Research Result

An Experiment Study of Multi Blend Concrete by using Metakaolin and Silica Fume

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ABSTRACT

Metakaolin is a relatively new mineral admixture for concrete. It is comparable to silica fume in pozzolanic reactivity, but is lower in price. The effects of metakaolin and silica fume on various properties of concrete were investigated and compared in this study. Test results have indicated that (i) blended mortar with Metakaolin can reach a higher temperature than 100% ordinary Portland cement; (ii) Metakaolin exhibits lower pozzolanic activity than silica fume. Hydration heat of silica fume is greater than that of Metakaolin; (iii) it is supposed that three elementary factors influence the contribution that Metakaolin makes to mortar strength when it partially replaces cement in mortar. These are the filler effect, the acceleration of ordinary Portland cement hydration, and the pozzolanic reaction of Metakaolin with calcium hydroxide.

KEYWORDS

Metakaolin, Silica fumes, compression test, flexural test. Cracking; shrinkage; silica fume; slump; strength

1. INTRODUCTION

Concrete is the most essential element of infrastructure development across the world and a well- designed concrete could be a durable construction material. There is growing concern about the environmental aspect of Portland cement, as the cement industry is responsible for about 2.5% of all global emissions from industrial sources. Particularly, CO2 emission has been a severe problem in the world due to the greenhouse effect. After the Rio-de Janeiro Earth Summit in 1992 and following the Kyoto Protocol in 1997, many countries have agreed to reduce the emission of CO2. Long term compressive strength of both silica fume and Metakaolin mixes can be improved. Addition of varied percentage of fibers made with steel to the optimum percentage of compressive & flexural tensile strength as 15% & 27% respectively. The fly ash and Metakaolin with 20% as replacement of cement in concrete developed the better compactness of concrete microstructure, showed Compressive and Flexural tensile strength approximately 20% and 15% higher. In this experiment Supplementary materials silica fume and Metakaolin in varying percentages i.e. 0% of silica fume and 0% of Metakaolin for normal concrete, 0% of silica fume and 20% of Metakaolin, 05% of silica fume and 15% of Metakaolin, 10% of silica fume and 10% of Metakaolin, 15% of silica fume and 5% of Metakaolin, 20% of silica fume and 0% of Metakaolin of total dosage (i.e.20%) by weight of cement.

2. LITERATURE REVIEW

Ayobami Busari (2019)

The interest and utilization of cement have prompted a ton of examination in working on its strength, solidness, life cycle, temperature impact and some more. Working on the strength and solidness of cement is extremely foremost in the development of essential foundation in a bid to make it feasible.

M. Jayasri (2021)

This paper presents the consequences of an exploratory examination on the mechanical properties of underlying substantial utilizing Steel fiber (SF), Polypropylene fiber (PF) and Metakaolin (MK). The impacts of these strands and MK on different properties of M30 grade concrete are contemplated. MK Steel fiber content and Polypropylene fiber content were shifted in rate by weight of concrete. Every one of the examples was water relieved and tried following 28 days. It is seen that huge improvement in the primary presentation of cement is accomplished by the expansion of 15% MK in typical cement.

Vijay Singh Rawat (2019)

Quick foundation advancement overall increases the interest for concrete. Because of extreme interest of concrete cement and at same time shortage of these significant parts of the development business, it is fundamental for discover elective enhancements of concrete and cement. In this respect, we have zeroed in on incomplete elective material of concrete cement. Fly debris and Metakaolin were tried for their execution in the concrete as an advantageous material. Concrete having 35 MPa Compressive strength was focused on in the trial examination.

B. Naresh Goud (2017)

Valuable cementitious materials like silicon oxide vapor, fly debris, slag, Rice Husk Debris and Metakaolin are used lately as concrete elective material for developing HSC with advanced usefulness, energy and strength with diminished porousness. This paper has been composed so as to make the capability of Metakaolin accessible to the development business at large.

