fresh stage and increase the strength in the long term at hardened stage, in addition of that CRM can reduce the total cost of mixing depends on the replacement percentage. The experimental work included the workability test as well as mechanical test of SCC. Workability test determined the flowability, filling ability and segregation resistance by slump flow, slump T_{50}, L-box and V-funnel testes. The mechanical properties by applying compressive strength, splitting tensile strength and flexural strength were investigated. There were a total of nine mixes created with different CRM contents. The result showed that the MIRHA needed more water as compared to SF to achieve the similar fresh properties, similarly concrete with 5% SF showed about 9.70% higher compressive strength after 90 days, 5.10 MPa high tensile strength and 10.12 MPa flexural strength when compared with other mixes.

Keywords: self compacting concrete, fly ash, MIRHA, silica fume.

1. INTRODUCTION

Self-compacting concrete (SCC) is the innovation concrete mix that has ability to resist the segregation and to flow under its own weight not by the vibration. The properties of SCC have been studied in many research due to it is important and ability to solve the problems of concrete mix [1, 2]. To achieve the SCC mix it is required to reduce the aggregate contents and increase the cement amount as well as the addition of chemical admixture such as super plasticizer [3, 4]. The increase in cement content will lead to increase the total cost, to avoid this problem the Cement Replacement Material (CRM) can be used. Much research has been conducted to investigate the properties of self-compacting concrete containing mineral admixture [5]. Fly ash is the famous type of CRM to replace the cement content in the concrete and can be increase the workability properties of SCC mix [6, 7]. Fly ash with different level of replacement in SCC mix has been studied to ensure the effectiveness and optimum degree of replacement can be used in SCC [8-10]. The microwave incinerated rice husk ash (MIRHA) was investigated by M. F. Nuruddin, *et al*., after the burning of rice husk ash which showed high silica and micro porous, the utilization of MIRHA to the strength of SCC depend on their amorphous silica content which can be extracted by proper burning of rice husk ash [11-14]. Silica fume was used in the SCC mix as the type of CRM and can be improve the workability characteristic of the SCC mix as well as enhancement of compressive strength [15, 16]. The main objective of this study was to investigate the effects of different types of CRM and their content on the fresh and mechanical properties of SCC, these different CRM; fly ash, silica fume, and MIRHA were selected for this study.

2. EXPERIMENTAL PROGRAM

(a) Material selection

ASTM, type-1 ordinary Portland cement (OPC) was used in the experiment, its chemical composition is presented in Table-1. Fly ash used in this study was class F according to the BS EN 450:1995 and originally obtained from the Manjung power station, Lumut, Perak, Malaysia. The chemical compositions are provided in Table-1. Silica fume was acquired from Elkem materials in dry densified form with Grade 920E with LOI fewer than 4% and particular area (BET) of 15-35 m^2/gram verifying towards the mandatory needs of ASTM C1240. Chemical composition of silica fume is shown in Table-1. Microwave incinerated rice husk ash (MIRHA) was obtained by the burning the dried rice husk ash at 700^0C in the automatic microwave incinerator of Universiti Teknologi PETRONAS, their chemical properties are tabulated in Table-1. Figures 1 and 2 shown the photo and XRD result of four-type of binder used in the experiment, respectively. The fine aggregate used in the experiment were clean natural sand with specific gravity of 2.61 and fineness modulus of 2.76, maximum size not more than 3. 35mm. While the coarse aggregate was used as (10-5) mm crushed granite stone of BS: 812-103.2-1989 with a specific gravity of 2.66 in SSD. The both aggregates were sieved as illustrated in Table-2. HRWR superplasticiser from SIKA-KIMIA; Malaysia was used for improving the workability of concrete. It is a highly effective liquid based superplasticiser for the production of free flowing concrete that complied with the requirements of BS 5075.

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Figure-1. Photo of OPC, Fly ash, Silica fume and MIRHA, respectively.

