AN EXPERIMENTAL STUDY ON PARTIAL REPLACEMENT OF OPC BY METAKAOLIN AND ALCCOFINE IN SELF COMPACTING CONCRETE

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Abstract— Now-a-days there is an enormous development occurred in the field of concrete technology. Many researchers have carried out several studies to investigate the possible utilization of broad range of supplementary cementitious materials as partial replacement of Portland cement. The use of supplementary cementitious materials in the production of concrete can result in major saving of cost and energy. It also helps to improve the strength and durability properties of concrete. The present investigation is carried out to study the effect of metakaolin and alccofine as partial replacement of cement separately and combine on compressive strength, flexural strength and as well as split tensile strength of self compacting concrete.

A normal mix design is done through IS: 10262 code for M45 grade and mix has done, when it is successful by reaching its target mean strength after 28 days, the design is fixed. Then this design has to be changed to SCC mix design by using super plasticizer and changing some mix proportions that are increasing powder content, decreasing coarse aggregates through EFNARC guide lines and the mix has passed through all the workability properties. Finally specimens casted by obtained mix design proportions for Metakaolin SCC, Alccofine SCC and (Metakaolin+Alccofine) SCC are tested for compressive strength, flexural strength and split tensile strength respectively for 28 days of curing period. Then obtained results from Metakaolin SCC specimen, Alccofine SCC and (Merakaolin+Alccofine) SCC specimen are analyzed and compared.

Keywords- *Self compacting Concrete (SCC); Alccofine; Metakaolin; Compressive Strength; Flexural Strength; Split Tensile Strength*

INTRODUCTION

The self compacting or super workable concrete, also known as self consolidating concrete is a highly flow able or self leveling cohesive concrete that can spread readily into place through and around dense reinforcement under its own weight. It adequately fills formwork without segregation or bleeding, and without the need for significant vibration. Self compacting concrete mix has a low yield stress and an increased plastic viscosity. The mix requires minimal force to initiate flow yet have adequate cohesion to resist aggregate segregation and excessive bleeding, i.e., coarse aggregate can float in the mortar without segregating. The yield stress is reduced by using an advanced synthetic high range water reducing admixture (HRWR), while the viscosity of the paste is increased by using a viscosity modifying admixture (VMA) or by increasing the percentage of fines incorporated into the self compacting concrete mix design.

Modern applications of self compacting concrete is focused on high performance; better and more reliable quality, dense and uniform surface texture, improved durability, high strength and faster construction. In Japan and Europe, self compacting concrete technology has been extensively used in bridges, buildings and tunnel construction, where as in USA, used in precast concrete industry, tanks, bridge decks and architectural concretes. Metakaolin is different from natural pozzolans or other types of artificial pozzolans in such a way that it requires a sequence of processes to obtain pozzolanic property. Metakaolin is a thermally activated alumino-silicate material obtained by calcining kaolin clay within the temperature range 650–800 °C Thermal activation process of the kaolin clay depends mainly on the mineralogical composition. Unlike industrial by-products, such as silica fume, fly ash, and blast-furnace slag, metakaolin is refined carefully to lighten its color, remove inert impurities, and control particle size. This well-controlled process results in a highly reactive white powder that is consistent in appearance and performance. The particle size of MK is generally less than 2μm, which is significantly smaller than that of cement particles. It is typically incorporated into concrete to replace 5 to 20 wt% of cement. Alccofine 1203 (AF) is a specially processed product based on slag of high glass content with high reactivity obtained through the process of controlled granulation. The raw materials are composed primary of low calcium silicates. The processing with other select ingredients results in controlled particle size distribution. Due to its unique chemistry and ultra fine particle size, alccofine 1203 provides reduced water demand for a given workability, even upto 70% replacement level as per requirement of concrete performance. Alccofine 1203 can also be used as a high range water reducer to improve compressive strength or as a super workability aid to improve flow. Due to the lower water demand alccofine 1203 can be

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used as partial replacement for Portland cement which effectively enhances the properties of concrete, both in its fresh and hardened state.

