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Research Article

Assessment of Fresh and Hardened Properties of Self-Compacting Concrete made with Fly ash as Mineral Admixture

Ahmed Fathi[a*], Nasir Shafiq[a], Muhd Fadhil Nuruddin[a] and Ali Elheber[a]

[a]Civil Engineering Department, Universiti Teknologi PETRONAS-Malaysia

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Abstract

This paper study the effect of fly ash (FA) added to self-compacting concrete (SCC) mixture with different percentages. the experiments were conduct by varying the percentage of fly ash as mineral admixture and the amount of water, the fresh requirement of SCC was investigated by using the slump test, V-funnel and L-box as specified by guidelines on SCC by European Federation of National Associations Representing Producers and Application of Specialist Building Products for Concrete (EFNARC), addition of that the compressive strength, tensile strength and porosity test were investigate. Test result found out that the higher compressive strength was found with 5% of PVA and water to cement ratio was 0.25 , also the result found out that the fly ash will increase the compressive strength and decrease the porosity of SCC at long term.

Keywords: *Self compacting concrete , fly ash and mirha*

1. Introduction

The introduction of self-compacting concrete (SCC) to the construction Industry has resulted in a major change in concrete construction process, with large benefits being made not only in productivity but to the overall cost of project. Since its development in the late eighties, there has been large amount of research study the mix design, placing methods, fresh properties and strength of various SCC mixes (Okamura, H et al,1997). SCC mixes usually contain a powerful super plasticizer and often utilize a large quantity of powder materials and/or viscosity modifying admixtures (Ozawa et al,1989). The super plasticizer is required for producing a highly fluid concrete mix, while the viscosity modifying agents are necessary to maintain sufficient viscosity of the mix, and then reducing bleeding and segregation/settlement(Subramanian et al,2002). The powder materials used mostly include limestone powder, fly ash, granulated ground blast furnace slag, metakaolin, rice husk ash, etc. Furthermore, coarse aggregate content is greater lower in SCC mixes than in traditional vibrated concrete mixes to reduce the risk of blocking of concrete flow by congested reinforcement and narrow openings in the formwork(Ferraris et al,1999). Due to the significant .

Differences in the mix proportions of content and also in placing and compaction processes between the SCC and Vibrated mix, it is not clear to assume that SCC would have the same durability characteristics as traditional concrete if their Strength grade was similar. In view of its growing popularity of use in structures that require a high standard of durability, knowledge of the durability performance of SCC mixes is urgently needed (Khayat et al,1997; Patrick Stahli et al,2007). Okamura study the new type of concrete called latter self-compacting concrete (SCC) which can flow easily under its own weight without needed to equipment of vibration. He used coarse aggregate as 50% of the solid volume and fine aggregate content as 40% (Okamura, et al,1997).Ozawa focused on improved characteristics of SCC suggested by Okamura and he completed the first prototype of SCC using material available in market, he found out that the used of super plasticizer in mixture of SCC lead to increase its workability(Ozawa et al,1989).Subramanian and Chattopadhyay replace Portland cement partially by fly ash and blast furnace, they justify the amount of viscosity modifying admixture added to SCC mix to eliminate the bleeding of the mixture (Subramanian et al,2002).Ferraris, et al. used V-flow and U-flow as two rheometer to examine the workability of SCC mix because the workability can be defined as the main property to defined the compatibility of concrete , he found out that there is no correlation between the result coming by this two rheometer(Ferraris et al,1999) .Kuroiwa developed other new type of concrete named as Super-workable; he used materials normally found in convential concrete in order to achieve excellent resistance to segregation without need to vibration(Kuroiwa et al,1993).Khayats, et al. study the mechanical properties of SCC by using