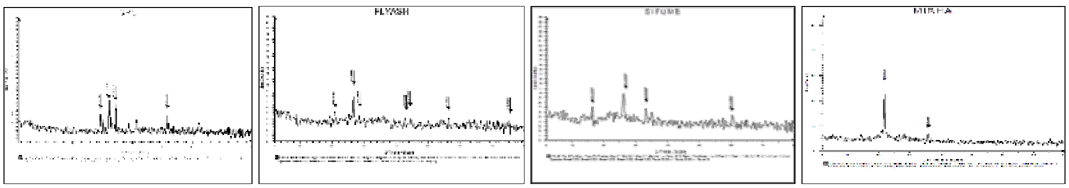

Figure-2. The XRD test result of OPC, Fly ash, Silica fume and MIRHA, respectively.

Table-1. Chemical composition of binder used in this study.

Chemical Composition	Percentage %			
	OPC[1]	FLY ASH [1]	SILICA FUME [2]	MIRHA[3]
SiO_2	20.3	56.39	96.36	90.75
Al_2O_3	4.2	17.57	0.21	0.75
Fe_2O_3	3	9.07	0.77	0.28
CaO	62	11.47	0.24	0.87
MgO	2.8	0.98	0.52	0.63
SO_3	3.5	0.55	0.55	0.33
K_2O	0.9	1.98	0.102	3.77
Na_2O	0.2	1.91	0.12	0.02

[1]OPC and Fly ash , the data provides by Shafiq, *et al*., [17]
[2]Silica fume, the data provides by M.F. Nuruddin, *et al*., [8]
[3]Test result obtained from XRF's Universiti Teknologi PETRONAS, Malaysia

Table-2. Sieve analysis of aggregate.

BS sieve size (mm)	Passing (%)	
	CA 10-5 mm	Fine aggregate
10.00	91.2	-
5.00	85.4	-
3.35	68.4	56.7
2.36	46.9	50.2
2.00	33.2	39.3
1.18	18.7	23.5
0.60	7.9	11.6
0.30	-	7.3
0.21	-	4.8
0.15	-	1.2
Pan	0	0

(b) Mix proportion

A development of 9-mix of self-compacting concrete based on the CRM amount. The binder content, superplasticizer, fine and coarse aggregate kept constant as 600kg/m^3, 12 kg/m^3, 900kg/m^3 and 750kg/m^3, respectively as illustrated in Table-3. In the control mix the total binder was 100% OPC while in the mix two and three the cement were replaced by 10 % and 30 % of fly ash respectively, the 5% and 10% of silica fume were applied in mixes four and five, 10% and 15% of MIRHA are used to replace the cement in mix six and seven. The last two mix was replaced by a combination of 30% fly ash with 10% silica fume in mix eight and 30% fly ash with 10% MIRHA in mix nine. The fresh properties of SCC mixes were checked by slump flow, slump T_{50}, L-box and V-funnel, the result was compared by the Specification of European Federation of Producers and Applicators of Specialist Products for Structures - EFNARC [18]. The compressive strength at 7, 28, 90 days with splitting tensile strength as

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well as the flexural strength at 28 days were performed in order to investigate the hardened properties of SCC mix.

Table-3. Mix proportioning.

Code mix	Binder content Kg/m^3				WATER	
	OPC	**FLY ASH**	**SILICA FUME**	**MIRHA**	**W/C**	**W (Kg/m^3)**
A	600	0	0	0	0.33	200
B	540	60	0	0	0.37	200
C	420	180	0	0	0.46	192
D	570	0	30	0	0.35	200
E	540	0	60	0	0.36	192
F	540	0	0	60	0.39	209
G	510	0	0	90	0.41	209
H	360	180	60	0	0.56	200
I	360	180	0	60	0.56	200

Note: For all concrete mixtures, coarse aggregate =750 kg/m^3, fine Aggregate = 900 kg/m^3 and Superplasticizer = 12kg/m^3.
C: control mix, *OPC*: Ordinary Portland cement, *FA*: Fly ash
MR: Microwave incinerated rice husk ash, *SL*: Silica fume

Figure-3. SCC in plastic state - homogeneous, non-segregating and no bleeding.