MATERIALS USED

2.1 Physical Properties of Cement, Fine Aggregate and Coarse Aggregates used

S.NO	PHYSICAL PROPERTIES OF MATERIALS	TESTS RESULTS
1	Normal consistency of cement	30%
2	Setting Times of cement	
	Initial	35 minutes
	Final	560 minutes
3	Compressive Strength of cement	
	3 days	27.2 N/mm^2
	7 days	38.36 N/mm^2
	28 days	54.46 N/mm^2
4	Specific Gravity of cement	3.15
5	Specific Gravity of aggregates	
	Coarse aggregates	2.7
	Fine aggregates	2.67

2.2 Metakaolin

Physical properties of Metakaolin

Specific Gravity	2.40 to 2.60
Physical Form	Powder
Color	Off white, Gray to Buff
Brightness	80-82 unter L

Chemical properties of Metakaolin

SiO_2	51-53%	CaO	< 0.20%
Al_2O_3	42-44%	MgO	< 0.10%
Fe_2O_3	< 2.20%	Na_2O	< 0.05%
TiO_2	< 3.0%	K_2O	< 0.40%
SO_3	< 0.5%	L.O.I	<0.50%

2.3 Alccofine

Chemical properties of Alccofine

Contents	% by weight of samples
SIO_2	33.6
SO_2	0.19
AL_2O_2	22.6
FE_20_2	2.2
Mno	0.62
Mgo	8.00
Cao	31
N20	0.42
Chloride content	0.02
Sulphide Sulphur	1.1
Specific gravity	2.86 ± 0.02

Physical Properties of Alccofine

Colour	Off-white
Odour	Odourless when dry but may give rise to sulphide odour when wet
Mean particle size	5 - 30 micron
P_h	When wet, up to 12
Boiling point	>1700°C
Melting point	>1200°C
Density	at 20°C 2.4 - 2.8 g/cm3

EXPERIMENTAL WORK

Experimental work consists of basic mix design of SCC concrete of grade M45 with satisfying EFNARC guidelines then preparing the trail mixes for different mix proportions of Alccofine and Metakaolin both separately and combine. Finally testing and analyzing the results for both fresh and hardened states.

Test Specimen and Test Procedure

Cube casting specimens of dimension 150mm X 150mm X 150mm, cylinder casting specimen of diameter 95mm and length 220mm, and prism casting specimens of size 500mm X 100mm X 100mm were casted. The specimens were cured for 7and 28days.

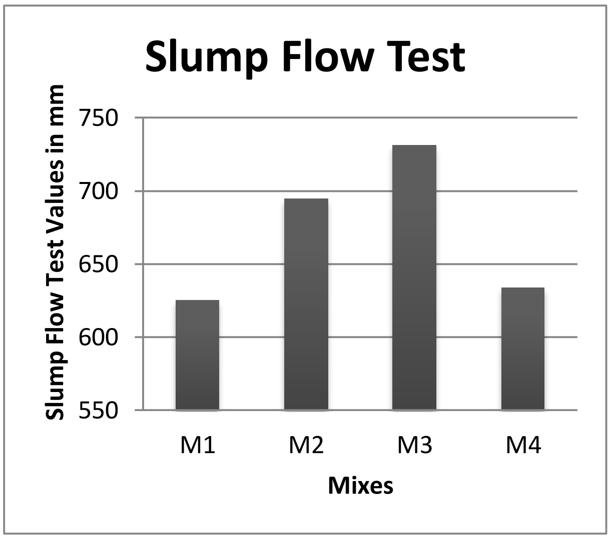
TESTS ON CONCRETE

4.1Fresh State Tests of SCC with Metakaolin

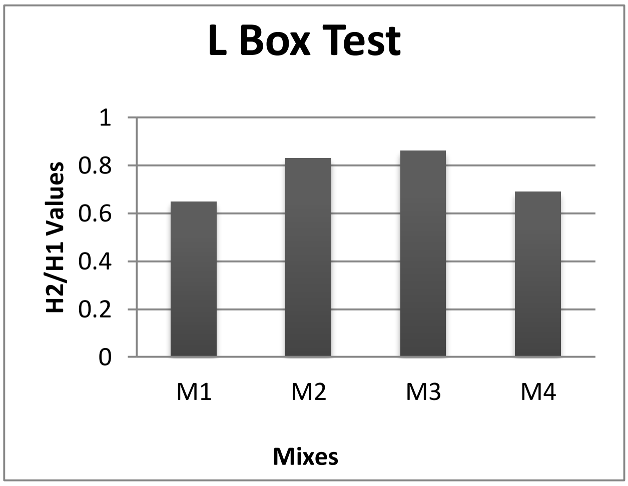
Mix Type	**Slump flow (mm)** 650mm-800mm	**L box (H_2/H_1)** (0.8-1.0)	**V funnel (sec) 6-12 sec**
M1 (5% MK)	625	0.65	15