Ahmed Fathi and **Ali Elheber** are PhD students and **Muhd Fadhil Nuruddin** is Professor

different cementations material and chemical admixture to attain slump flow about 630mm, the mechanical properties and modulus of elasticity of SCC was higher than that of normal vibrated concrete (NVC)(Khayat, et al,1997).G. pons, et al. applied the compressive and splitting tensile test to the SCC mix incorporating either adherent metal fibers or polymeric synthetic slipping fibers or combination of both, he found out that the hybrid fibers self-compacting concrete(HFSCC) can be inferred from the properties of SCC with one type of fibers(FSCC)[8].Abdul kadir Cuneyt Aydin study the effect of carbon and steel as hybrid inclusion on the SCC mix, he found out that the flow ability of SCC mix differ from that of plain concrete, also he observed that the workability of SCC mix can be retain by increased the amount of paste, to provide this problem more amount of pozzolanic should be used (Abdulkadir et al,2009).Srinvasa , et al. used glass fibers inclusion on the SCC mix and that lead to reduction in bleeding which result to improve the homogeneity of the mixture (Srinivasa et al).M.L.V prasad, et al. examine the stress-strain curve behavior and mechanical properties of SCC for no fiber and that using glass fiber(GFSCC),he found out that the addition of glass fiber to SCC lead to enhance the peak strain at 85% of ultimate strength(M.L.V. Prasad at al,2009).Burak Felekoğlu, et al. examine the strength of SCC with fly ash and two polymer micro-fibers (polypropylene and polyvinyl alcohol), he found out that the used of fly ash in SCC mix improved the fractional bond between polypropylene fiber (PP) and matrix while the used of polyvinyl alcohol(PVA)in SCC lead to rupture of fiber (Burak et al,2009).Minds, et al. added some of mineral admixture (fly ash, blast furnace and silica fume) to the SCC mix to improve the workability, strength and to achieve compatibility of SCC mix (Mindess, et al,2003).Gebler and Klieger used class F fly ash and class C fly ash in concrete mix to examine its air-entraining, they found out that the used of class C fly ashes in concretes appeared more stable than that of concretes containing fly ash class F because class C fly ash have lower carbon content and organic matter, this fact help concretes containing class C fly ash lose less air than that of concretes containing fly ash class F (Gebler et al,1986).Naik and Singh evaluated the compressive strength and bleeding of concretes mix containing two type of fly ash; class C fly ash and class F fly ash. They found out that concrete containing class C fly ash showed higher early age (1 to 14 days) and less bleeding than that of concretes containing class F fly ashes (Naik et al,1997) The objective of this study focus on the effect of different percentage of FA on the properties of SCC and make comparison between the normal SCC which it is binder is 100% cement and that contain fly ash.

Experimental producers

A-Materials

The specification and properties of material has been used in experiment are listed below

B- Cement

ASTM, type-1 ordinary Portland cement (OPC) was used in the experimental, it is chemical composition are presented in table (1).

C- Fly ash

Fly ash used in this study was class F according to the BS EN 450:1995 and originally obtained from manjung power station, lumut, perak, Malaysia. The chemical compositions are provided in table (1).

Table 1Chemical composition of binder

Chemical composition	Percentage%	
	OPC	FLY ASH
Loss on ignition	2	4.2
Free Calcium Oxide	-	0.1
Sulfur trioxide (SO3)	3.5	0.9
Silicon dioxide (SiO2)	20.3	51.2
Calcium oxide (CaO)	62	5.6
Magnesium Oxide (MgO)	2.8	2.4
Ferric oxide (Fe2O3)	3	6.6
Aluminum Oxide (Al2O3)	4.2	24.0
Potassium Oxide (K2O)	0.9	1.1
Sodium Oxide (Na2O)	0.2	2.1
Loss on ignition	2	4.2
Free Calcium Oxide	-	0.1
Sulfur trioxide (SO3)	3.5	0.9
Silicon dioxide (SiO2)	20.3	51.2
Calcium oxide (CaO)	62	5.6

Note: 1 fly ash from manjung , Malaysia , data provided by shafiq, et.al. [14]

D-Aggregate

The fine aggregate used in experiment was dry 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 in two groups (20-8) mm and (8-4) mm crushed granite stone (BS 812-103.2 1989) with specific gravity of 2.66 in SSD. The both aggregate was sieved as lustrated in table (2).

E-Superplasticizer

Superplasticizer used in experiment was sikament-NI high Range water-reducing concrete admixture naphthalene formaldehyde sulphonate type, optain by Sika kimia .sdn. Bhd according to BS 5075.