(c) Casting and experimental procedure

The methodology of the experiment was tested the fresh properties and then hardened properties such as compressive strength, splitting tensile and flexural strength which can be conducted if the freshness requirement was achieved as requirements. The SCC mixes were prepared using drum mixer, the mixer was firstly washed with water to ensure that there is no absorption inside and secondly the both aggregate were mixed with the half of water and left it for 2 minutes to let the water completely absorbed with aggregate, then thirdly the cement and mineral admixture (if needed) is added with mix of remaining water and super plasticizer for 4-minutes to allow the reaction of chemical admixture to completed, and finally the mixer left for 4 minutes to allow the ingredients to distribute uniformly inside the concrete mixer. Each sample was tested to determine the density and compressive strength at various stages after undergoing water curing. The cube specimens were kept at a room temperature of 20°C for 24 h after casting. After demolding, the specimens were transferred to the water tank for further curing until the age of the test. The specimens have been tested on the saturated surface dry condition according to BS 1881: Part 114. The compressive strength of the cube (100mm^3) immediately tested after obtaining their densities according to BS 1881: Part 116 for each test age. The splitting tensile and flexural strength tests were conducted by using the cylinders (100*200mm) according to ASTM C496 and beam (100*100*500 mm) BS EN 12390-5:2009 respectively. The axial compressive load was applied to 100 mm^3 cube samples by using a universal testing machine (UTM) with a capacity of 1000 KN.

3. EXPERIMENTAL RESULT

(i) Fresh properties

The outcomes of fresh testes for SCC mixes are provided in the Table-4, the factors such as slump-flow and T_{50} duration of SCC varieties. The slump flow signifies the mean diameter in the mass of concrete after discharge of a typical slump cone, the diameter is measured in 2 vertical with respect directions. In relation to slump flow, all SCC mixes showed acceptable slump flows in the range of 650-768 mm that is a sign of the good deformability. The FA and S.F mixes have proven

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greater than MIRHA as well as multi-CRM mixes which demonstrated lower slump-flow values. Attributable to its spherical shape; FA and S.F contaminants had a spherical geometry and coarse particle size leading to decrease the surface area. A partial replacement of cement by FA and S.F group reductions down on the friction in the fine aggregate-paste interface and enhances the cohesiveness, and also resulted in elevated workability. The slump flow test continues in the concrete to achieve a diameter of fifty centimeters (T_{50}) for the mixes was under 5 s and many types of SCC mixes demonstrated flow time values in the range of 2-5s. Both slump-flow values and also the T_{50} time have been in good agreement for that particular from the values provided by EFNARC specifications. From the V-funnel test result we can see that all SCC mixes recorded values within the EFNARC range, the mixes B, C, D and E show minimum time of funnel comparing with control mix, while the mixes F, G, H and I show more time. The same trend was obtained by l-box result because the SCC mixes gave values within the range of 0.8 to 1.0.

Figure-4. Slump flow, L-box and V-funnel for fresh tests.

Table-4. Fresh test result.

Code mix	Slump flow (mm)	Slump T_{50} second	V-funnel Second	L-box
A	650	2	6	0.8
B	720	4	10	0.89
C	700	3	7	0.87
D	700	3	6	0.94
E	768	3	8	0.84
F	680	5	9	0.8
G	660	4	10	0.9
H	690	4	11	0.95
I	660	5	12	0.90
EFNARC	600-800	2-5	6-12	0.8-1.0

(ii) Compressive strength result

The compressive strength test had been conducted for 7, 28 and 90 days, three molds were cast for each one and the average was calculated. The results are tabulated in Table-5. It shows the relative effect of CRM on the compressive strength of the SCC mixes. From the result we can see that the result of the last two mix has decreased the compressive both at 28 and 90 days and that can be attributed to the double pozzolanic replacement create high porosity and less finer microstructure compared with FA and SF. The 5% of SF increase the compressive by 9.7% compared with 5.21% of 10% SF, while 30% of FA perform well than 10% of FA as 4.31% and 3.89%, respectively after 90 days of curing. Regarding to the MIRHA mixes; the 10% of MIRHA gain high compressive strength than 15% of MIRHA by 2.41% and 1.08%, respectively. In case of multi-CRM mixes in (H) and (I); the combination of 10% SF with 30% FA show compressive strength better than the other mix of 10% of MIRHA and 30% of FA.

