AN EXPERIMENTAL INVESTIGATION OF M30 GRADE SELF COMPACTING CONCRETE USING SUPPLEMENTARY CEMENTITIOUS MATERIALS

M Amala , Assistant Professor, Department of Civil Engineering, Easwari Engineering College, Chennai-89, Tamil Nadu, India.
Dr.S.Meenakshi Sudarvizhi, Professor & Head, Department of Civil Engineering ,Pandian Saraswathi Yadav Engineering College, Arasanoor , Tamil Nadu, India.
Dr. S.Kandasamy, Associate Professor, Department of Civil Engineering , Veltech Rangarajan Dr Sagunthala R&D Institute Of Science and Technology, Avadi, Chennai 62, Tamil Nadu, India
Dr.N.Radhakrishnan, Assistant Professor, Department of Civil Engineering, PSR Engineering College Sivakasi,Tamil Nadu, India.
Dr.Natchimuthu. **S ,** Associate Professor, Department of Civil Engineering, New Horizon College of Engineering, Bengaluru, Karnataka, India.
Dr.K.Mohan das, Professor, Department of Civil Engineering, CMR College of Engineering & Technology, Kandlakoya Village, Medchal road, Hyderabad, India.

Abstract

Self-compacting concrete (SCC) is a type of high-performance concrete which compacts on its own weight without any vibration. It is application of SCC have been restricted due to lack of standard mix design procedure and testing methods. Its gaining wide acceptability because no vibration is needed and noise pollution is eliminated [1]. The Construction process is safer and more productive. In the present study the mix design for M30 grade self-compacting concrete (SCC) was carried out in accordance with EFNARC 2002 guidelines. The SCC is made with 30% replacement of Cement with varying percentage of Fly ash (FA) and Metakaolin (MK) i.e., 0%, 7.5%, 15%, 22.5% and 30% and along with addition of Super plastizer 1.5% to the volume of cement content. The testresults for acceptance characteristics of SCC such as slump flow test, V-funnel test, L-box test and J-ring test were satisfactory as per EFNARC for developed mix proportions of M30 grade SCC mix. Further, Compressive strength, tensile strength and flexural strengthat the age of 7 and 28 days were also determined and 0% to 30% replacement of MK and FA can be regarded asa suitable replacementsand optimized mix proportions have been recommended for M30 grade of MK and FA based SCC from this experimental study.

Keywords, *SCC, Fly ash, Metakaolin, Compressive strength, tensile strength and flexural strength.*

1. Introduction

Self-compacting concrete (SCC) was first developed in Japan (in the mid to late 1980s) as a means to create uniformity in the quality of concrete by controlling the ever-present problem of insufficient compaction by a workforce that was losing skilled labour and by the increased complexity of designs and reinforcement details in modern structural members [1][2]. Durability was the main concern and the purpose was to develop a concrete mix that would reduce or eliminate the need for vibration to achieve consolidation [3]. Self-compacting concrete achieves this by its unique fresh state properties. In the plastic state, it flows under its own weight and maintain homogeneity while completely filling any formwork and passing around congested reinforcement [4]. The elimination of vibrating equipment improves the environment on and near construction and precast sites where concrete is being placed, reducing the exposure of workers to noise and vibration. The improved construction practice and performance, combined with the health and safety benefits, make SCC a very attractive solution for both precast concrete and civil engineering construction.

The process is quite complex and can be simplify by understanding the relative significance of various mixture parameters on key properties of SCC [5]. This includes deformability, passing ability,filling capacity and segregation resistance. As with any new technology, there was clearly a learning curve to overcome, and refinement of the materials and mix proportions used to take care and patience to finally achieve optimum performance [6].

2. Materials Used and Mix Design

2.1 Material used

2.1.1 Cement

Ordinary Portland cement of grade 53 confirming to IS 12269-1987 was used. The properties of cement are given in Table 1.

Table 1: Physical Properties of Cement

S.No.	Test conducted	Result
1	Standard Consistency	32%
2	Initial Settings time	32 min
3	Final Setting time	612 min
4	Specific Gravity	3.16
5	Fineness	6.88%

2.1.2 Fine aggregate

Natural River Sand of size below 4.75 mm confirming to zone II of IS 383-1970 was used as fine aggregate. Lab tests were Conducted for fine aggregate to determine its physical properties as per IS:2386 (Part III). The test results are shown in Table 2.

