Study on Strength Properties of Ternary Blended Concrete with Fiber

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***Abstract*—Concrete is a versatile material extensively used in construction applications throughout the world. Properly placed and cured concrete exhibits excellent compressive-force-resisting characteristics In the present experimental investigation a mix design high strength concrete of M60 & M80 is tried using triple blending technique with ternary blend of condensed silica fume and metakaolin as partial replacement by weight of cement at various blended percentages ranging between 5% – 15% with steel fibers having aspect ratio of 50. The various proportions of steel fibers are added at 0.5%, 0.75%, 1.0%, 1.25% and 1.5% as total fiber percentages. The workability is measured for its consistency using compaction factor method. The present work is on finding the optimum replacement of cement by metakaolin, condensed silica fume and ternary blend of condensed silica fume and metakaolin from which maximum benefit in various strengths and workability of the mix can be obtained. The results of fiber reinforced specimens with various percentages of ternary blend are compared with control specimens to study the behavior of FRC properties with various percentages of the blends as partial replacement by weight of cement. Sufficient number of cubes, cylinders and beams were cast. The cast specimens were tested for the change in compression, tension and flexural strength at 7 & 28 days for M60. The cast specimens were tested for the change in compression, tension and flexural strength at 28 days for M80. It is concluded that specimens with total fiber content of 1.5% showed better strength in all proportions and blend proportion of 10% condensed silica fume and 5% metakaolin showed maximum strength in compression, tension and flexural.**

***Index Terms*—HPC[1], Metakaolin [2], FRC[3]**

I. Introduction

Concrete is the mostly used material in various types of construction, from the flooring of a hut to a multi storied high rise structure from pathway to an airport runway, from an underground tunnel and deep sea platform to high-rise chimneys and TV Towers. In the last millennium concrete has demanding requirements both in terms of technical performance and economy while greatly varying from architectural masterpieces to the simplest of utilities. It is the most widely used construction materials. It is difficult to point out another material of construction which is as versatile as concrete. High strength concrete is used extensively throughout the world like in the oil, gas, nuclear and power industries are among the major uses. The application of such concrete is increasing day by day due to their superior structural performance, environmental friendliness and energy conserving implications. Apart from the usual risk of fire, these concretes are exposed to high temperatures and pressures for considerable periods of times in the above mentioned industries. Applications of mineral admixtures such as silica fume, metakaolin and ground granulated blast furnace slag in concrete are effective easy to future increase the strength and make durable for high strength concrete.

A. High Strength Concrete

Metakaolin is the pozzolanic material which is mainly derived from a clay mineral "kaolinite", since it is calcined at higher temperatures it's named as "metakaolin," A further advantage of pozzolan mortars is their lower environmental impact, when compared to cement mortars, due to lower energy consumption during production and CO_2 absorption by carbonation. The addition of metakaolin to mortars and concretes also has a positive effect in terms of durability. Calcium hydroxide accounts for up to 25% of the hydrated Portland cement, and calcium hydroxide does not contribute to the concrete's strength or durability. Metakaolin combines with the calcium hydroxide to produce additional cementing compounds, the material responsible for holding concrete together. Less calcium hydroxide and more cementing compounds means stronger concrete. Metakaolin, because it is very fine and highly reactive nature, gives fresh concrete a creamy, non-sticky texture that makes finishing easier. Extensive reaserch work has been carried on the use of pozzolanas in construction materials. Out of the above pozzolonas admixtures fly ash can be considered as the one, which is abundantly available. Fly ash concrete possesses certain desirable and enhanced properties compared to ordinary plane concrete. Metakaolin made from purified kaolin is not industrial waste product, can be recommended to be used along with cement to derive certain enhanced properties for concrete in special situations.

In the present investigation an attempt has been made to study the properties of concrete such as workability, compressive strength, split tensile strength and flexural strength of fibrous concrete composite with addition of various proportion of condensed silica fume and metakaolin as partial replacement by weight of cement to arrive at optimum properties.

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II. Material Details

The scope of present investigation is to study strength properties on plain concrete, concrete with replacement of varying percentages of metakaolin and silica fume along with steel fibres in different total percentages of 0%, 0.5%, 0.75%, 1.0%, 1.25%, and 1.5% for M60 & M80 concrete mix.

