Experimental Study on Self-Compacting Concrete using Silica fume and Metakaolin as Replacement for Cement

By,
R. Jayasankar[1], S. Alarmelumangai[2], M. Selvam[3], M. Srinivasan[4],
G. Rajagavi[5], R. Vijayakumar[6]
[1]Associative Professor,[2] Assistant Professor,[3,4,5,6] Final Year Students,
Department of Civil Engineering,
A.V.C College of Engineering, Mannampandal, Mayiladuthurai.

Abstract— Concrete has to be heavily vibrated for flow into very intricate forms or forms that have a lot of reinforcing bars. Hence to overcome these defects the self-compacting concrete is used. Self-compacting concrete is a flowing concrete mixture that is able to consolidate under its own weight. This project deals with the self-compacting concrete where the cement is partially replaced with silica fume and metakaolin. Here ordinary Portland cement is replaced with 5%, 10%, 15% and 20% combination of both silica fume and metakaolin. From the experimental investigations, it is observed that there is increase in the hardened properties (compressive strength) for replacement of silica fume. Similarly, there is increase in the hardened properties (compressive strength) for replacement of metakaolin.

Keywords— Self-compacting concrete, Silica fume, Metakaolin, Compressive strength.

1. INTRODUCTION

The Self Compacting Concrete is an innovative concrete that does not require vibration for placing and compaction. It is able to flow under its own weight, completely filling formwork and achieving full compaction, even in the presence of congested reinforcement. It Reduced equipment costs as no vibration are required. The first usable version of self-compacting concrete was completed in 1988 and was named "High Performance Concrete", and later proposed as Self-Compacting High-Performance Concrete". Due to its excellent deformability, low risk of blockage, and good stability to ensure high filling capacity of the formwork it is widely used in construction especially in places where heavy reinforcement is provided. Self-Compacting Concrete can achieve the below mentioned characteristics by its unique fresh properties as Filling ability, Passing ability, Resistance to segregation. Silica fume (SF) is one of several types of industrial by-products generated. Silica fume is very effective in the design and development of high strength high performance concrete. The natural kaolin clay is heated to 650 – 900°c to obtain Metakaolin. Metakaolin is the anhydrous calcined form of the clay mineral kaolinite. Minerals that are rich in kaolinite are known as china clay or kaolin, traditionally used in the manufacture of porcelain. The addition of silica fume and metakaolin as a partial replacement for cement of 5%, 10%, 15% and 20% and it is very advantageous. The hardened self-compacting concrete is homogeneous, dense and has the same engineering properties anddurability as traditional vibrated concrete.

2. LITERETURE REVIWE

N R Gayawala, D B Raijiwala

They did an investigate on self compacting concrete- A concrete of next decade. In this current investigation the research on discrete hardened properties of Self compacting concrete utilizing the Ordinary Portland cement and low-calcium fly ash as binder material. The hardened properties like compressive strength are investigated in experimental work and are compared with M25 grade of concrete. The proportion was taken as trial and error approach. After 13 to 14 trials they decided the mix proportion.

Badogiannis(1) et.al (2014)

Examined the durability of metakaolin based self-compacting concrete. In this study concrete was prepared by replacing cement with metakaolin. The properties such as open porosity, sorptivity, water and gas permeability were evaluated in their study against control mix. Fresh properties of SCC such as slump flow value, V funnel and L box permeability test etc., were evaluated. The effect of metakaolin as a replacement material had an enhances effect in the chloride penetration resistance and it not enhances surface water permeability.

Ramezanianpour(2) et.al(2012)

Investigated the performance of concrete mixtures containing local metakaolin in terms of compressive strength, water penetration, sorptivity, salt ponding, Rapid chloride Permeability test (RCPT) and electrical resistivity at 7, 28, 90 and 180 days. In addition, microstructure of the cement pastes incorporating metakaolin was studied by XRD and SEM tests. The percentage of metakaolin replacing PC is at 0%, 10%, 12.5% and 15% by mass. The water binder ratio used in this study were0.35, 0.4 and 0.5 having a constant total binder content of 400 kg/m³.

Sreedhanya Chandran[1] Lathi Karthi[2]

Investigation is made on mechanical properties such as compressive strength, split tensile strength etc., were improved by the incorporation of metakaolin as a partial replacement material for cement. The effect of sulphate on self-compacting concrete were not examined and a study has to be conducted on SCC with metakaolin as a partial replacement material for cement to analyze its sulphate resistance behavior.

The experimental results that the compressive strength decreases with the increases in percentage of fly ash and increases in percentage of silica fume. In this study the compressive strength and workability are found by using various percentages. Though there is reduction in strength due to the use of fly ash and increase in strength due to the use of silica fume in concrete.