M2 (10% MK)	**695**	**0.83**	**12**
M3 (15% MK)	**731**	**0.86**	**9**
M4 (20% MK)	634	0.69	5

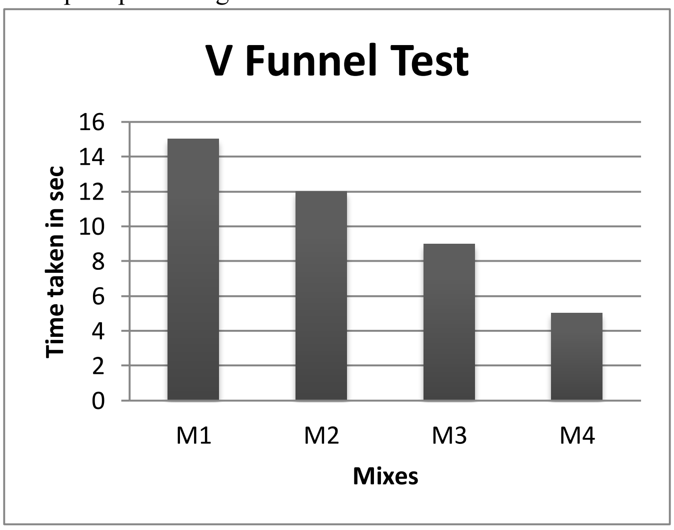
Graph representing slump flow test



Graph representing L box test



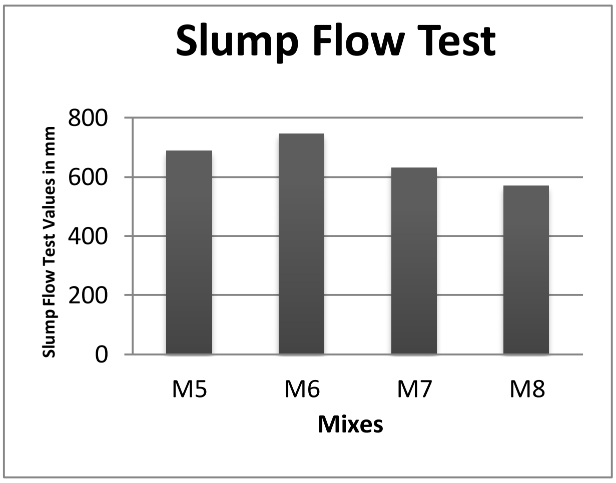
Graph representing V Funnel test



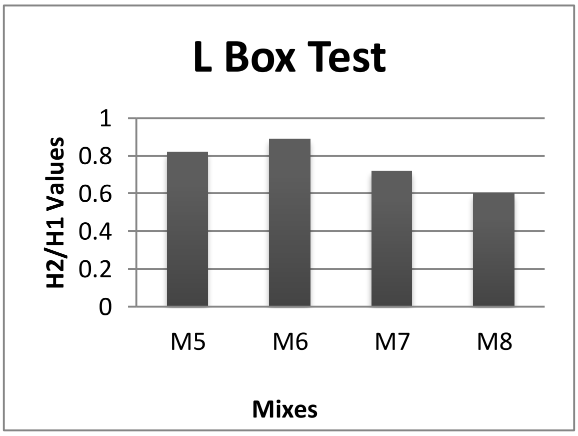
4.2Fresh State Tests of SCC with Alccofine

Mix Type	Slump flow (mm) 650mm-800mm	L box (H_2/H_1) (0.8-1.0)	V funnel (sec) **6-12 sec**
M5 (5% AF)	**690**	**0.82**	**11**
M6 (10% AF)	**745**	**0.89**	**8**
M7 (15% AF)	630	0.72	5
M8 (20% AF)	570	0.6	5