A. Cement

Locally available Ordinary Portland Cement of 53 grade of ULTRATECH Cement brand confirming to ISI standards has been procured and following tests have been carried out.

B. Metakaolin

The Metakaolin is obtained from the 20 Microns limited Company at Vadodara in Gujarat by the brand name Metacem 85 C. The specific gravity of Metakaolin is 2.5. The Metakaolin is in conformity with the general requirement of pozzolana. The Physical and chemical results are tabulated in Table I and Table II.

TABLE I. Physical Properties of Metakaolin Given

Specific Gravity:	2.54	D10	<2.0um
Physical Form:	Powder	D50	<4.5um
Color:	Off-White	D90	<25um
Brightness:	80-82Hunter L	BD (lbs/ft^3)	20-25
BET:surface area	15 m^2/gram	BD(g/cm3)	0.4

TABLE II. Chemical Composition of Metakaolin Given

SiO_2	51-53%	CaO	<0.20%
AlO_3	42-44%	MgO	<0.10%
Fe_2O_3	<2.20%	Na_2O	<0.05%
TiO_2	<3.0%	K_2O	<0.40%
SO_4	<0.5%	L.O.I.	<0.50%
Li_2O_5	<0.2%		

C. Silica Fume and Its Sources

Silica fume is, when collected, an ultra fine powder have the basic properties are Atleast 85% SiO_2 content. Mean particle size between 0.1 and 0.2 micron. Minimum specific surface of 15,000 m^2/kg. Spherical particle shape.

The powder is normally grey in color but this can vary according to the source.

Fine aggregate: The locally available Natural river sand conforming to grading zone-II has been used as Fine aggregate. Following tests have been carried out per the procedure given in IS 383 (1970Machine crushed granite confirming to IS 383-1970 [12] consisting 20 mm maximum size of aggregates has been obtained from the local quarry. It has been tested for physical and mechanical properties such as Specific gravity, Sieve Analysis, Bulk density, Crushing and Impact values

D. Super Plasticizer-

The super plasticizer used in this experiment is SP430. It is manufactured by FOSROC, Bangalore. Super Plasticizers are new class of generic materials which when added to the concrete causes increase in the workability. They consist mainly of naphthalene or melamine sulphonates, usually condensed in the presence of formaldehyde.

E. Triple Blending Mixes Tried in the Present Investigation

In the present investigation triple blending cement concrete mixes have been tried for various strength properties. Mineral admixtures like CSF & MK have been employed along with cement and triple blended cement concrete mixes are prepared. The respective percentages of CSF & Mk have been varied from 0% to 15% as replacement of cement. Steel fibers of 1mm dia & 50mm length with an aspect ratio of 50 have been tried along with above mixes. The fiber % has been varied from 0 to a maximum of 1.5%

F. Mix Design Calculations

Design of High Strength Concrete By Doe Method

Estimated quantities in 1 m^3 of M60 concrete :

Cement = 590.94kg
Fine aggregates = 597.21kg
Coarse aggregates = 1016.88kg
Water = 195kg

The ratio comes to be 1: 1.07: 1.75@0.33 for M60 grade concrete.

Estimated quantities in 1 m^3 of M80 concrete :

Cement = 650 kg
Fine aggregates = 559.8 kg
Coarse aggregates = 995.2 kg
Water = 195 kg

The ratio comes to be 1: 0.86: 1.53 @ 0.30 for M80 grade concrete

III. Moulding of Specimens and Curing

In the present investigation grade of concretes M60 & M80 has been considered. The mix of concrete is designed as per the guidelines given in DOE method (32,38,31), subsequently mixes were prepared with a partial replacement of cement by Condensed silica fume & Metakaolin at percentages of 5,10,15% by weight of cement along with 0, 0.5%, 0.75%,1.0%, 1.25% and 1.5% of steel fibers.

