STUDY THE INFLUENCE OF METAKAOLIN AND FOUNDRY SAND ON SELF-COMPACTING CONCRETE PROPERTIES

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Abstract - *Self- compacting concrete is the flowable concrete which flows by its own weight even in the congested reinforcement without using any vibrators. Where the use of vibrating is not possible and as the pumpable concrete SCC is used, so workability is main property of SCC.*

In the present study mineral admixtures metakaolin and foundry sand and chemical admixtures Master Glenium SKY 8233 are used. Metakaolin is used as the cement replacing material (5%, 10%, 15% and 20%), and foundry sand is used as sand replacing material (10%, 20%, 30% and 40%) in the SCC mix to improve the compressive strength and split tensile strength of concrete without any effect on its workability with various replacement levels and chemical admixture Master Glenium SKY 8233 is used to improve workability of concrete without segregation.

As per EFNARC guidelines SCC mix is done and workability of fresh concrete is studied by slump flow, T50, J-Ring, L- Box and U-Box tests.

Key Words: SCC, Metakaolin, Foundry sand, Master Glenium SKY 8233, EFNARC

1. INTRODUCTION

Self compacting concrete is the flowable concrete that spreads by its own weight, which is suitable in the difficult conditions such as in the congested reinforcement and also where the use of vibrating is not possible. The main characteristics of SCC are in fresh state its workability i.e., passing ability, filling ability, flow ability and resistance to segregation.

Now days, in this developing technologies, industries are also developing. At the same way industrial solid waste is also increasing. Majority of industries are not interested for the safe disposal of solid waste. By using that industrial waste in the concrete, the waste management and disposal cost will reduce.

In this present study foundry sand is used in the preparation of SCC which is the byproduct of ferrous and nonferrous metal casting industries. This sand has been used as a molding material because of it unique engineering properties. And also metakaolin used in this study which is the anhydrous calcined form of the clay mineral kaolinite. The particle size of metakaolin is smaller than cement particle, but not as fine as silica fume. From the previous investigation studies noted that, replacing the Portland cement with metakaolin 8-20% (by weight) to produce a concrete mix, it exhibits the favorable engineering properties. Chemical admixture Master Glenium SKY 8233 is used to maintain workability of SCC. Master Glenium SKY is the modified polycarboxylic ether and it is free from chloride & lo alkali. This is primarily developing the application in the high performance concrete where the highest durability and performance is required and it is compactable with all types of cements. Here Master Glenium is used to get high workability without segregation and bleeding.

2. MATERIALS AND METHODOLOGY

2.1. Cement

Ordinary Portland cement of 53 grade is used conforming to IS: 12269- [2013] in the preparation of mix.

2.2. Fine aggregates

The test results for physical properties of zone- II sand are 2.49 specific gravity, 2.87 fineness modulus and 1600 kg/m3 bulk density. Water absorption is 1.3% and surface moisture is 0.1%.

2.3. Coarse aggregates

Crushed granite aggregates of size 10mm were used. Properties of coarse aggregate are 2.74 specific gravity, 1450 kg/m3 bulk density, water absorption 1.08% and surface moisture is nil.

2.4. Admixtures

In the present study two types of admixtures are used to improve the concrete properties.

- Mineral admixtures
- Chemical admixtures

2.4.1. Mineral admixture (Metakaolin)

In this present study Metakaolin is used as mineral admixture, which blended with Portland cement in order to improve the strength and durability of concrete and mortars. It reduces the porosity of hardened concrete.

Fig-1: Metakaolin

Properties of Metakaolin are given in the following table

Table -1: Properties of Metakaolin

Sl. No.	Chemical	Mass%
1	SiO_2	52.86%
2	CaO	0.28%
3	MgO	0.20%
4	Fe_2O_3	0.45%
5	Al_2O_3	44.10%
6	Loss on Ignition	0.85%
7	Na_2O	0.25%
8	K_2O	0.20%
9	TiO_2	0.36%
10	Brightness	93.50%
11	Whiteness	95.80%
12	Retain on 500 mesh	0.05%
13	Bulk density	0.50 g/cc
14	Oil absorption	64.00 ml/100 g
15	Water absorption	6.680 ml/100 g

2.4.2. Foundry sand

In this present study foundry sand is used in the preparation of SCC which is the byproduct of ferrous and nonferrous metal casting industries. This sand has been used as a molding material because of its unique engineering properties. Foundry sand consists primarily of silica sand, coated with a thin film of burnt carbon, residual binder (bentonite, sea coal, resins) and dust.