Table 2: Physical Properties of Fine Aggregate

S.No.	Test conducted	Result
1	Specific gravity	2.57
2	Water Absorption	1.3%
3	Bulk density	1524Kg/m^3
4	Fineness modulus	2.75

2.1.3 Coarse aggregate

Coarse aggregate used in this study consist of crushed stone of size 12 mm and below. Lab tests were conducted on coarse aggregate to determine the different physical properties as per IS: 383-

1970. The test results are shown in Table 3.

Table 3: Physical Properties of Coarse Aggregate

SI.No.	Test conducted	Result
1	Specific gravity	2.67
2	Water Absorption	1.7%
3	Bulk density	1608 Kg/m^3
4	Fineness modulus	6.65

2.1.4 Superplasticizer

Conplast SP 430 is based on Sulphonated Naphthalene Polymer [7] and supplied as brown liquid instantly dispersible in water, having specific gravity of 1.220 to 1.225 at 30°C.

Table 4: Typical Properties of Superplasticizer

Properties	Limits
Appearance	Light brown liquid
Relative Density	1.09 ± 0.01 at 25 ^{0}C
Ph	>6

2.1.5 Fly Ash

Fly ash Class F normally produced anthracite or bituminous coal. Class F Fly ash has pozzolanic properties only.

Table 5: physical properties of Fly Ash

SI.No.	Test conducted	Result
1	Specific gravity	2.51
2	Water Absorption	1.3%
3	Bulk density	1524 Kg/m^3

2.1.6 Metakaolin

Metakaolin is the anhydrous calcined form of the clay mineral kaolinite.

Table 6: Physical Properties of Metakaolin

SI.No.	Test conducted	Result
1	Specific gravity	2.3
2	Bulk density	388 Kg/m^3
3	Color	Off white

2.2 Mix Design For M30 Grade

Details:

Design strength of SCC = 30 Mpa
Aggregate size = 12.5mm (passing)
Specific gravity of Coarse aggregate = 2.67
Bulk density of Coarse aggregate = 1608 Kg/m^3
Specific gravity of Fine aggregate = 2.57
Bulk density of fine aggregate = 1524 Kg/m^3
Specific gravity of Cement = 3.16
Volume ratio of fine aggregate = 45 %
Volume ratio of coarse aggregate = 50 %
Air content in SCC = 2 %

Step 1: Target Mean Strength

$= F_{ck} + T_s$
= 30 + (5*1.65)
= 38.25 Mpa

Step 2: Air Content

Net Volume of Concrete
Let Total Volume = 1000 Litre
Assume Air Content = 2 % = 20 Litre

Step 3: Calculation of Coarse Aggregate

As Per **EFNARC** Guidelines
Range Of Coarse Aggregate = **50-60 %**
% Of Coarse Aggregate in Drum = 50%
Specific Gravity of CA = 2.61
Dry-Rodded Unit Weight = 1608 Kg/m^3
Coarse Aggregate Weight = 1608*(50/100)
= 804 Kg/m^3
Coarse Aggregate Volume = 804/(2.61*1000)
= 0.308 Kg/m^3
% Of Volume of CA Occupied Per M^3 = 30.8 %

Step 4: Mortar Volume

Mortar Volume = Volume of concrete – Volume of coarse aggregate
= 1 – 0.308
= 0.692 m^3

Step 5: Fine Aggregate Volume:

% of Fine Aggregate in Mortar volume = 45
Fine Aggregate Volume = 0.692 *(45/100)
= 0.312m^3

Step 6: Paste Volume:

Paste Volume = Volume of mortar – Volume of FA
= 0.692 – 0.312
= 0.38m^3

Step 7: Determination of Paste Composition:

Specific gravity of cement = 3.15
Specific gravity of Fine Aggregate = 2.18
Specific gravity of Metakaolin = 2.3
Air content = 2%
Ratio of Water/ binder (by weight) = 0.38
Binder Material (400 to 600 kg/m^3) = 550 kg/m^3
Water (by weight) = 0.39 * 550 = 214.5 litre
70% of cement content used = 550*(70/100)
= 385 kg/m^3
30% of Fly Ash content used = 550*(30/100)
= 165 kg/m^3
% of SuperPlasticizer = 1.5% of cement content
= 385*(1.5/100) = 5.8 l/m^3