R.M. Sawant (2015)

Due to overall infrastructural improvement, since twentieth century utilization of cement has colossally expanded which brought about weighty assembling of concrete. Creation of concrete outcomes in weighty ecological contamination because of emanation of CO2 gas.

Netravati T Shepur (2014)

Concrete is the most normally utilized material for development Different kinds of pozzolanic materials that further develop concrete properties have been utilized in concrete industry for quite a while. Metakaolin is a dehydroxylated aluminum silicate. It is a shapeless non solidified material, comprised of lamellar particles. From the late exploration works utilizing Metakaolin, it is obvious that it is a extremely successful pozzolanic material and it viably upgrades the strength boundaries of cement.

3. MATERIAL INTRODUCTION

3.1 Concrete

One of the materials that appears straightforward but is actually complex is cement concrete. Its complex behaviours must be fully understood in order to use this material profitably and economically. To gain a better understanding of the intricate behaviour of these materials, research is currently being done on the behaviours of concrete with regard to long-term drying shrinkage, creep, fatigue, morphology of gel structures, bonds, and fracture mechanisms, as well as fibrous concrete.

Ingredients of concrete

1. Cement
2. Fine Aggregate
3. Coarse Aggregate
4. Metakaolin
5. Silica Fumes
6. Water

3.2 Cement

Cement is a popular binding material, is a very important civil engineering material. This article concerns the physical and chemical properties of cement, as well as the methods to test cement properties.

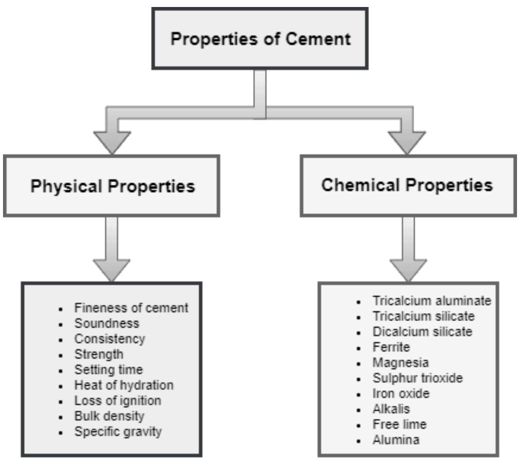


Fig.1 properties of cement

3.3 Aggregate

Aggregate' is a term for any particulate material. It includes gravel, crushed stone, sand, slag, and recycled concrete and geo-synthetic aggregates. Aggregate may be natural, manufactured or recycled.

3.3.1 Fine Aggregates:

Fine aggregates are usually sand or crushed stone that are less than 9.55mm in diameter. Sand, crushed stones, ashes, cinder, etc. are the examples of the fine aggregate.

Table 1 Grading of fine aggregates

S. No.	IS Sieve Designation	percentage passing			
		Grading Zone I	Grading Zone II	Grading Zone III	Grading Zone IV
1	2	3	4	5	6
1	10mm	100	100	100	100
2	4.75mm	90-100	90-100	90-100	95-100
3	2.36mm	60-95	75-100	85-100	95-100
4	1.18mm	30-70	55-90	75-100	90-100
5	600µ	15-34	35-59	60-79	80-100
6	300µ	5-20	8-30	12-40	15-50
7	150µ	0-10	0-10	0-10	0-15

3.3.1 Coarse Aggregate:

Coarse is naturally occurring and can be obtained by blasting quarries or crushing them by hand or crushers.