Initially the ingredients of concrete viz., coarse aggregate, fine aggregate, cement, condensed silica fume and Metakaolin were mixed to which the water and Superplasticizer were added and thoroughly mixed. Water was measured exactly. Then it is applied to the dry mix and it was thoroughly mixed until a mixture of uniform color and consistency was achieved which is then ready for casting. Prior to casting of specimens, Workability is measured in accordance [9], [17] and is determined by slump test and compaction factor test. Superplasticizer SP 430 supplied by Fosroc Ltd. was added upto 4 % to maintain the mix in workable condition,

After the casting, the moulds are kept for air curing for one day and the specimens were removed from the moulds after 24 hours period of moulding of concrete.

Marking has been done on the specimens to identify the %Condensed silica fume and %Metakaolin. To maintain the constant moisture on the surface of the specimens, they were placed in water tank for curing as shown in photograph 3.5 and 3.6. All the specimens have been cured for the desired age.

TABLE III COMPRESSIVE STRENGTH USING 1.25% FIBERS- RESULTS

S.NO	%CSF	% MK	7 days Compressive strength using 1.25% fibers-results			28 days Compressive strength using 1.25% fibers-results		
			Strengthin N/mm^2	% increase over 0%	%increase over preceding	Strength in N/mm^2	% increase over 0%	% increase over preceding
M_0	0	0	51.68	-	-	72.30	-	-
M_1	15	0	53.60	3.70	3.70	74.10	2.48	2.48
M_2	0	15	55.70	7.70	3.90	77.56	7.27	4.66
M_3	5	10	52.70	1.97	-5.30	78.50	8.57	1.21
M_4	10	5	54.50	5..40	3.40	78.50	8.57	0.00

Figure. 1. Compression strength test in progress

Figure. 2. Flexure Test in Progress

Figure. 3. Split Tensile Strength Test in Progress

IV. RESULTS AND DISCUSSIONS

A. General

In the present project work experimental investigation is carried out on Triple Blended Concrete mixes using two mineral admixtures- condensed silica fume and metakaolin along with ordinary portland cement. Various proportions of Silica Fume and Metakaolin are tried as replacement to cement. Strength properties of concrete mixes prepared using these Triple Blended Cement mixes are determined. the results obtained are discussed herein.

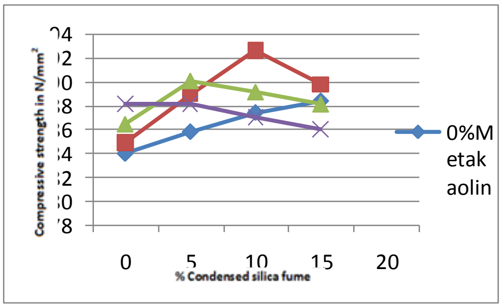
B. Workability

Workability of various triple blended mixes was determined by using slump cone and compaction factor apparatus. With water cement ratio of 0.33 and with an addition of maximum 2% superplasticizer the M60 concrete mixes with blended admixtures of condensed silica fume and metakaolin were found to have a compaction factor of 0.89 to 0.76.The tests showed decreased values of slump and compaction factor with increase in total percentage of blended admixtures of CSF and MK. With total steel fibre percent of 0.5, 1.0 and 1.5 and 1.5 super plasticizer in the M60 concrete mix with blended admixtures of 10% CSF and 5% MK and for the same water cement ratio the workability is found to be nearly 0.86 to 0.81.

With water cement ratio of 0.3 and with an addition of maximum 4% superplasticizer the M80 concrete mixes with blended admixtures of condensed silica fume and metakaolin were found to have a compaction factor of 0.93 to 0.79.The tests showed decreased values of slump and compaction factor with increase in total percentage of blended admixtures of CSF and MK. With total steel fibre percent of 0.5, 1.0 and 1.5 and 3.55 super plasticizer in the

M80 concrete mix with blended admixtures of 10% CSF and 5% MK and for the same water cement ratio the workability is found to be nearly 0.87 to 0.81.

C. Compressive Strength



The results and graphs are as shown in Table III and graph 1.