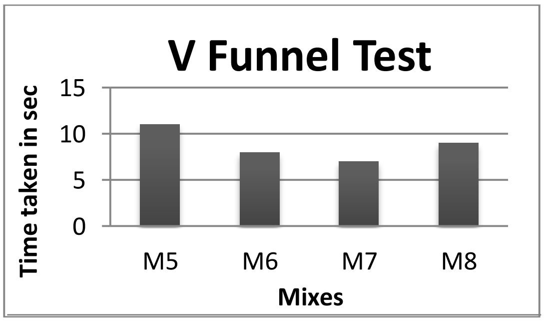
Graph representing slump flow test



Graph representing L box test



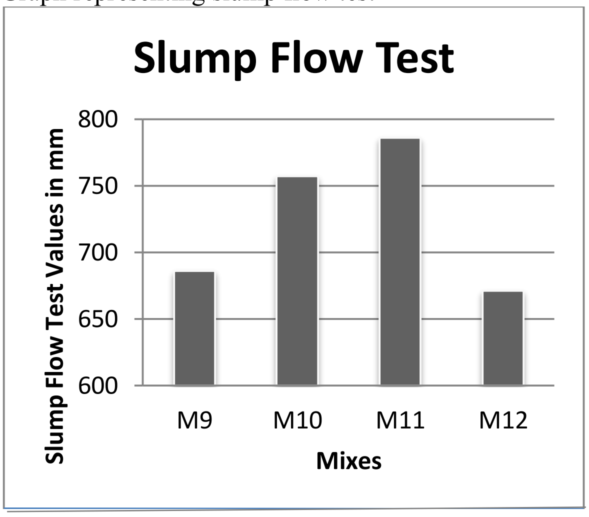
Graph representing V funnel test



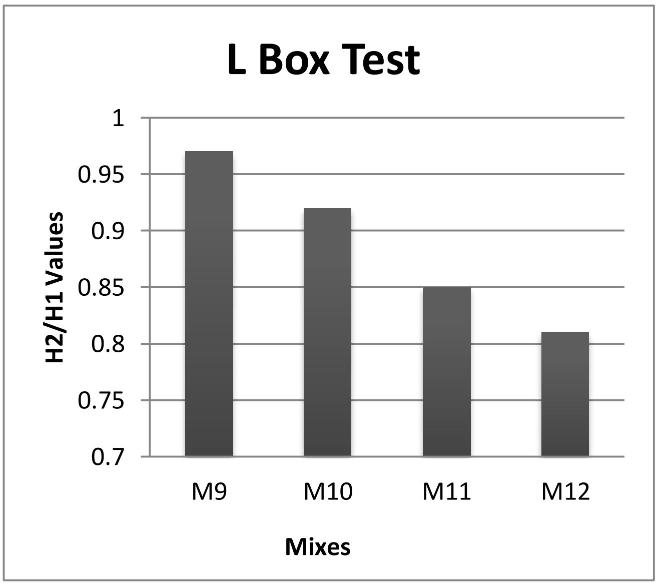
4.3Fresh State Tests of SCC with Alccofine and Metakaolin

Mix Type	Slump flow (mm) 650mm-800mm	L box (H_2/H_1) (0.8-1.0)	V funnel (sec) 6-12 sec
M9 (10% AF, 10%MK)	686	0.97	11
M10 (15% AF, 10%MK)	757	0.92	8
M11 (10% AF, 15%MK)	786	0.85	7
M12 (15% AF, 15%MK)	671	0.81	9