Step 8: Total Volume of Paste:

Total Volume of Paste = Volume of cement + Volume of FA + SP + Air + Water
volume of Cement = 385/ (3.16*1000) = 0.122 m^3
volume of Fly Ash = 165/ (2.18*1000) = 0.0756 m^3
volume of super plasticizer = 0.012 m^3
volume of water = 0.209 m^3
Air content = (2/100) *9.81 = 0.196 m^3
Total Volume of Paste = 0.122+0.0756+0.0122 +0.196+0.209
=0.427m^3

Step 9: Materials Required:

Table 7: Materials Required

Materials	Per m^3	Mix proporation
Cement	385 kg/m^3	1
Fly ash	165 kg/m^3	0.43
Fine aggregate	782 kg/m^3	2.03
Coarse aggregate	804 kg/m^3	2.08
Water	214.5 $litre/m^3$	0.4
Super plasticizer	5.8 $litre/m^3$	0.015

Table 8: Mix proportions

Cement	Fine Aggregate	Coarse Aggregate	Water-powder ratio	Fly Ash
1	**2.03**	**2.08**	**0.4**	**0.43**

2.2.1 Replacing Fly ash by Metakaolin with Five Different Ratios:

Total Cementious Material = Cement + Fly ash
(100%) (70%) (30%)

Table 8: Replacing Fly ash by metakaolin with 5 different ratios

Mix	Cement content (%)	Fly ash (%)	Metakaolin (%)	Total content (%)
M1	70	30	0	100
M2	70	22.5	7.5	100
M3	70	15	15	100
M4	70	7.5	22.5	100
M5	70	0	30	100

2.2.2 Test methods for SCC

Mix 1: 0 % metakaolin

Table 9: Workablilty Details of Mix1

S.No	Workability tests	values	Results
1	Slump Test (mm)	692	Pass
2	T50cm Slump (sec)	3.8	Pass
3	J-Ring test(mm)	8.3	Pass
4	L-Box(h2/h1)	0.9	Pass
5	V-Funnel (sec)	7.3	Pass

Mix 2: 7.5 % Metakaolin

Table 10: Workablilty Details of Mix2

S.No	Workability tests	values	Results
1	Slump Test (mm)	716	Pass
2	T50cm Slump (sec)	3.4	Pass
3	J-Ring test(mm)	9.2	Pass
4	L-Box(h2/h1)	0.95	Pass
5	V-Funnel (sec)	6.7	Pass

Mix 3: 15 % Metakaolin

Table 11: Workability Details of Mix3

S.No.	Workability tests	Values	Results
1	Slump Test (mm)	698	Pass
2	T50cm Slump (sec)	4	Pass
3	J-Ring test(mm)	8.7	Pass
4	L-Box(h2/h1)	0.92	Pass
5	V-Funnel (sec)	7	Pass

Mix 4: 22.5 % Metakaolin

Table 12: Workablilty Details of Mix4

SI.No.	Workability tests	Values	Results
1	Slump Test (mm)	682	Pass
2	T50cm Slump (sec)	4.3	Pass
3	J-Ring test(mm)	9	Pass
4	L-Box(h2/h1)	0.9	Pass
5	V-Funnel (sec)	7.3	Pass