F- Mix Proportion

In the design mix of SCC there were two group depend on the different water to binder ratios as 0.25 &0.32 named as series I and series II, each series contain 4-mix, the cementations content, superplacticizer were kept constant as 500kg/m3 and 3% respectively, also the amount of fine aggregate was constant as 850kg/m3 while there were two type of coarse aggregate was used depend on it is size as 310 kg/m3 and 615 kg/m3. For each series there were control mix in which does not contain fly ash, the replacement of fly ash were proposed to be as 5%, 10% and 15% by weight of cement. The objective of this study is to assess the effect of different percentages of fly ash on the workability characteristic of SCC mix, addition of that the objective was extend to hardened properties of concrete mix that effect by fly ash such as compressive strength, split tensile strength and porosity test in order to investigate the durability of the SCC mix. The compressive strength was tested for 1,3,7,28,56 and 90 days while the tensile strength and porosity test were conducted at 90 days. The design mix is shown in table (3).

Table 2 Sieve analysis of aggregates

BS sieve size (mm)		Passing%	
	CA (20-8) mm	CA(8-4) mm	Fine aggregate Mm
20	99.2	-	-
14	72.4	-	-
10	31.3	-	-
5	3	20.6	-
3.35	2.1	3.1	-
2.36	1.8	1.3	66.7
2	-	0.7	62.1
1.18	-	0.7	47.2
0.6	-	-	32.3
0.3	-	-	29.1
0.21	-	-	12.4
0.15	-	-	7.8
Pan	0	0	0

G- Casting and Experimental Procedure

The concrete mix can be classified as SCC if their workable test such as slump flow , V-funnel and L-Box were satisfied attain the requirement as in EFNARC. The methodology of the experimental was test firstly the fresh properties and after that the hardened test such as compressive strength ,tensile strength and porosity can conduct if the freshness requirement was happening. The SCC mix were prepared using drum mixer, the mix was firstly washed with water to ensure that there is no absorption and secondly the both aggregate were mixed with the half of water and left it for 8 minutes to let the water completely absorbed with aggregate, then thirdly the cement and fly ash (if needed) is added with mix of remaining water and superplasticizer , and finally the mixer left for 5 minutes to allow the reaction of chemical admixture is completed.

Test Results

H- Workability Test

The slump flow was used to investigate the flow ability of the mix while the V-funnel used to study the viscosity with resistance of segregation and then L-Box to establish the passing ability, table (4) below shows the results obtained for this purpose.

Table (4) shows that the 8-mix of SCC were in the range of limit as stated in EFNARC , the slump flow results was measured between 550 to 650 mm for both series and the result indicate that the adding of fly ash will increase the flowability comparing with the normal SCC (100% cement) , V-funnel flow time also was carried out and from table (4) the 8-mix OF SCC has good viscosity and their values was in range of 6 to 12 second as EFNARC , also the L-Box test has been done in order to check the passing ability and from table (4) we can see that all mixes has maintain the requirement as EFNARC.

J- Compressive Strength Test

Compressive strength test were carried out for 1,3,7,28,56 and 90 days with cube size of 100 mm3, the test was done according to BS EN 12390-3:2002 by 2000 KN digital machine & flexural testing machine in concrete laboratory of UNIVERSITY TEKNOLOGY PETRONAS , the table (6)below show the average compressive strength of three sample per each mix.

There are many variables such as w/c ratio ,SP and fly ash contents may affect the compressive strength .in the following sub-section the influence of such variables is discussed.

K-Effect of w/c ratio and Fly ash content ton Compressive Strength for series I

From graph (1) we can see that although the mix (A) has the lower w/c ratio as 0.25 but their compressive results were low due to the it is binder made from cement only, when the cement start to replace by fly ash from mixes (B), (c) and (D) the compressive became high as with 0.26 and 0.28 as w/c ratio, the mix (D) exhibit lower result compare with (B) &(C) because to the high w/c ratio, so at 5% and 10% as percentage replacement of fly ash. .the high compressive strength will exist .