3. MATERIALS

Cement

Cement is a binder, a substance used in construction that sets and hardens and can bind other materials together. The most important types of cement are used in the components in the production of mortar in masonry and of concrete, which is a combination of cement and an aggregate to form strong building materials available in the world.

Silica Fume

Silica Fume also known as condensed silica fume or micro silica is very fine, non-crystalline produced in electric arc furnaces as a by-product of the production of elemental silicon o silicon allows. The specific gravity ranges from 2.2 to 2.3. Silica fume is added to Portland cement concrete to improve its properties, in particular compressive strength, bond strength and abrasion resistance.

Table 1: Physical Properties of Silica fume

Physical State	Solid- Non-Hazardous
Specific Gravity	2.23
Mean grain size (μm)	0.15
Colour	White
Odour	Odourless

Table 2: Chemical Composition of Silica Fume

Chemical Name	Ingredients percentage
Silicon dioxide (Sio_2)	85
Aluminium Oxide ($Al_2 O_3$)	1.12
Iron Oxide ($Fe_2 O_3$)	1.46
Calcium Oxide (CaO)	0.2-0.8
Magnesium Oxide (MgO)	0.2-0.8
Sodium Oxide (Na_2 O)	0.5-1.2
Potassium Oxide (K_2 O)	0.5-1.2

Metakaolin

Metakaolin is the anhydrous calcined form of the clay mineral kaolinite. Minerals that are rich in kaolinite are known as china clay or kaolin, traditionally used in the manufacture of porcelain. It is a product that is manufactured for use rather than a by-product and is formed when china clay, the mineral kaolin, is heated to a temperature between 600 and 800ºC.

Its quality is controlled during manufacture, resulting in a much less variable material than industrial pozzolans that are by-products The particle size of metakaolin is smaller than cement particles, but not as fine as silica fume usually 8% - 20% (by weight) of Portland replaced by metakaolin. Such a concrete exhibits favorable engineering properties.

Table 3: Physical Properties of Metakaolin

Physical State	Solid- Non-Hazardous
Specific Gravity	2.30
Mean grain size (μm)	1-2
Colour	Light Creamy White
Odour	Odourless

Table 4: Chemical Composition of Metakaolin

Chemical Name	Ingredients percentage
Silicon dioxide (Sio_2)	53
Aluminium Oxide ($Al_2 O_3$)	43
Iron Oxide ($Fe_2 O_3$)	1.2
Calcium Oxide (CaO)	0.5
Magnesium Oxide (MgO)	0.4
Sodium Oxide (Na_2 O)	-
Potassium Oxide (K_2 O)	-

Fine Aggregates

The fine aggregates used in natural sand. The sand is sieved to remove all pebbles. The sieve size used is 4.75mm. And the sand must be sieved by 2.36mm sieve. The grading should be uniform throughout the work. The moisture content or absorption characteristics must be closely monitored as quality of SCC will be sensitive to such changes.

Coarse Aggregates

Crushed gravel stones obtained by crushing of gavel or hard stone are used as coarse aggregate. The maximum size of aggregates is generally limited to 12.5 mm. the aggregates serves as reinforcement to add strength to the overall composition. Aggregates are formed due to natural disintegration of rock hence they derived many gravity, hardness strength, physical and chemical stability.

Water

Water is one of the important elements in construction. It is required for preparation of mortar, is utilized in the hydration of cement to form the binding matrix in which the inert aggregates are held in suspension until the matrix is hardened and the remaining water serves as a lubricant between the fine and coarse aggregates and make concrete workable. The pH in surface water is 6.5 to 8.5 and the pH range for ground water is 6 - 8.5.

Control Mix Design

The mix design properties were designed as per IS 10262 code book using EFNARC guide lines, 1:1.545:1.961 (Cement: Fine Aggregate (FA): Coarse Aggregate (CA)).

From the mix percentage the weight of silica fume and metakaolin required is tabulated and calculated.

Table 5: Weight of material used

CEMENT (Kg/m^3)	FINE AGGREGATE (Kg/m^3)	COARSE AGGREGATE (Kg/m^3)	WATER (lit/m^3)
448.5	693.25	879.64	269.1

Table 6: Weights of cement, silica fume and metakaolin required

	Replacement % of cement by Silica Fume and Metakaolin (SF + MK)	(SF + MK) (2.5 + 2.5) = 5%	(SF + MK) (5 + 5) =10%	(SF + MK) (7.5 + 7.5) =15%	(SF + MK) (10 + 10) =20%
CEMENT	Silica Fume (Kg/m^3)	11.213	22.425	33.638	44.85
	Metakaolin (Kg/m^3)	11.213	22.425	33.638	44.85
	Cement (Kg/m^3)	426.075	403.65	381.225	358.8

EXPERIMENTAL PROCEDURE

Ordinary Portland Cement (grade 43), conforming to IS:8112-2013 was used with properties, Fine aggregate with 4.75mm maximum size was used while th coarse aggregate had a 12.5mm nominal size. Fine aggregate should be sieved by 2.36 mm. To casting a cube as per IS code in 150mm X 150mm X 150mm size. To Collect a material batched and weighed by mix proportions. Take quality of water as per the quality and prepared a cube for 5%, 10%, 15% and 20% the prepared cubes should take for test after 7, 14 and 28 days. To test conducted by using compression testing machine and the values should be calculated. And then the Compressive strength value has been tabulated and chart comparison should be prepared for clarity and the results are compared to each other.