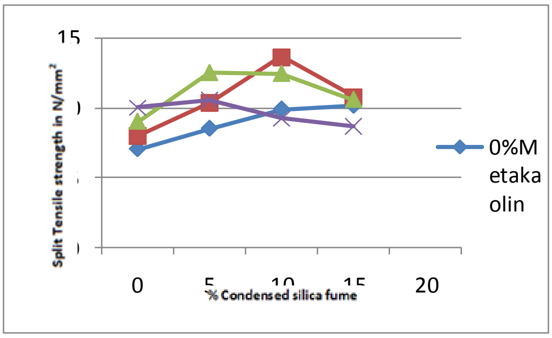
1). It has been observed that with the addition of Silica fume and Metakaolin, the strength of concrete at the age of 28 days has increased with various proportions of the mix. The increase in strength is in the range of 2.01% - 20.94% (Table 4.1) for M60 and 2% - 10.36% (Table 4.13) for M80. On analysing the tested specimens it is observed that the bonding between the concrete materials is of very high quality. The combination of blended admixtures of 10% CSF and 5% MK by partial replacement by weight of cement has showed high increase in strength by 20.94% & 10.36% when compared base reference mix. The Blended mix proportions beyond this combination of 10% CSF and 5% MK showed decreasing trend in compressive strength showing minimum strength of 87.0 N/mm^2, at a combination of 10% CSF and 15% MK in the M80 concrete mix but still exhibited higher strength and an increase of 3.67% than the base reference mix without any admixtures.

2). Among the fibres percentages, 1.5% is found to give the highest compressive strength among all the fibrous mixes. Compare to the same mix without fibres the strength increase is nearly 17% and compare to base mix it is 27.38%.

TABLE IV. SPLIT TENSILE STRENGTH USING 1.25% FIBERS- RESULTS

S.NO	%CSF	% MK	7 days Split tensile strength using 1.25% fibers-results			28 days Split tensile strength using 1.25% fibers-results		
			Strength in N/mm^2	% increase over 0%	%increase over preceding	Strength in N/mm^2	% increase over 0%	% increase over preceding
M_0	0	0	4.52	-	-	5.86	-	-
M_1	15	0	6.04	33.62	33.62	6.51	11.09	11.09
M_2	0	15	5.08	12.38	-15.89	6.10	4.09	-6.29
M_3	5	10	5.01	10.84	-1.35	6.04	3.07	0.98
M_4	10	5	4.83	6.85	-3.58	6.57	12.11	8.77

D. Split Tensile Strength



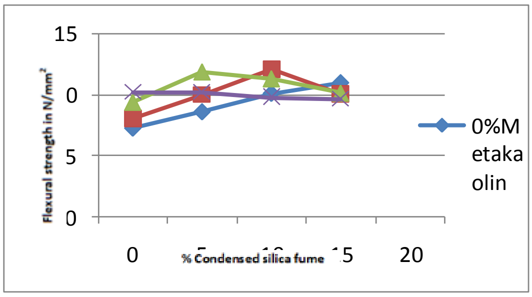
The results and graphs are as shown in table-4 and graph 2

1). It has been observed that with the addition of Silica fume and Metakaolin, the strength of concrete at the age of 28 days has increased with various proportions of the mix. The increase in strength is in the range of 1.88% - 18.16% (Table 4.5) for M60 and 16.75% - 118.85% (Table 4.19) for M80. On analysing the tested specimens it is observed that the bonding between the concrete materials is of very high quality. The combination of blended admixtures of 10% CSF and 5% MK by partial replacement by weight of cement has showed high increase in strength by 18.16% & 118.85% when compared base reference mix. The Blended mix proportions beyond this combination of 10% CSF and 5% MK showed decreasing trend in compressive strength showing minimum strength of 7.96 N/mm^2, at a combination of 10% CSF and 15% MK in the M80 concrete mix but still exhibited higher strength and an increase of 38.92% than the base reference mix without any admixtures.

2). The same trend is observed with steel fibers in the M80 Concrete mix with various combinations of blended percentages of CSF and MK. It is found that the M80 mix concrete with total steel fibre percentage of 1.5 and admixture percentages of 10% CSF and 5% MK showed maximum increase in strength of 211.87% when compared to base reference mix without admixture and fibre and other specimens with total fiber percentages of 0.5, 0.75, 1.0 and 1.25 also exhibited higher strengths when compared to base reference mix. .