From graph (2) we can see that although the mix (E) has the lower w/c ratio as 0.32 but their compressive results were low due to the it is binder made from cement only, when the cement start to replace by fly ash from mixes (F), (c) and (G) the compressive became high as with 0.34 and 0.36 as w/c ratio, the mix (F) exhibit lower result compare with (G) &(H) because to the high w/c ratio, so at 5% and 10% as percentage replacement of fly ash the high compressive strength will exist.

Table 3Mix Design Proportion

MIX CODE		CEMENT			FINE AGG	COARSE AGG		WATER			SP	
			FA%	FA		(20-8) mm	(8-4) mm	Weight	W/C	W/B		Weight
SERIES I	A	500	0	0	850	310	615	125	0.25	0.25	3	15
	B	475	5	25	850	310	615	125	0.25	0.26	3	15
	C	450	10	50	850	310	615	125	0.25	0.28	3	15
	D	425	15	75	850	310	615	125	0.25	0.29	3	15
SERIES II	E	500	0	0	850	310	615	160	0.32	0.32	3	15
	F	475	5	25	850	310	615	160	0.32	0.34	3	15
	G	450	10	50	850	310	615	160	0.32	0.36	3	15
	H	425	15	75	850	310	615	160	0.32	0.38	3	15

All units in kg/m3

Table 4 Workability Test Results

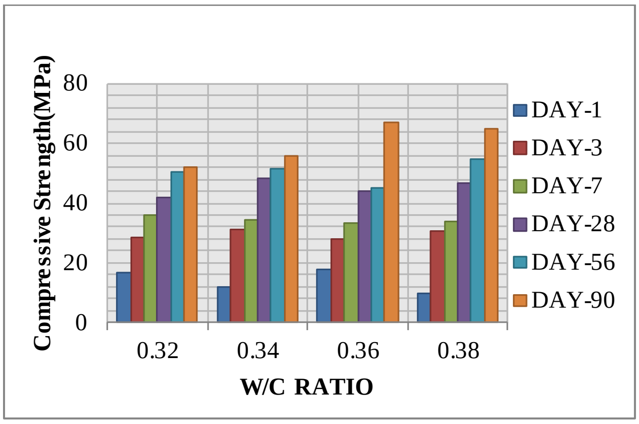
MIX	Slump Flow	V-funnel Time	L-BOX
	mm	second	H1/H2
A	550	8	0.85
B	600	6	0.8
C	610	12	0.9
D	650	10	0.8
E	580	6	0.95
F	630	9	0.92
G	650	10	0.9
H	610	8	0.98

Table 5 Workability Test Results

FRESH TEST	Min	Max
Slump flow mm	650	800
V-funnel Second	6	12
L-box	0.8	1

Table 6 Workability Test Results

COMPRESSIVE STRENGTH (MPa)						
MIX	1-Day	3-Day	7-Day	28-Day	56-Day	90-Day
A	35.78	50.09	58.9	69.19	74.2	83.1
B	32.48	55.49	56.26	79.15	90.98	95.44
C	24.32	52.98	56.76	81.32	94.21	95.08
D	13.87	29.82	34.33	75.44	88.03	88.83
E	16.71	28.49	35.94	42.02	50.23	52.16
F	12.15	31.22	34.62	48.11	51.64	55.59
G	17.81	28.23	33.41	43.78	45.15	66.98
H	9.59	30.89	34.11	46.65	54.51	65.09



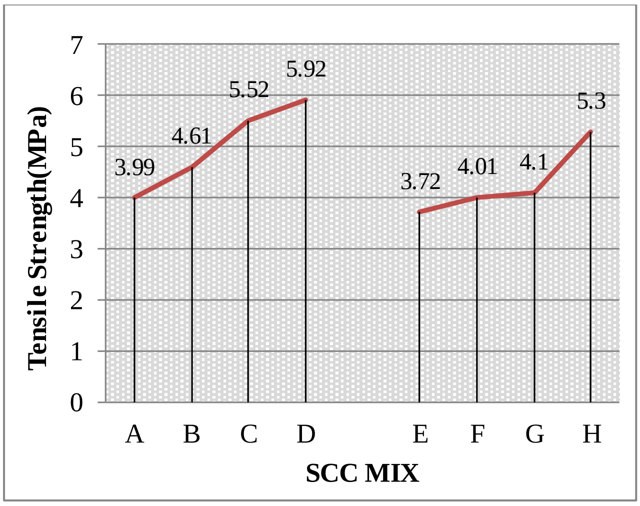
Graph (2) W/c ratio &Fly ash content VS compressive Strength for series II

M- Split tensile Strength Test

Tensile strength test was carried out at the curing age of 90 days with cylinder of diameter 150 mm and length of 300 mm , the test were performed according to the BS: Part 117: 1973 by digital testing machine , table (7) reported the results of this test.