Table 2 Grading of Coarse aggregates

IS sieve designation		Percentage passing for single-sized aggregate of nominal size					Percentage passing for grade aggregate of nominal size			
	63mm	40mm	20mm	16mm	12.5mm	10mm	40mm	20mm	16mm	12.5mm
80mm	100						100			
63mm	85-100	100					95-100	100		
40 mm	0-30	85-100	100				95-100	100		
20mm	0-5	0-20	85-100	100			30-70	95-100	100	100
16mm				85-100	100				90-100	
12.5mm					85-100	100				90-100
10mm	0-5	0-5	0-20	0-30	0-45	85-100	10.-35	25-55	30-70	40-85
4.75mm			0-5	0-5	0-10	0-20	0-5	0-10	0-10	0-10
2.36mm						0-5				

3.4 Metakaolin

Metakaolin is a high-quality pozzolanic material. Metakaolin is one of the most widely used mineral admixtures these days. It helps concrete obtain both higher performance and economy. Metakaolin is produced by the calcinations of pure or refined kaolinite clay at a temperature between 650°C to 850°C. Kaolin clay is the raw material for the Metakaolin. Kaolinite clay is a mineral which is fine and white in colour and it is used in the manufacturing of porcelain. Kaolinite clay is also known as china clay or kaolinclay.

Table 3 Chemical composition of Metakaolin

Chemicals	Percentage (%)
SiO2	62.62
Al2O3	28.63
Fe2O3	1.07
\MgO	0.15
CaO	0.06
Na2O	1.57
K2O	3.46

Table 4 Physical Properties of Metakaolin

S.No.	Properties	Value
1	Physical form	powder
2	Colour	white /grey
3	Fineness	700 to 900 m^2/kg
4	Specific surface	8 to 15 m^2/g
5	Specific Gravity	2.5

3.5 Silica Fume

It has also been called silica fume, micro silica, amorphous silica and other similar names. Silica fume was also used for one of the flyovers at Mumbai where, for the First time in India 75mpa concrete was used in 1999. Binder, aggregates, water and in most cases with ready mixed concrete, one or more types in chemical admixtures.

3.5.1 Role Of Silica Fume In Concrete

Silica fume is the result during the manufacture of silicon or of various silicon alloys. Silica fume, which contains more than 80% to 85% of SiO2 in amorphous form, is suitable to be used in cement andconcrete industries. The typical particle size of silica fume is around 0.1-0.5µm and the nitrogen BET surface is 20,000 m3 /kg. It is used increasingly in the world as a mineral admixture to produce high performance concrete. Silica fume is light and has a low bulk density of 250-300 kg/m3. It was utilizedfirst in 1970's as an additive

Table-5 Physical properties of silica fume

S. No.	Properties	Values
1	Size	0.15 micron
2	Fineness	8.09
3	Specific gravity	2.25

Table 6 Chemical composition of silica fume

Chemical properties	SF (%)
Al2O3	0.4
SiO2	97.1
Fe2O3	0.3
CaO	0.3
SO3	0.2
Na2O	0
L.O.I	1.7
MgO	0

•It eliminates the growth of Ca(OH)2 at the cement – aggregate interface, or transforms Ca(OH)2 intoCaSiO3 hydrate by the pozzolanic reaction between silica and lime.

•It removes large pores at the cement – aggregate interface, making it denser.

As a result of these actions of silica fume, it gives significant improvement in mechanical properties and drastic improvement in durability and impermeability. While providing significantstrength and durability, silica fume can create an increase in water demand to reach specific workability levels due to the increase in specific area.

4. PROBLEM STATEMENT

From the above literature review the following conclusions can be drawn:

(i) Using of self-compacting concrete in place of normal mix slightly increases the shear capacity of beams.

(ii) (ii) Up till the maximum value the characteristics strength of concrete increases and after the optimum value the characterize strength decreases.

(iii) (iii) The split tensile strength and flexural strength also increases while there is decrease in water absorption capacity.

(iv) (iv) When the cement was replaced with Metakaolin and Silica Fume at various proportions then there is slight increase in the percentage of the characteristics strengths.