Fig-2: Foundry sand

Table -2: physical properties of foundry sand

Sl. No	Property	Value
1	**Specific gravity**	2.63
2	**Water absorption**	1.9%
3	**Bulk density**	1950 kg/m3
4	**Voids ratio**	0.62
5	**Porosity**	38.27%

Table lists the chemical composition of a typical sample of spent foundry sand as determined by x-ray fluorescence.

Table -3: Chemical composition of Foundry sand

Sl. No	Constituent	Content (%)
1	SiO_2	83.93
2	Al_2O_3	0.021
3	Fe_2O_3	0.950
4	CaO	1.03
5	MgO	1.77
6	SO_3	0.057
7	LoI	2.19

2.4.3. Chemical admixture

Chemical admixture Master Glenium SKY 8233 is used to maintain workability of SCC. This is primarily developing the application in the high performance concrete where the highest durability and performance is required and it is compactable with all types of cements. Here Master Glenium is used to get high workability without segregation and bleeding.

Table -4: Properties of MasterGlenium SKY 8233

Sl. No.	Property	Test Data
1	Aspect	Reddish brown liquid
2	Chemical type	Polycarboxylic ether
3	Specific gravity	1.08
4	Chloride content	< 0.2%
5	Approx. air entrainment	1% at normal dosages
6	Relative Density	1.08 ± 0.02 at 25°C
7	pH	>6
8	Dosage	500 ml to 1500 ml per 100 kg of cementations material
9	Solid content	> 32%
10	Conforming standard	ASTM C 494 Type F
11	Form	Viscous liquid
12	Transport	Not classified as dangerous
13	Labelling	No hazard label required

2.5. INITIAL MIX COMPOSITION

As per EFNARC Guidelines of SCC the initial mix composition is as follows.

- Water/powder ratio by volume of 0.80 to 1.10
- Total powder content - 160 to 240 litres (400-600 kg) per cubic meter.
- Coarse aggregate content normally 28 to 35 per cent by volume of the mix.
- Water: Cement ratio is selected based on requirements in EN 206. Typically water content does not exceed 200 litre/m3.
- The sand content balances the volume of the other constituents

Further modifications will be necessary to meet strength and other performance requirements.

2.5.1. Adjustment of the mix

Laboratory trials should be used to verify properties of the initial mix composition. If necessary, adjustments to the mix composition should then be made. Once all requirements are fulfilled, the mix should be tested at full scale at the concrete plant or at site. Depending on the apparent problem, the following courses of action might be appropriate:

- using additional or different types of filler, (if available);
- modifying the proportions of the sand or the coarse aggregate;
- using a viscosity modifying agent, if not already included in the mix;
- adjusting the dosage of the superplasticizer and/or the viscosity modifying agent;
- using alternative types of superplasticizer (and/or VMA), more compatible with local materials;
- Adjusting the dosage of admixture to modify the water content, and hence the water/powder ratio.

3. SCC Mix Scenario

A SCC mix with 27.08% coarse aggregate content of concrete volume has been designed for water/ binder ratio 0.438 (by weight). Cement has been replaced with 5%, 10%, 15% and 20% of Metakaolin and Fine aggregate has been replaced with 10%, 20%, 30% and 40% of Waste Foundry Sand and combinations of both Metakaolin and Foundry Sand by percentage weight of cementations material.

Table -5: SCC Mix Scenario

Mix Type	Binder Kg/m³	Water/Powder Ratio	Water l/m³	Fine Aggregate Kg/ m³	Coarse aggregate Kg/ m³	SP l/ m³
SCC	500	0.438	219	905.88	756.16	2.4

Based on this initial mix total 14 concrete mixtures were studied. Mix types with percentage relative proportions of constituent materials are shown in Table