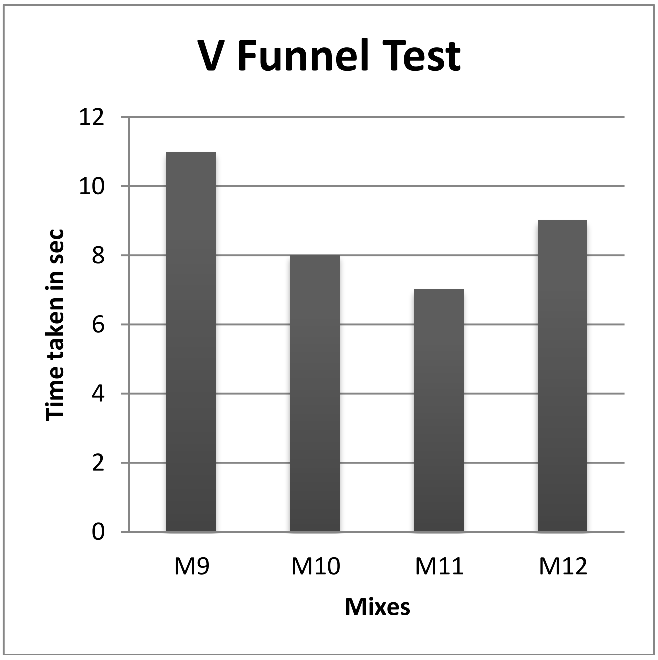
Graph representing slump flow test



Graph representing L box test



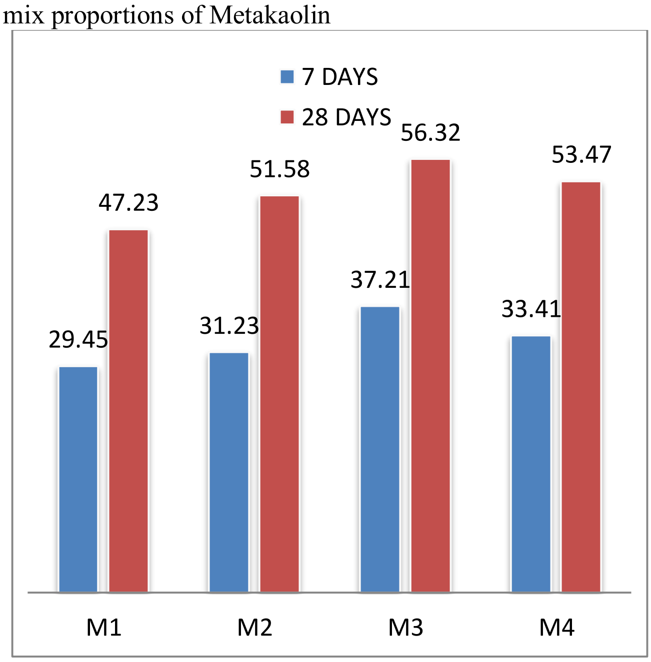
Graph representing V Funnel test



4.4 Compressive Strength Results of SCC with Metakaolin (M Pa)

MIX TYPE	PROPORTIONS OF METAKAOLIN	COMPRESSIVE STRENGTH (N/mm^2) 7 DAYS	COMPRESSIVE STRENGTH (N/mm^2) 28 DAYS
M1	5	29.45	47.23
M2	10	31.23	51.58
M3	**15**	**37.21**	**56.32**
M4	20	33.41	53.47

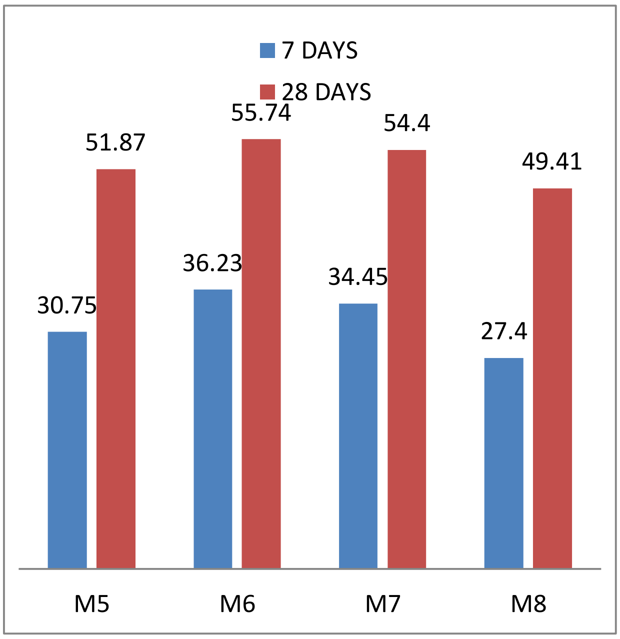
Graph representing Compressive strength results for different mix proportions of Metakaolin



4.5 Compressive Strength Results of SCC with Alccofine (M Pa)

MIX TYPE	PROPORTIONS OF ALCCOFINE	COMPRESSIVE STRENGTH (N/mm^2) 7 DAYS	COMPRESSIVE STRENGTH (N/mm^2) 28 DAYS
M5	5	30.75	51.87
M6	**10**	**36.23**	**55.74**
M7	15	34.45	54.4
M8	20	27.4	49.41