3). Among the fibres percentages, 1.5% is found to give the highest compressive strength among all the fibrous mixes. Compare to the same mix without fibres the strength increase is nearly 96% and compare to base mix it is 211.87%.

E. Flexural Strength:



The results and graphs are as shown in Table 5 and Graph 3

1). It has been observed that with the addition of Silica fume and Metakaolin, the strength of concrete at the age of 28 days has increased with various proportions of the mix. The increase in strength is in the range of 2.09% - 18.81% for M60 and 18.21% - 66.16% for M80. On analysing the tested specimens it is observed that the bonding between the concrete materials is of very high quality. The combination of blended admixtures of 10% CSF and 5% MK by partial replacement by weight of cement has showed high increase in strength by 18.81% & 66.16% when compared base reference mix. The

Blended mix proportions beyond this combination of 10% CSF and 5% MK showed decreasing trend in compressive strength showing minimum strength of 9.83 N/mm^2, at a combination of 10% CSF and 15% MK in the M80 concrete mix but still exhibited higher strength and an increase of 34.65% than the base reference mix without any admixtures.

TABLE V. FLEXURAL STRENGTH USING 1.25% FIBERS- RESULTS

S.NO	%CSF	% MK	7 days Flexural strength using 1.25% fibers- results			28 Flexural strength using 1.25% fibers- results		
			Strength in N/mm^2	% increase over 0%	%increase over preceding	Strength in N/mm^2	% increase over 0%	% increase over preceding
M_0	0	0	5.77	-	-	6.71	-	-
M_1	15	0	6.00	3.98	3.98	6.86	2.23	2.23
M_2	0	15	5.20	-9.87	-13.33	6.00	-10.58	-12.53
M_3	5	10	6.37	10.39	22.50	6.71	0.00	11.83
M_4	10	5	6.40	10.91	0.47	7.80	16.24	16.24

2). In the case of blended CSF and MK at higher percentage of replacement by weight of cement, the strength has decreased when compared to mixes with lower replacement. 15% is focused to be optimum with the both admixtures.

3). Among the fibres percentages, 1.5% is found to give the highest compressive strength among all the fibrous mixes. Compare to the same mix without fibres the strength increase is nearly 98% and compare to base mix it is 163.97%.

V. CONCLUSIONS

Based on the experimental study undertaken the following conclusions are drawn.

An effective and efficient triple blended concrete mix can be prepared with the addition of condensed silica fume and Metakaolin to OPC. This triple blended mix is not only cost effective also it renders the concrete to achieve several beneficial properties.

When the mineral admixtures like silica fume or Metakaolin are added at higher percentages to cement, the workability of concrete is getting reduced. There is a need to add superplasticizer dosage to maintain constant medium workability.

In the case of triple blended concrete 10% CSF & 5% MK gives highest strength without fibre reinforcement

As the total percent of fibre is increased the compressive strength is also increasing.

The highest compressive strength for fibre mixes is obtained with 10% CSF & 5% MK and 1.5% steel fibre.

Split tensile strength is more in the case of triple blended concrete. Highest tensile strength is obtained with 10% CSF and 5% MK.

Highest tensile strength is obtained with 10% CSF 5% MK and 1.5% total steel fibres

Flexural strengths are also higher for triple blended concretes with various combinations, these values are further increased with addition of fibres.

Without fibres for a combination of 10% CSF and 5% MK the flexural strength is higher than the reference. For other combinations the increase is in between.

The highest flexural strength with 10% CSF 5% MK and 1.5% fibre is high by nearly 163.97% than that of reference mix.

On the basis of the present experimental study it is finally concluded that optimum concrete mixes can be obtained by carrying out triple blending with Condensed silica fume and Metakaolin. These mixes posses not only higher strength but also many other beneficial properties like better durability, better crack resistance, low permeability, cost effectiveness etc. Triple blended concrete mixes are quite suitable for high performance concrete(HPC).

VI. SUGGESTIONS FOR FUTURE WORK

Further work may be continued with triple blended concrete mixes using other type of mineral admixtures.

Work may be carried out on long term properties. Testing of prototype elements may be conducted to asses the flexural properties like deflections, rotations, ductility, crack formation etc.

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