RESULT AND DISCUSSION

Compressive strength

A test result is the average of at-least three standard cured strength specimens made from the same concrete sample and tested at the same age. The dimensions of the cube are 150mm X 150 mm X 150 mm. At first, the cube mould is prepared by connecting it properly with nuts and bolts. Then, it is thoroughly applied with grease in all nuke and corner of the mould. Now the prepared concrete is kept in three layers then the compaction or vibration are ignored. Finally leveling is done in the mould. It is allowed to set for 24 hours and then demoulded. The load was applied without shock and increased continuously at a rate of approximately 140 Kg/cm^2/min until the resistance of the specimen to the increased load broke down and no greater load could be sustained. It is done on curing of cubes after 7, 14 and 28 days. This process is repeated for the percentages 5%, 10%, 15% and 20%.

Compressive Strength Test

Compressive Strength (fc) = P/A

Where,

P – Load at Failure in Kg and

A – Surface area of bearing cube in mm^2

Fig 1: Cube Casting

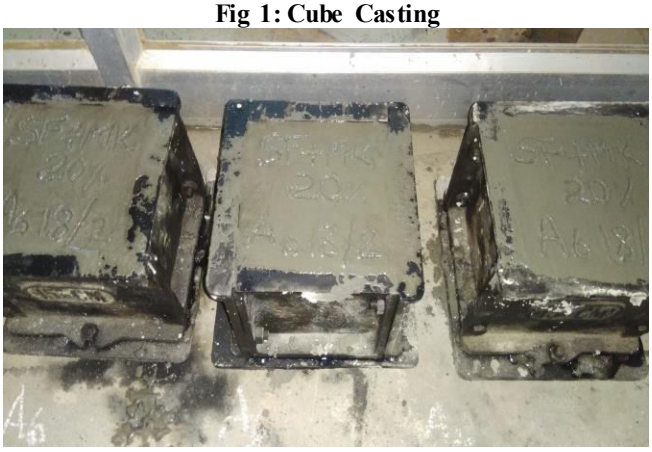


Fig 2: Cube testing

Table 7: Compressive strength of concrete (7 days)

S.NO	SPECIMEN	COMPRESSIVE STRENGTH (N/mm^2)
1	Conventional	11.453
2	(SF + MK) 5%	15.696
3	(SF + MK) 10%	20.434
4	(SF + MK) 15%	22.338
5	(SF + MK) 20%	23.718

Fig 3: Compressive strength of concrete (7 days)

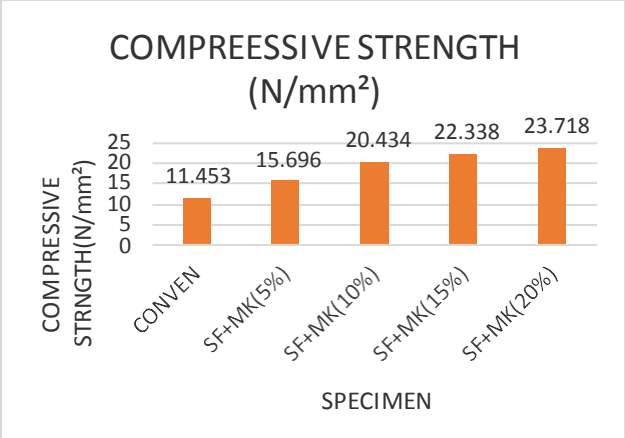


Table 8: Compressive strength of concrete (14 days)

S.NO	SPECIMEN	COMPRESSIVE STRENGTH (N/mm^2)
1	Conventional	16.735
2	(SF + MK) 5%	17.093
3	(SF + MK) 10%	22.541
4	(SF + MK) 15%	23.224
5	(SF + MK) 20%	24.154

Fig 4: Compressive strength of concrete (7 days)