Table 7 Tensile Strength Test Results

MIX	TENSILE STRENGTH (MPa)
A	3.99
B	4.51
C	5.52
D	5.92
E	3.72
F	4.01
G	4.1
H	5.3



Graph (3)Tensile strength of SCC mix

The graph above shows that the split tensile strength of the SCC mix increase as the percentage of fly ash increase, regarding to the comparison of two series we found out that the series I has high tensile strength than the series II and that due to it is low value of w/c ratio. The mix C shows the higher result which contains 10% of fly ash and 0.25 w/c ratio.

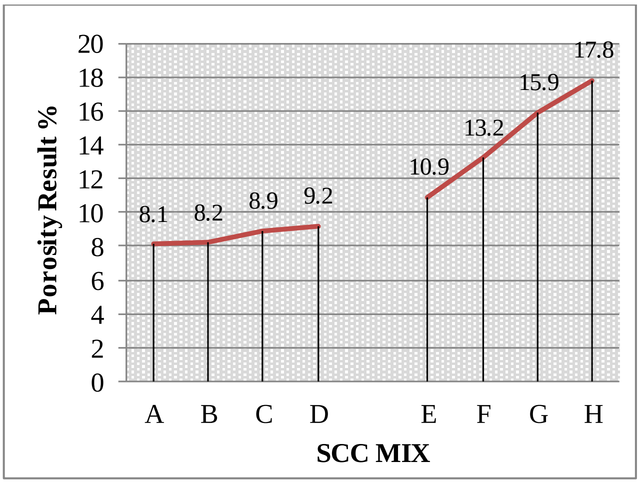
N- Porosity Test Result

The porosity test one of the important factor play vital role to control the short and long term performance of concrete, the test was carried out by using vacuum saturation method according to the RILEM CP 113 with details explained by Shafiq and Capera (N.Shafiq et al,2004) , the test were conducted on slices of cylinder cores with size of (0.048*0.315*0.205)m3 , the slices were put inside vacuum for 30 minutes after that the desiccators was filled with water for 6 hours and finally after 24-hours soaked in water , the samples were dried at 100±5 C

Table 8 Porosity Test Result

MIX	Porosity %
A	8.1
B	8.2
C	8.9
D	9.2
E	10.9
F	13.2
G	15.9
H	17.8

Table (8) reported the result obtained from tis test of 8 SCC mix for 28-day curing.



Graph(4) Porosity of SCC mix

From graph above we can see that the porosity in percentage has direct proportional relationship with the w/c ratio, whereby the porosity result in case of 0.25 w/b ratio was less than that obtained with 0.32 w/b , while C.S.Poon , et.al, stated that the decreasing of w/b ratio resulted in lower porosity for the normal concrete and fly ash concrete , when the content of fly ash increased the pore diameter will decrease also.

Conclusion and Discussion

From the results and discussion, following main conclusions were drawn:
Self-compacting concrete containing 10% fly ash content and 3% superplasticiser was produced with a range of w/c between 0.28 and 0.38 that satisfied the requirements of filling ability, passing ability and the segregation resistance. For FASCC, by lowering the w/c from 0.38 to 0.25, the compressive strength was increased in the range of 47% to 65%. With a water/cement ratio of 0.25 and 0.28 in FASCC, compressive strength was determined more than 80 MPa at the age of 28 days that was exceeded to 100 MPa at the age of 1 year. At the age of 3 day, FASCC achieved 57% of the 28 days strength. At the age of 90 days the FASCC was increased about 12% as compared to the 28 days strength.

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