5. MIX DESIGN – (FOR THE GRADE M30 PLAIN CONCRETE)

The mix design is carried out according to (Mix design code) IS code 10262:2009 Through following step – As per IS Code 10262:2009 (New revised code)

Step I - Design Stipulation

Grade Designation = M30

Type of Cement = OPC 53 Grade; IS 2269:1987 (ACC Cement)

Max. Nominal Size = 20 mm to 12 mm (Mixed in ratio 60:40)

Shape of Coarse Aggregate = Angular

Min. Cement Content = 320 kg/m3

Max. W/C Ratio = 0.50

Workability = 50 mm to 100 mm slump

Exposure Condition = Moderate

Chemical admixture = not used

Step II - Test Data for Material

Specific gravity of coarse aggregate = 2.71

Specific gravity of Fine aggregate = 2.62

Free surface moisture of sand = 0.31%

Free surface moisture of coarse aggregate= 0.50%

Water absorption of coarse aggregate=0.81%

Water absorption of sand =0.81 %

Step III Using the table no. 8 IS 456-2000

The value of standard duration for M 30 =5

(as per table -1 of IS 10262- 2009)

grade of concrete Standard Deviation

Step IV Target Strength

Target Strength = fck + (1.65*SD)

Target Strength = 30 + (1.65 x 5)

Target Strength = 38.25 N/mm2

Step V For the required target strength the W/C ratio

For the required target strength, the W/C ratio =0.45

for 28 days strength of cement of IS 4031-1962

Step VI Check for W/C ratio

Minimum requirement of cement and W/C ratio for different grade of concrete

Table 7 Selection of water and Sand content

Grade	Nominal size of aggregate	Water content in cum of concrete in Kg	Sand as % of aggregate by absolute volume	Remarks
Up M_{35}	10mm	208	40	Sand zone II Water/ Cement Ratio 0.6
	20mm	186	35	
	40mm	163	30	
Beyond M_{35}	10mm	200	28	Compaction Factor 0.8
	20mm	186	25	

From Table 6.14 IS 10262:2009 for 20 mm aggregate = 186 liters (From 25 to 50 mm slump range)

Step VIII Determination of cement content

We know that W/C ratio = 0.45

Cement = 186

Cement Content = 186/0.45

Cement Content = 414 kgs

Step IX Referring to the table from step V

Referring to the table from step V for severe exposure of =320 kg/cum

M 30 Grade the min cement content

Hence adopt 414 kg/cum of cement content = 414 >320

Hence OK

Step X Proportion of volume of coarse aggregate and fine aggregate content

It is necessary to increase the volume of coarse aggregate to reduce the fine aggregate content because the volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate (ZONE II) in the current case has a water cement ratio of 0.45. The volume of coarse aggregate increases proportionately as the water cement ratio decreases by 0.05, increasing by 0.01 for every 0.05 increase or decrease in the water cement ratio.

Therefore, corrected proportion of volume of coarse aggregate for the water cement ratio of 0.45 = 0.61

Volume of coarse aggregate = 0.61

Volume of fine aggregate content = 1-0.61

Volume of fine aggregate content = 0.39

Step XI Mix Calculation

The mix calculation per unit volume of concrete shall be as follows-

A) Volume of concrete = 1 m3

B) Volume of Cement =

B) Volume of Cement = $\dfrac{Mass\ of\ cement \times 1}{Specific\ gravity\ of\ cement \times 1000}$

Volume of Cement = $\dfrac{414 \times 1}{3.15 \times 1000}$

Volume of Cement = 0.131 m3

C) Volume of Water = $\dfrac{Mass\ of\ \text{water} \times 1}{Specific\ gravity\ of\ \text{water} \times 1000}$

Volume of Water = $\dfrac{186 \times 1}{1 \times 1000}$

Volume of water = 0.186 m3

D) Volume of all in aggregate = A - (B + C)

= 1 – (0.131 + 0.186)

Volume of all in aggregate = 0.683 m3

E) Mass of Coarse aggregate = 0.683 X Volume of C.A X Specific gravity of C.A X 1000

= 0.683 X 0.61 X 2.71 X 1000

= 1128.06 kg/m3

F) Mass of Fine aggregate = 0.683 X Volume of F.A X Specific gravity of F.A X 1000