Mix 5: 30 % Metakaolin

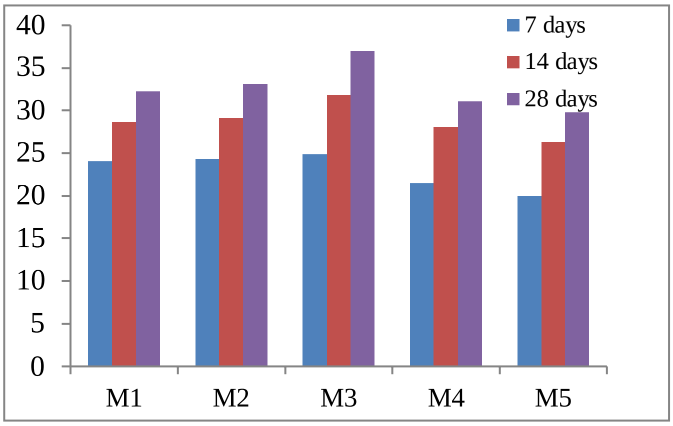
Table 13: Workablilty Details of Mix5

SI.No	Workability tests	Values	Results
1	Slump Test (mm)	660	Pass
2	T50cm Slump (sec)	4.6	Pass
3	J-Ring test(mm)	7.8	Pass
4	L-Box(h2/h1)	0.85	Pass
5	V-Funnel (sec)	7.8	Pass

2.2.3 Hardened Properties for Metakaolin Replacement

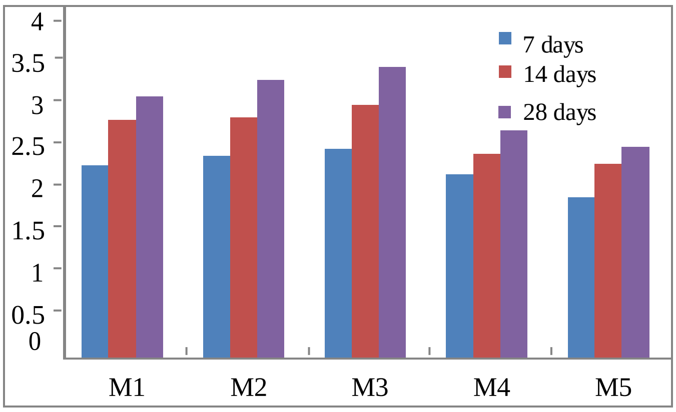
The results of the tests like compressive strength, split tensile strength and flexural strength for cement replacement with Metakaolin and Fly ash of different percentages namely 0%,7.5%, 15%, 22.5% & 30% as shown below figures.

Figure 1 Graph showing Compressive Strength at various proportions of Metakaolin



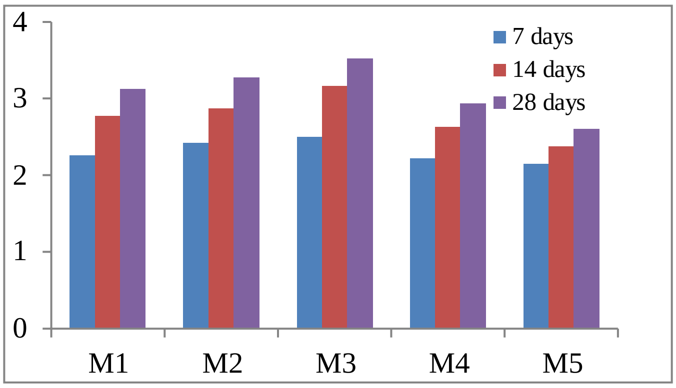
A 7 days result of SCC was equal to 7 days strength of conventional concrete [9], at starting stage strength was low but at 28 days result for all the mix of SCC there was almost an average of 50% strength increasedshown in Fig. 1. At 15% mix (M 3) replacement of Fly ash and metakaolin gave more compressive strength when compare to other mix. After that compressive strength was decreasing gradually by increase of replacement material (metakaolin). By comparing the influence of metakaolin, in mix M3 (15 % replacement) have more strength and there was 18.75% increase in strength when compared to conventional concrete [10].

Figure 2 Graph showing Split Tensile Strength at various proportions of Metakaolin



A 7 days result of SCC was equal to 7 days strength of conventional concrete, at starting stage strength was very low but at 28 days result for all the mix of SCC there was almost an average of 40% strength increased shown in Fig. 2. At 15% mix (M 3) replacement of Flyash and metakaolin gave more tensile strength when compare to other mix. After that split tensile strength was decreasing gradually by increase of replacement material(metakaolin). By comparing the influence of metakaolin, in mix M3 (15 % replacement) have more strength and there was 16.5% increase in strength when compared to conventional concrete.