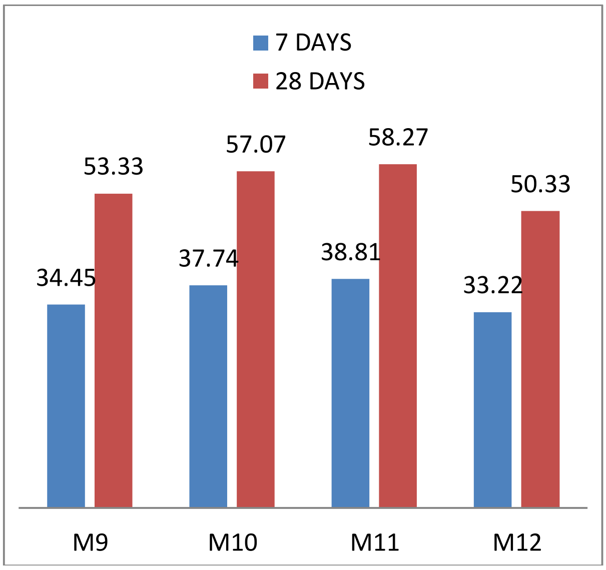
Graph representing Compressive strength results for different mix proportions of Alccofine



4.6 Compressive Strength Results of SCC with Alccofine and Metakaolin (M Pa)

MIX TYPE	PROPORTIONS OF METAKAOLIN AND ALCCOFINE		COMPRESSIVE STRENGTH (N/mm^2)	
	METAKAOLIN	ALCCOFINE	7 DAYS	28 DAYS
M9	10	10	34.45	53.33
M10	10	15	37.74	57.07
M11	15	10	38.81	58.27
M12	15	15	33.22	50.33

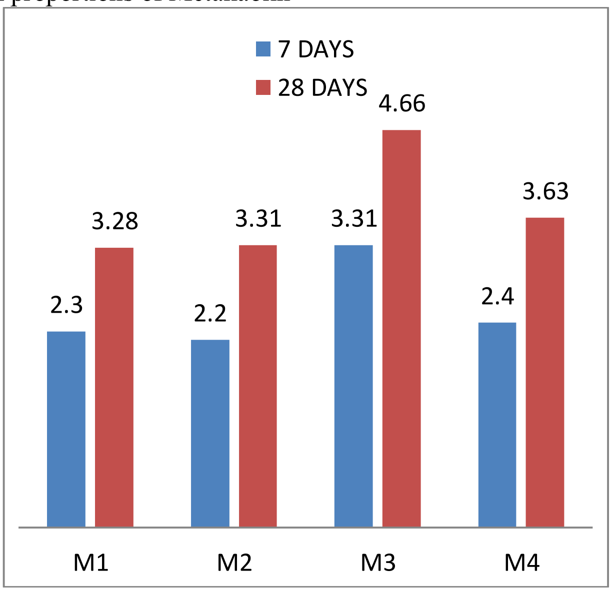
Graph representing Compressive strength results for different mix proportions of Alccofine and Metakaolin



4.7 Split Tensile Strength Results with Metakaolin

MIX TYPE	PROPORTIONS OF METAKAOLIN	SPLIT TENSILE STRENGTH (N/mm^2) 7 DAYS	SPLIT TENSILE STRENGTH (N/mm^2) 28 DAYS
M1	5	2.3	3.28
M2	10	2.2	3.31
M3	15	3.1	4.66
M4	20	2.4	3.63

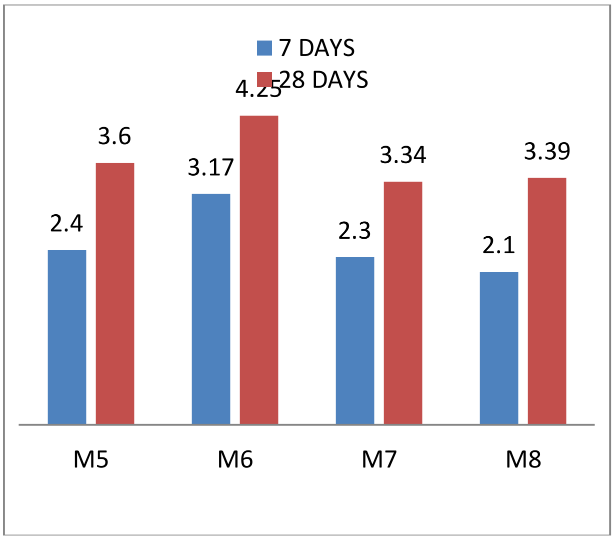
Graph representing Split Tensile strength results for different mix proportions of Metakaolin