Sl No	Mix Type	Binder Kg/m³		Water/ Powder Ratio	Water l/m³	Fines Kg/ m³		Coarse aggregate Kg/ m³	SP l/ m³
		Cement	Metakaolin			Sand	Foundry Sand		
1	SCC	500	--	0.438	219	905.88	--	756.16	2.4
2	MK5	475	25	0.438	220.67	905.88	--	756.16	2.4
3	MK10	450	50	0.438	222.34	905.88	--	756.16	2.4
4	MK15	425	75	0.438	224.01	905.88	--	756.16	2.4
5	MK20	400	100	0.438	225.68	905.88	--	756.16	2.4
6	FS100	500	--	0.438	235.2	--	905.88	756.16	2.4
7	FS10	500	--	0.438	220.721	815.292	90.588	756.16	2.4
8	FS20	500	--	0.438	222.44	724.704	181.176	756.16	2.4
9	FS30	500	--	0.438	224.16	634.116	271.764	756.16	2.4
10	FS40	500	--	0.438	225.88	543.528	362.352	756.16	2.4
11	MK5+FS10	475	25	0.438	222.39	815.292	90.588	756.16	2.4
12	MK10+FS20	450	50	0.438	225.78	724.704	181.176	756.16	2.4
13	MK15+FS30	425	75	0.438	229.17	634.116	271.764	756.16	2.4
14	MK20+FS40	400	100	0.438	232.56	543.528	362.352	756.16	2.4

Table -6: SCC mixes with various replacement levels

Note: From the above table;

MK= Metakaolin

FS = Foundry Sand

For example, MK10 + FS20 = 10% metakaolin replaced with cement and 20% foundry sand replaced with fine aggregate.

4. WORKABILITY TEST ON SELF COMPACTING CONCRETE

A concrete mix can only be classified as self-complicating if it has the following characteristics.

(a) Filling ability

(b) Passing ability

(c) Segregation resistance

Several test methods have been developed in attempts to characterize the properties of SCC. Test methods for workability properties of SCC based on EFNARC specification and guidelines.

Table -7: Workability tests and their properties

Sl. No	Method	Property
1	Slump flow by Abrams cone	Filling ability
2	T50cmslumpflow	Filling ability
3	J-ring	Passing ability
4	L-box	Passing ability
5	U-box	Passing ability

Fig -3: Slump flow test (a) Before releasing cone (b) After releasing the cone

Fig -4: J- Ring Test (a) Setup (b) After releasing possibility checking

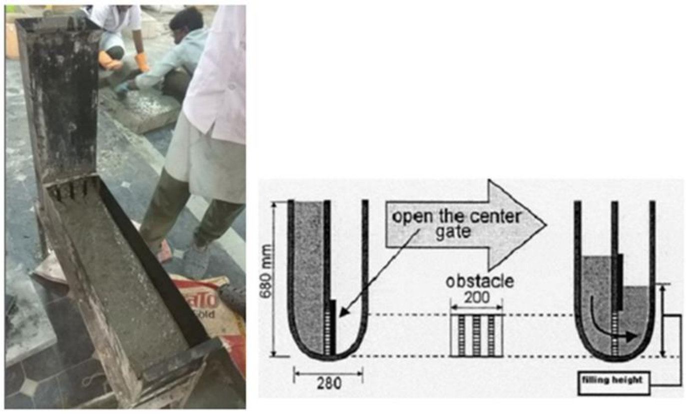

Fig -5: (a) L- Box test (b) U- Box test layout

4.1. Acceptance criteria for Self-compacting Concrete

These requirements are to be fulfilled at the time of placing. Likely changes in workability during transport should be taken into account in production.

Typical acceptance criteria for Self-compacting Concrete with a maximum aggregate size up to 20 mm are shown in Table

Table -8: Acceptance criteria for Self-compacting Concrete

Sl. No	Method	Units	Typical range of values	
			Minimum	Maximum
1	Slump flow by Abrams cone	Mm	650	800
2	T50cmslumpfl ow	Sec	2	5
3	J-ring	Mm	0	10
4	L-box	(h2/h1)	0.8	1.0
5	U-box	(h2-h1) mm	0	30

5. RESULTS AND DISCUSSIONS

5.1. Workability test results of SCC

Table -9: Workability test results of SCC with various replacement levels

Mix Type	Slump Flow (mm)	T50 (sec)	J- Ring (mm)	L- Box (h2/h1)	U- Box (h2-h1) mm
SCC	665	3.05	5.6	0.875	5
MK5	675	2.73	4.3	0.84	5
MK10	679	1.85	4.7	0.827	6
MK15	665	3.1	5.1	0.89	9
MK20	670	2.7	6.1	0.84	9
FS100	650	3.5	7.3	0.91	19
FS10	660	3.02	6.0	0.85	8
FS20	655	3.07	6.5	0.99	10
FS30	665	3	6.3	0.89	14
FS40	685	3.53	7	0.867	18
MK5+FS10	675	2.6	6.0	0.85	5
MK10+FS20	695	2.5	7.1	0.98	6
MK15+FS30	680	2.47	6.3	0.93	8
MK20+FS40	685	2.9	5.8	0.95	9