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Table-5. Compressive strength result.

CODE mix	Compressive strength Mpa			Relative effect		
	7-day	28-day	90-day	Change in 7-day result %	Change in 28-day result %	Change in 90-day result %
A	71.10	76.40	81.82	0	0	0
B	69.91	78.05	85.00	-1.67	+2.16	+3.89
C	65.59	79.19	85.35	-7.75	+3.65	+4.31
D	70.36	80.42	89.76	-1.04	+5.26	+9.70
E	67.81	79.18	86.08	-4.63	+3.64	+5.21
F	65.03	77.82	83.79	-8.54	+1.86	+2.41
G	63.90	77.15	82.70	-10.13	+1.77	+1.08
H	60.25	70.67	78.75	-15.26	-14.04	-3.70
I	62.56	73.70	78.85	-12.01	-29.71	3.63

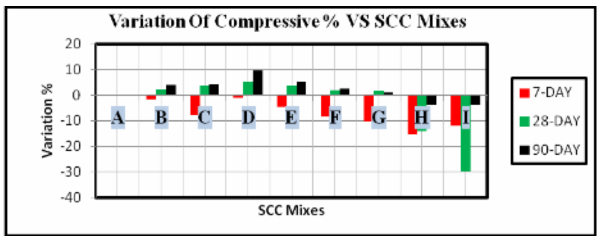

Figure-5. Variation of Compressive strength %.

(iii) Splitting tensile strength result

Concrete cylinder specimens of diameter 100mm and 200mm length were cast for testing in the age of 28, days in compliance with BS 1881: part 117:1983. Table-6 shows the result of splitting tensile strength of 28 days per each mix. The mixed groups that are (H) and (I) supply the low value of the final result in comparison with the other mixes. The 5% of silica fume record high result as 5.10 MPa while 30% of fly ash shows 4.8 MPa.

Table-6. Mechanical test result.

Code mix	Density KN/m^3	Splitting strength MPa	Flexural strength MPa
A	2.41	3.85	8.64
B	2.34	4.56	9.35
C	2.29	4.65	8.43
D	2.32	5.10	10.12
E	2.25	4.80	7.68
F	2.38	3.82	9.79
G	2.39	3.78	7.59
H	2.32	3.49	6.76
I	2.31	3.60	8.25

(iv) Flexural strength test result

Table-6 show the result of flexural strength test which was conduct on the beam of size (100*100*500) mm^3 according to the BS 1881: part 118:1983. The 5% of the SF own highest value as 10.12 Mpa while the 10% of MIRHA also record high value as 9.79 Mpa compared with the control mix .

(v) Density

Density of concrete samples was measured after the curing duration to check the effect of curing on the sample and these tests was complying with the BS 1881: part 114:1983. From Table-6 we can decide that all the SCC mixes do not have change in density comparing with the control mix.

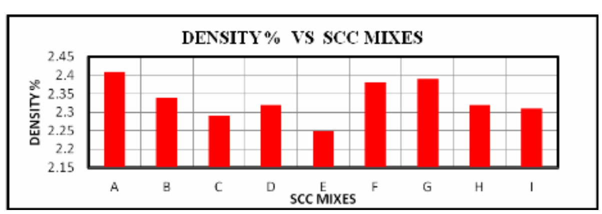

Figure-6. Density % vs SCC mixes.

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Figure-7. Compressive, splitting tensile and flexural strength tests.

4. CONCLUSIONS AND DISCUSSIONS

The detailed experimental work conducted in this study and analysis revealed the following conclusion:

a) Some of the CRM has positive effects on self-compacting concrete; mechanical and fresh properties.
b) Silica fume requires less water demand as compared to MIRHA for achieving the similar fresh properties.
c) 5% SF and 30% FA mixes showed highest compressive strength as compared to the control mix. Whereas all CRM mixes resulted in high flexural strength, which was due to the negligible bleeding and high cohesiveness.
d) The performance of MIRHA to replace the cement depends on the burning degree which will affect the microstructure of the binder.
e) Mixes (H) and (I) show poor result in both fresh and mechanical properties due to the double replacement of CRM.

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