4.8 Split Tensile Strength Results with Alccofine (M Pa)

MIX TYPE	PROPORTIONS OF ALCCOFINE	SPLIT TENSILE STRENGTH (N/mm^2) 7 DAYS	SPLIT TENSILE STRENGTH (N/mm^2) 28 DAYS
M5	5	2.4	3.60
M6	10	3.17	4.25
M7	15	2.3	3.34
M8	20	2.1	3.39

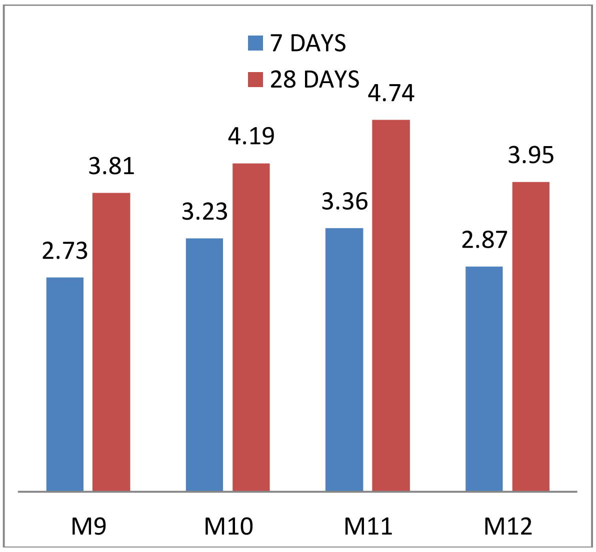
Graph representing Split Tensile strength results for different mix proportions of Alccofine



4.9 Split Tensile Strength Results with Alccofine and Metakaolin (M Pa)

MIX TYPE	PROPORTIONS OF METAKAOLIN AND ALCCOFINE		SPLIT TENSILE STRENGTH (N/mm^2)	
	METAKAOLIN	ALCCOFINE	7 DAYS	28 DAYS
M9	10	10	2.73	3.81
M10	10	15	3.23	4.19
M11	15	10	3.36	4.74
M12	15	15	2.87	3.95

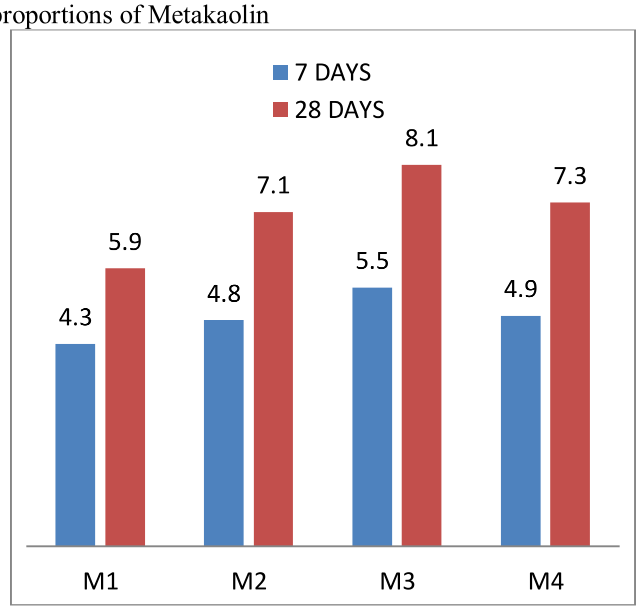
Graph representing Split Tensile strength results for different mix proportions of Alccofine and Metakaolin



4.10 Flexural Strength Results with Metakaolin(M Pa)

MIX TYPE	PROPORTIONS OF METAKAOLIN	FLEXURAL STRENGTH (N/mm^2) 7 DAYS	FLEXURAL STRENGTH (N/mm^2) 28 DAYS
M1	5	4.3	5.9
M2	10	4.8	7.1
M3	15	5.5	8.1
M4	20	4.9	7.3