5.2. Compressive strength

The average compressive strength values of SCC mix with various replacement levels at different ages as follows:

Table -10: Average compressive strength values of SCC mix with various replacement levels

Sl. No	Mix Type	7 days (N/mm2)	28 days (N/mm2)	56 days (N/mm2)
1	SCC	32.15	40.46	49.84
2	FS100	19.99	30.97	45.12
3	MK5	35.38	42.43	54.64
4	**MK10**	**39.64**	**45.72**	**64.69**
5	MK15	37.26	43.62	60.45
6	MK20	26.54	37.53	43.41
7	FS10	31.39	40.92	55.12
8	**FS20**	**33.61**	**42.92**	**57.64**
9	FS30	26.77	34.44	50.54
10	FS40	22.91	31.68	43
11	MK5+FS10	29.12	41.8	55.23
12	**MK10+FS20**	**26.81**	**45.14**	**56.49**
13	MK15+FS30	23.17	39.37	51.31
14	MK20+FS40	22.45	38.18	46.68

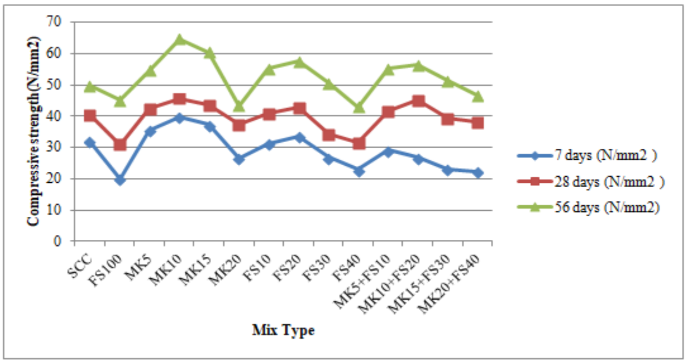

Chart -1: Graphical representation of compressive strength results

5.3. Split tensile strength

The average Split Tensile strength values of SCC mix with various replacement levels at different ages as follows:

Table -11: Average Split Tensile strength values of SCC mix with various replacement levels

Sl. No	Mix Type	7 days (N/mm2)	28 days (N/mm2)	56 days (N/mm2)
1	SCC	1.911	2.29	4.01
2	FS100	1.79	2.097	3.712
3	MK5	1.968	2.47	4.253
4	**MK10**	**2.53**	**3.51**	**4.47**
5	MK15	2.39	3.11	4.045
6	MK20	1.958	2.97	3.893
7	FS10	1.39	2.92	4.12
8	**FS20**	**1.61**	**2.97**	**4.44**
9	FS30	1.47	2.44	4.01
10	FS40	1.091	2.168	3.49
11	MK5+FS10	1.712	2.35	3.623
12	**MK10+FS20**	**2.18**	**2.914**	**4.49**
13	MK15+FS30	2.13	3.037	3.531
14	MK20+FS40	1.645	3.18	3.268

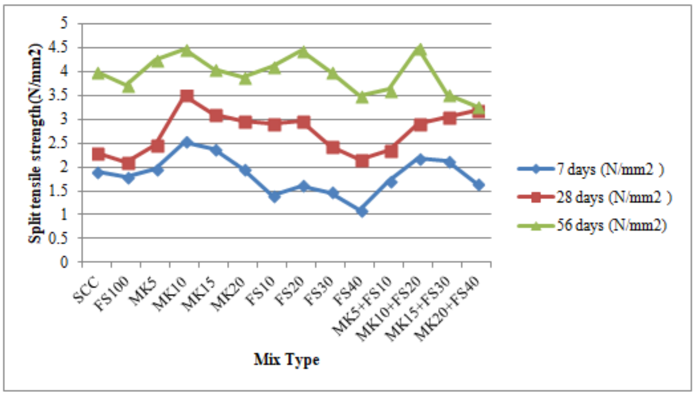

Chart -2: Graphical representation of Split tensile strength results

From the previous studies,

At 15% replacement of metakaolin with cement maximum compressive strength occurred and at 10% replacement maximum split tensile strength occurred [Shahiron Shahidan et al (2017); "Physical and mechanical properties of self-compacting concrete containing superplasticizer and metakaolin"].