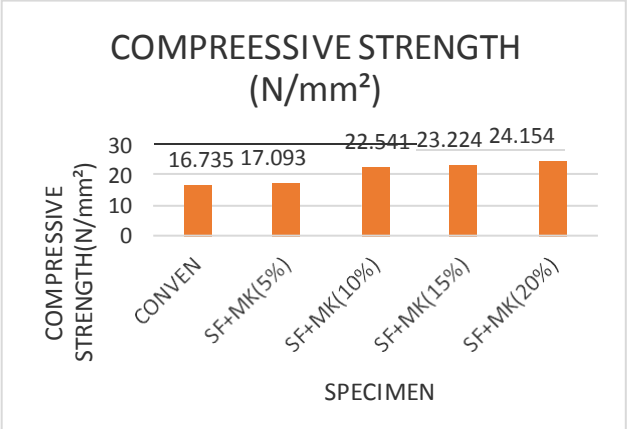
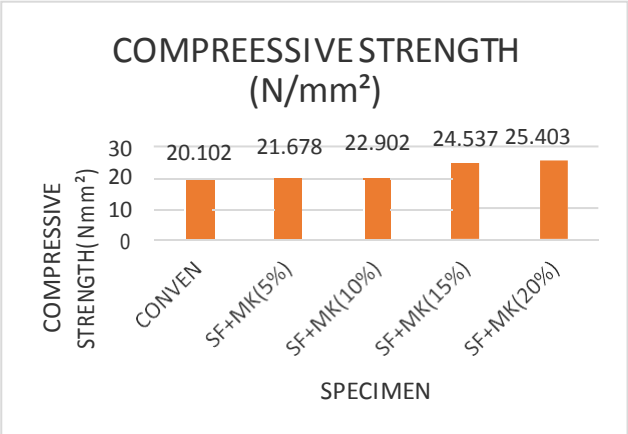


Table 9: Compressive strength of concrete (28 days)

S.NO	SPECIMEN	COMPRESSIVE STRENGTH (N/mm^2)
1	Conventional	22.047
2	(SF + MK) 5%	19.678
3	(SF + MK) 10%	22.902
4	(SF + MK) 15%	24.537
5	(SF + MK) 20%	25.403

Fig 5: Compressive strength of concrete (7 days)



CONCLUSION

SCC gives good finishing as compared to ordinary concrete without any external mean of compaction.

From the experiment it is concluded that partial replacement of Ordinary Portland Cement with Silica fume and Metakaolin does not affect the properties of concrete to perform the Self-Compacting Concrete.

It is evident from the experimental results that the compressive strength increases with the increase in percentage of silica fume and metakaolin.

As there is no specific mix design for SCC, the mix design can be done in any method and required adjustments can be done as per IS code and EFNAC guide lines.

When the cement is replaced with some percentage mix of silica fume and metakaolin is increased the value of compressive strength.

The value of Compressive strength is increased towards the increase in percentage of silica fume and metakaolin.

Scope for future work

This investigation can be extended to different concrete mixes with chemical as well as mineral admixtures.

REFERENCE

[1] Dinesh.A, Harini.S, Jasmine Jeba.P, Jincy.J, Shagufta Javed, Experimental Study on Self Compacting Concrete, IJESRT Journal of Engineering, ISSN: 2277-9655, March 2017.

[2] Sreedhanya Chandran, Lathi Karthi, Literature Review on Self Compacting Concrete Containing Metakaolin, IJSART, 2395-1052, March 2018.

[3] N R Gayawala, D B Raijiwala, Self-Compacting Concrete A Concrete of Next Decade, Technical Journals Online, 213-218, December, 2011.

[4] EFNARC (The European Federation of Specialist Construction Chemicals and Concrete System), The European Guidelines for Self-Compacting Concrete, May 2015.

[5] Reena K, Mallesh M, Experimental Studies on M20 Self Compacting Concrete, International Journal of Advanced Technology in Engineering and service volume N0.02 Issue No. 09, September 2014.

[6] Krishna Murthy N, Narasimha Rao A V, Ramana Reddy I V and Vijaya Sekhar eddy M, Mix Design procedure for self-compacting concrete, IOSR Journal of Engineering, Vol 2, Issue 9(2012), PP 33-41.

[7] Dhiyaneshwaran S, Ramanathan P, Baskar L and Venkata Subramani R (2013), Study on durability characteristics of Self-Compacting Concrete with fly ash, Jordan journal of civil engineering, Vol7, No 3

[8] EN206-1: 2000 – Concrete Part 1 – "Specification, Performance, production and conformity"

[9] Mahalingam B and Nagamani K (2011), Effect of processed fly ash on fresh and hardened properties of self-compacting concrete, International journal of earth science and engineering, ISSN 0974-5904, Vol. 04, No.05.

[10] KEnnoche S, Zerizer A, Benmounah A, Hami B, Fomulation and characterization of self-compacting concrete with silica fume (2013), Journal of Engineering and technology Research, Vol.5(5), PP 160-169.