Figure 3 Graph showing Flexural Strength at various proportions of Metakaolin



A 7 days result of SCC was equal to 7 days strength of conventional concrete, at starting stage strength was low but at 28 days result for all the mix of SCC there was almost an average of 38.5% strength increased shown in Fig. 3. At 15% mix (M 3) replacement of Flyash and metakaolin gave more Flexural strength when compare to other mix. After that Flexural strength was decreasing gradually by increase of replacement material (metakaolin). By comparing the influence of metakaolin, in mix M3 (15 % replacement) have more strength and there was 13% increase in strength when compared to conventional concrete.

3 Conclusion

Based on the above investigations the following conclusions have been drawn.

- Replacement of cement by a combination of Fly ash and Metakaolin in the range of 0 to 30 percent has no adverse effect on the workability properties of SCC.
- In the fresh state of SCC, in the presence of percentage of Metakaolin increases up to 15 %, it causes higher flow ability (Slump flow), passing ability (J-ring, L-box), and lower Filling ability (V-funnel) of SCC Mixes.
- In the fresh state of SCC, in the presence of percentage of Metakaolin increases 15 % to 30 %, it causes lower flow ability (Slump flow), passing ability (J-ring, L-box), and higher Filling ability (V-funnel) of SCC Mixes.
- The Comparison of 28 days Compressive strength of Optimum mix (M3) is increase up to 50% with respect to their 7 days compressive strength.
- Split tensile strength (28 days) of the optimum mix M3 is increase up to 40 % with respect to their 7 days strength.
- Flexural strength (28 days) of M3 mix is increasing up to 38.5% when compare with their 7 days strength.
- From the results of compressive strength, flexural beam strength and split tensile strength is noted that, increasing the strength up to adding a 15% of metakaolin in replacement of Fly ash or cement content and after 15 % slightly decreases the strength.

References

[1] Hajime Okamura and Masahiro Ouchi, *"*Self-Compacting Concrete*"*, Journals of Advanced Concrete Technologies, Vol. 1, No. 1 April 2003, pp. 5-15.

[2] N. Krishna Murthy, N. Aruna, and I.V.Ramana Reddy, "Influence of Metakaolin and Fly-ash on Fresh and Hardened Properties of Self Compacting Concrete", Vol 4, Issue 2 April 2013, pp. 223-239.

[3] Amala, M., Meenachi, A., Gopalan, A., Nanduri, P. R. K., & Ramesh, K. (2023). An experimental investigation of M30 grade self compacting concrete using mineral admixtures. Materials Today: Proceedings.

[4] S.Brundha and B.G Vishnuram , "Fresh and Durability studies of Polypropylene Fiber Reinforced Self-Compacting Concrete", Vol 4, Special Issue No. 01, March 2015.

[5] Bharath and Prakash "Effect of Partial Replacement of Cement in Self-Compacting Concrete by Fly Ash and Metakaolin", Vol. 4 Issue 07, July-2015.

[6] Dhiyaneshwaran, S., Ramanathan and P., Baskar, I. "Study on Durability Characteristics of Self-Compacting Concrete with Fly Ash", Vol. 7 Issue No.1, 2015.

[7] Amala, M., Meenachi, A., Gopalan, A., Nanduri, P. R. K., & Ramesh, K. (2023). An experimental investigation of M30 grade self-compacting concrete using mineral admixtures. Materials Today: Proceedings.

[8] Purumani Supriya "Experimental Investigation of M40 Grade on Self Compacting Concrete Using Mineral Admixtures", Vol 3, Issue 2, February 2016.

[9] Amala, M., et al. "Strengthening of compression member by ferrocement with high performance mortar–Jacketing technique." Materials Today: Proceedings 43 (2021): 1810-1818.

[10] Amala, M., & Harishmita, G. Self-compacting geopolymer concrete: A review.

[11] IS 12269-1987- Specification for 53 grade ordinary Portland cement

[12] IS 383:1970 - Specification for coarse and fine aggregates fromnatural sources for concrete.

[13] IS: 2386-1963 -Tests on coarse aggregates

[14] IS: 8142:1976 - Method of test for determining setting time of concrete

[15] IS: 516-1959 - Method of tests for strength of concrete

[16] IS: 5816-1999 - Splitting tensile strength of concrete, methods of test

[17] EFNARC - Specification and guidelines for self-compacting concrete