And at 10% replacement of foundry sand with fine aggregate in conventional concrete maximum compressive strength occurred [Vikas Srivastava et al (2015); "Utilization of waste foundry sand as partial replacement of fine aggregate for low cost concrete"].

Percentage increased or decreased in the strength of self compacting concrete for considered 14 mixes as follows:

Table -12: Percentage increased or decreased in the strength of self compacting concrete with various replacement levels

Sl. No	Mix Type	% Increased or Decreased			
		Compressive Strength		Split Tensile Strength	
		28 Days	56 Days	28 Days	56 Days
1	MK5	+4.86	+9.63	+7.86	+6.059
2	MK10	+13.00	+29.79	+53.27	+11.47
3	MK15	+7.81	+20.288	+35.807	+0.872
4	MK20	-7.24	-12.90	+29.69	-2.917
5	FS100	-23.45	-9.47	-8.427	-7.431
6	FS10	+1.136	+10.59	+27.51	+2.743
7	FS20	+6.08	+15.65	+29.69	+10.72
8	FS30	-14.87	+1.404	+6.55	0
9	FS40	-21.70	-13.72	-5.327	-12.96
10	MK5+FS10	+3.311	+10.81	+2.62	-9.65
11	MK10+FS20	+11.566	+13.34	+27.24	+11.97
12	MK15+FS30	-2.694	+2.949	+32.62	-11.94
13	MK20+FS40	-5.635	-6.34	+38.86	-18.503

6. CONCLUSIONS

Based on the experimentation conducted, the following observations were made and hence some conclusions:

- Particle size of metakaolin is smaller than cement; SCC with Metakaolin has good workability.
- Addition of foundry sand in concrete increases setting time of concrete compared to other SCC mixes.
- The workability of SCC is good while replaced with metakaolin, foundry sand and with both combination of reasonable replacement levels.
- 100% replacement of foundry sand is not economical in the concrete mix. It has minimum workability and negative strength results obtained.
- The percentage increase in the compressive strength at 10% addition of metakaolin is +29.79 for 56 days of curing and +13.00 for 28 days of curing and split tensile strength is +11.47 for 56 days of curing and +53.27 for 28 days of curing
- The percentage increase in the compressive strength at 20% addition of foundry waste sand is +15.65 for 56 days of curing and +6.08 for 28 days of curing and split tensile strength is +10.72 for 56 days of curing and +27.51 for 28 days of curing.
- The percentage increase in the compressive strength at 10% addition of metakaolin and 20% addition of foundry sand is +13.34 for 56 days of curing and +11.56 for 28 days of curing and split tensile strength is +11.97 for 56 days of curing and +27.24 for 28 days of curing.

SCOPE FOR FURTHER STUDY

The following experimental studies can be conducted in future with respect to self-compacting concrete

- The effect of addition of foundry waste sand on the durability characteristics of self-compacting concrete containing more than three admixtures.
- The effect of high temperature on the properties of self-compacting concrete containing more than three admixtures with Metakaolin and foundry waste sand.
- The effect of addition of foundry waste sand on the shrinkage and the creep properties of self-compacting concrete containing more than two admixtures.

Similarly there are lot more mineral admixtures which are the wastage of the industry. The other type of wastage used for manufacturer of concrete to reduce the problems of environmental attack.

RECOMMENDATIONS

- The use of Metakaolin and waste foundry sand can be encouraged in various applications in self compacting as well as in conventional concrete in civil infrastructure.
- Metakaolin and Foundry sand are here fine which leads to increases the workability of SCC.
- The foundry sand of various size distributions can be used to obtain cost effectiveness.

- The effect of foundry sand and time dependent mechanical properties can also be studied.
- Using foundry sand in self compacting concrete increases the fines in the paste volume and workability.
- Usage of Master Glenium SKY 8233 which is the viscous superplasticizer increases the workability and Rheology of SCC.
- Replacing Portland cement with 8-20% (by weight) metakaolin produces a concrete mix, which exhibits favourable engineering properties.

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