= 0.683 X 0.39 X 2.62 X 1000

= 697.88 kg/m3

Hence,

Cement = 414 kg

Water = 186 lts

Sand = 697.88 kg/m3

Coarse Aggregate= 1128.06 kg/m3

Table Mix proportion by (Saturated surface dry) mass

Cement	Water	Fine Aggregate	Coarse aggregate
414	186	697.88	1128.06
1	0.45	1.68	2.72

Table 8 The Final Trial Batches Quantities of Silica Fume, METAKAOLIN Per Cubic Meter of Concrete M30 are

Mix Code	Cement kg/m3	silica fume	Metakaolin kg/m3	Fine Aggregate kg/m³	Coarse Aggregate kg/m³	Water kg/m	W/C ratio
M30	414.00	0.00	0.00	697.88	1128.06	161.00	0.45
M-1	331.20	0.00	82.80	697.88	1128.06	161.00	0.45
M-2	331.20	20.70	62.10	697.88	1128.06	161.00	0.45
M-3	331.20	41.40	41.40	697.88	1128.06	161.00	0.45
M-4	331.20	62.10	20.70	697.88	1128.06	161.00	0.45
M-5	331.20	82.80	0.00	697.88	1128.06	161.00	0.45

6. RESULTS AND DISCUSSIONS

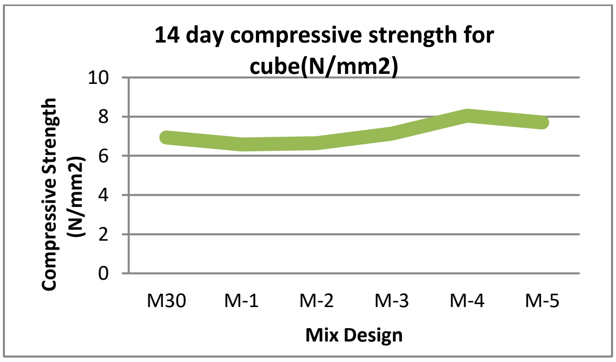
6.1 General

In this research we present found on to investigate the strength properties of Metakaolin and silica fumes. The partial replacement of Metakaolin and silica fumes with cement is performed in this experiment. Metakaolin is the waste product attained from steel manufacturing industry, is formed by the partition of molten steel from impurities. In this experiment Supplementary materials silica fume and Metakaolin in varying percentages i.e., 0% of silica fume and 0% of Metakaolin for normal concrete, 0% of silica fume and 20% of Metakaolin, 05% of silica fume and 15% of Metakaolin, 10% of silica fume and 10% of Metakaolin, 15% of silica fume and 5% of Metakaolin, 20% of silica fume and 0% of Metakaolin of total dosage (i.e.,20%) by weight of cement. Results are taken as a Beams and Cubes are casted to check the flexural strength and compressive of concrete at 14 days and 28 days.

6.2 Compressive Strength

Table 9 Compressive strength at 14 days of concrete cube by using Metakaolin and silica fume

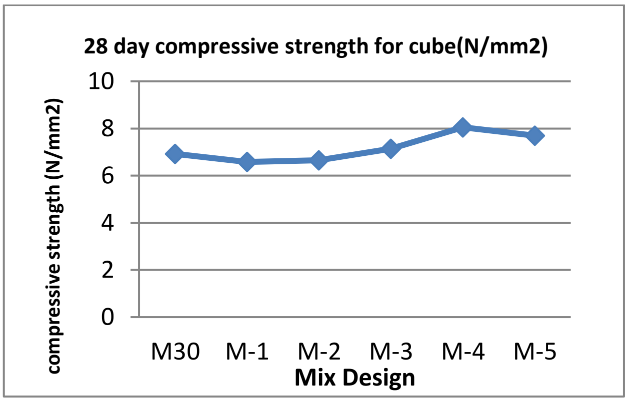
Mix Code	Compressive strength for cube(N/mm²)
M30	34.515
M-1	42.8048
M-2	43.8404
M-3	41.424
M-4	37.972
M-5	33.1392