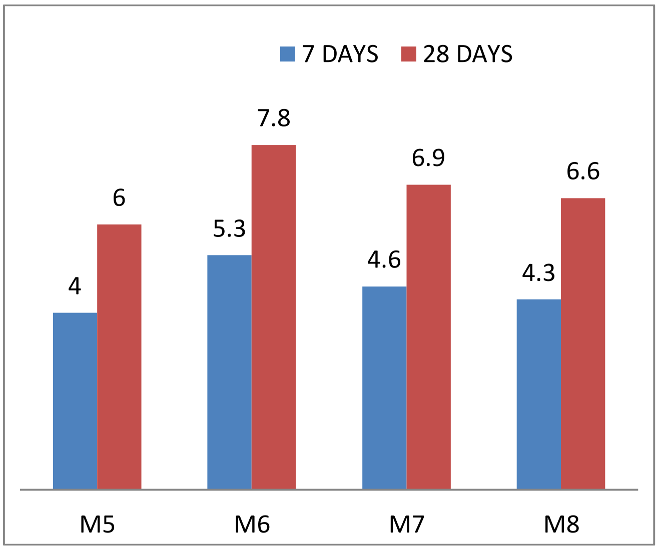
Graph representing Flexural strength results for different mix proportions of Metakaolin



4.11Flexural Strength Results with Alccofine(M Pa)

MIX TYPE	PROPORTIONS OF ALCCOFINE	FLEXURAL STRENGTH (N/mm^2) 7 DAYS	FLEXURAL STRENGTH (N/mm^2) 28 DAYS
M5	5	4.0	6.0
M6	10	5.3	7.8
M7	15	4.6	6.9
M8	20	4.3	6.6

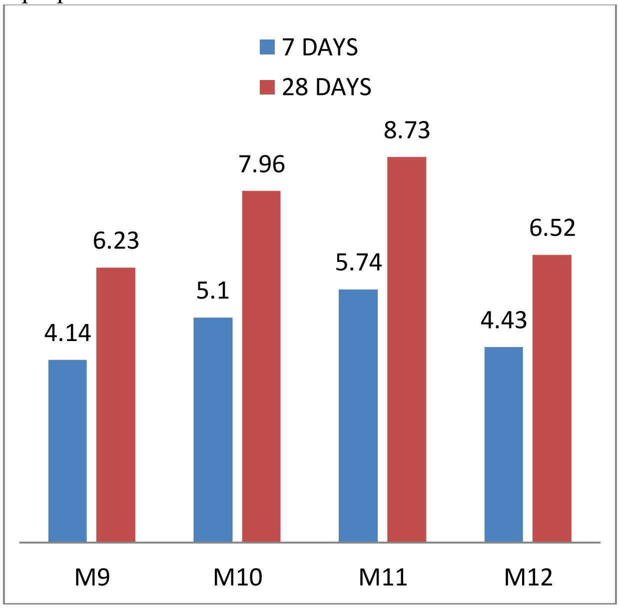
Graph representing Flexural strength results for different mix proportions of Alccofine



4.12 Flexural Strength Results with Alccofine and Metakaolin(M Pa)

MIX TYPE	PROPORTIONS OF METAKAOLIN AND ALCCOFINE		FLEXURAL STRENGTH (N/mm^2)	
	METAKAOLIN	ALCCOFINE	7 DAYS	28 DAYS
M9	10	10	4.14	6.23
M10	10	15	5.1	7.96
M11	15	10	5.74	8.73
M12	15	15	4.43	6.52

Graph representing Flexural strength results for different mix proportions of Alccofine and Metakaolin



1. CONCLUSIONS

Based on the extensive experimental investigations carried out on the Metakaolin and Alccofine as the partial replacements of cement in SCC the fallowing conclusions have been drawn.

It is observed that the

1. Upon the addition of Metakaolin and Alccofine had positive effects on the workability for some of the mixes i.e (M2,M3,M5,M6,M9,M10,M11,M12)
2. The replacement of cement by 15% Metakaolin in SCC had attained Optimum compressive, split tensile and flexural strengths.
3. The replacement of cement by 10% Alccofine in SCC had attained Optimum compressive, split tensile and flexural strength.
4. The replacement of cement by 15% Metakaolin and 10% Alccofine had attained Optimum compressive, split tensile and flexural strength
5. As the percentage of Metakaolin increase, V funnel time of self compacting concrete is also increasing.
6. The replacement of cement by Alccofine was relatively cheap and cost was comparable to the usual raw materials.
7. Optimum strengths achieved by replacement of cement with Metakaolin is greater than optimum strengths achieved by Alccofine.

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