Graph 1 Compressive strength at 14 days of concrete cube by using Metakaolin and silica fume

Table 10 Compressive strength at 28 days of concrete cube by using Metakaolin and silica fume

Mix Code	Compressive strength for cube (N/mm²)
M30	37.96
M-1	47.55
M-2	48.70
M-3	46.02
M-4	42.18
M-5	36.82



Graph 2 Compressive strength at 28 days of concrete cube by using Metakaolin and Silica fume

6.3 Flexural strength test

Table 11 Flexural strength at 14 days of concrete beam by using Metakaolin and silica fume

Mix Code	Flexural strength (N/mm²)
M30	5.18
M-1	4.86
M-2	4.92
M-3	5.28
M-4	5.95
M-5	5.69

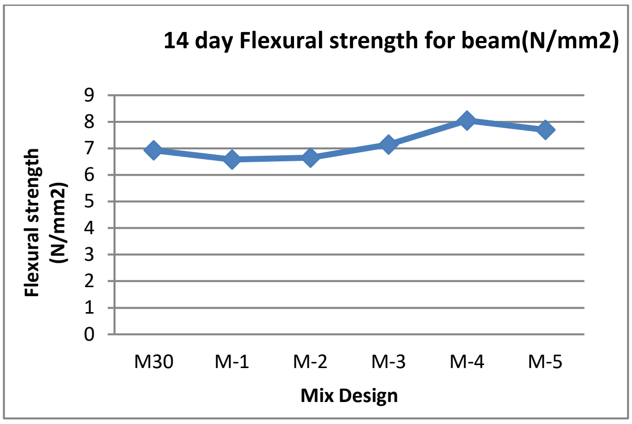


Fig 3 Flexural strength at 14 days of concrete beam by using Metakaolin and silica fume

Table 12 Flexural strength at 28 days of concrete beam by using Metakaolin and silica fume

Mix Code	Flexural strength (N/mm²)
M30	6.93
M-1	6.58
M-2	6.65
M-3	7.14
M-4	8.05
M-5	7.70

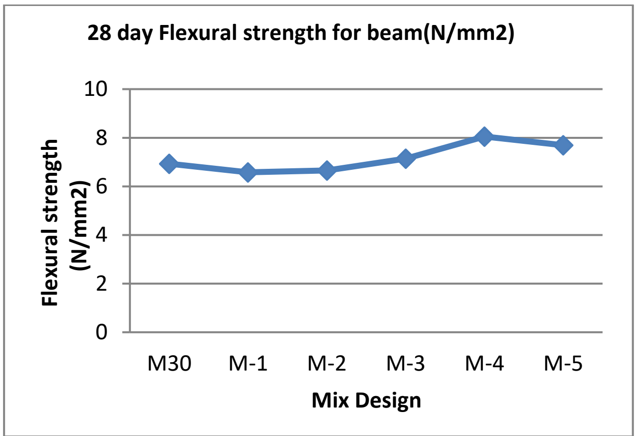


Fig 4 Flexural strength at 28 days of concrete beam by using Metakaolin and silica fume

7. CONCLUSION

The experimental investigations conducted on the behavior of concretes with METAKAOLIN and silica fume as partial replacements for cement.

- As Metkaolin and silica fume is partially replaced with the cement, the consumption of the cement is reduced and also the cost of construction is reduced.
- Thus, the workability is improved by the partial replacement of the Metakaolin and silica fume with cement.
- The use of Metakaolin and silica fume as a replacement of cement helps to reduce the Energy consumption in the manufacturing of cement.
- We find that there is increase in the strength of concrete that compressive strength is 48.70 N/mm2 flexural strength is 8.05 N/mm2
- We get the maximum compressive strength at 5% and 15% replacement of Metakaolin and silica fume with cement.
- We get the maximum Flexural strength at 15% and 5% replacement of Metakaolin and silica fume with cement.

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