Compressive Strength of Concrete using Ultra-Fine Fly Ash and Metakaolin (Alccofine)

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ABSTRACT- *In this research program, high volume ultra-fine fly ash concrete mixes produced with OPC 53 grade cement for higher grade M40 and M50. Initially control mix was produced with 100 % OPC cement. Further 40% of cement content was replaced with ultra-fine fly ash with Alccofine (Metakaolin) and properties were found. The Metakaolin (alccofine) were used in 10%, 15% and 20 % to enhance the concrete properties and to reduce cement content for both grades M40, and M50. In such a way overall cement content was reduced up to 60 %. Replacement of cement by UFFA with Metakaolin results in more improved and economical concrete. Compressive strength of specimens were determined in the laboratory. Combination of UFFA and Metakolin shows excellent improvement in compressive strength for both grade.*

Keywords Ultra-fine fly ash, metakaolin, ordinary portland cement, concrete, compressive strength.

I. INTRODUCTION

Cement both in mortar and concrete, is the most essential element of the infrastructure and has been known as a long-lasting construction material [16, 17]. Reuse of recycled or waste materials for the construction of civil structures is an issue of great importance in this century. Mixing of mineral admixtures in concrete and mortar improves compressive strength, pore structure and permeability. Some of this materials, known as pozzolana, which by themselves have no cementitious properties, however, when used with portland cement reacts to form cementitious materials. Partial replacement of portland cement in concrete reduces the volume of portland cement. This reduction in cement volume further reduces the construction cost, energy loss and waste emissions such as carbon dioxide (CO2) emission. This also, reduces the energy consumption and thus, reduces the rate of global warming [17, 18, and 19].

The use of supplementary cementitious material in high strength concrete and high performance concrete is common now a days. Providing alternative material to reduce cement consumption in concrete is quite challenging task. Although a no of studies have been conducted on use of SCM such as class c fly ash in HVFA concrete [1, 3, 5, 14] and in high strength concrete [4], class F fly ash [13], Fly ash in HVFA concrete [2, 6, 8, 11], to provide economical, ecological , green concrete and to minimize environmental problem. These studies shows excellent properties such as workability, density and compressive strength, flexural strength, split tensile strength, abrasion resistance etc. Among all the SCM in concrete fly ash plays an important role in reducing cost and providing alternative supplementary cementitious material to construction industry. The performance of fly ash can further be improved using mineral admixture such as GGBS and silica fume in concrete [11,13] and alccofine in ultra HPC [12]. Use of alccofine with UFFA shows improved performance of concrete. Previous research do not show much literature in this regard and there is a research gap in use of UFFA in construction application especially using alccofine. Therefore it can be said that there is a need of research and investigation in this particular area to understand the most beneficial and economical features of the UFFA with metakaolin (alccofine) in concrete for cement replacement.

II. OBJECTIVE OF THE STUDY

The research was aimed to investigate effect of fresh properties of concrete using ultrafine fly ash with alccofine (metakaoline) for cement replacement.

III. MATERIALS AND THEIR PROPERTIES

Cement

OPC 53 grade cement of Ultra tech was used for this research program.

Natural Sand

Locally procured natural sand was used as fine aggregate in concrete. Locally available Narmada sand (zone-II) was used

Aggregate

A combination of 20mm nominal size aggregate and 10mm nominal size aggregate is used as coarse aggregate in this experimental program. Both types of coarse aggregate were locally procured.

Water

The water used was ordinary tap water from the Bhopal city.

Ultra-Fine Fly ash

Fly ash used in this study was collected from Sarni thermal power plant.

Metakaolin

Commercially available Bags of Metakaolin were used in various proportions in this study.

IV. EXPERIMENTAL PROGRAM

To conduct experimental program following trials were prepared in the laboratory. Table 4.1 shows experimental program and table 4.2 and table 4.3 shows mix design parameters for the grade M40 and M-50.

Table 4.1 Experimental program

Grade	**Mix**	**W/C Ratio**	**(Cement +UFFA) (%)**	**Mineral Admixture** Metakaolin (%)	**Tests**
M40	M00	0.38	100 % OPC	00 %	Compressive strength at the age of 7, 28, 56 and 90 days
	M41	0.3	50% OPC+40% UFFA	10 %	
	M42	0.3	40% OPC+45% UFFA	15 %	
	M43	0.3	40% OPC+40% UFFA	20 %	
M50	M00	0.33	100 % OPC	00 %	
	M51	0.28	50% OPC+40% UFFA	10 %	
	M52	0.28	40% OPC+45% UFFA	15 %	
	M53	0.28	40% OPC+40% UFFA	20 %	

Table 4.2 Mix design parameters for grade M40 and M50

S. No.	Material	Source	M-40 Grade (Mix M-41)		M-50 Grade (Mix M-51)	
			Specific gravity	SSD weight	Specific gravity	SSD weight
1.	Cement	Ultra Tech OPC 53 grade	3150	200	3150	240
2.	Fly ash	Grasim Nagda	2250	250	2250	246
3.	Metakaolin	Kaolin Techniq Snow Cem	2500	50	2500	54
4.	Water	Natural water	1000	150	1000	151
5.	Fine Aggregate	Natural Sand	2690	667	2690	612
6.	Coarse Aggrgate-1 (10 mm)	(10 mm)	2810	455	2810	465
7.	Coarse Aggrgate-2 (20 mm)	(20 mm)	2840	689	2840	704
8.	Admixture	YPCUTB	1250	2.100	1250	2.376

Table 4.3 Mix design parameters for grade M40 and M50

1.	Grade of concrete	M40	M50
2.	Target Mean strength	48.25	58.25
3.	W/C ratio	0.30	0.28
4.	Actual volume considered	1.00	1.00
5.	Percentage of coarse aggregate (20 mm)	62.0	64.50
6.	Percentage of coarse aggregate (10 mm)	40	40
7.	Percentage of total cementitious material	500	540
8.	Percentage of fly ash	50	45.50
9.	Percentage of metakaolin	10	10
10.	Percentage of Fine aggregate	38.00	35.5
11.	Percentage of Natural Sand	100.0	100.0
12.	Percentage of air void	0.30	0.10
13	Admixture %	0.420	0.440

V. CASTING OF SPECIMENS

Various concrete mixes (M00, M41, M42, M43 and M00, M51, M52 and M53) were produced in the lab using ultra-fine fly ash (40 to 45 %) in combination with metakaolin (10 %, 15% and 20%) for M40 and M50. Control mix with 100 % OPC and other mixes were casted and tested in the laboratory. Total no of 12 concrete cube of 150 mm X 150 mm X 150 mm for each trial mix were prepared and tested at age of 7, 28, 56 and 90 days curing. Compressive strength is taken as the average compressive strength of three concrete cubes.

VI. RESULTS AND DISCUSSION

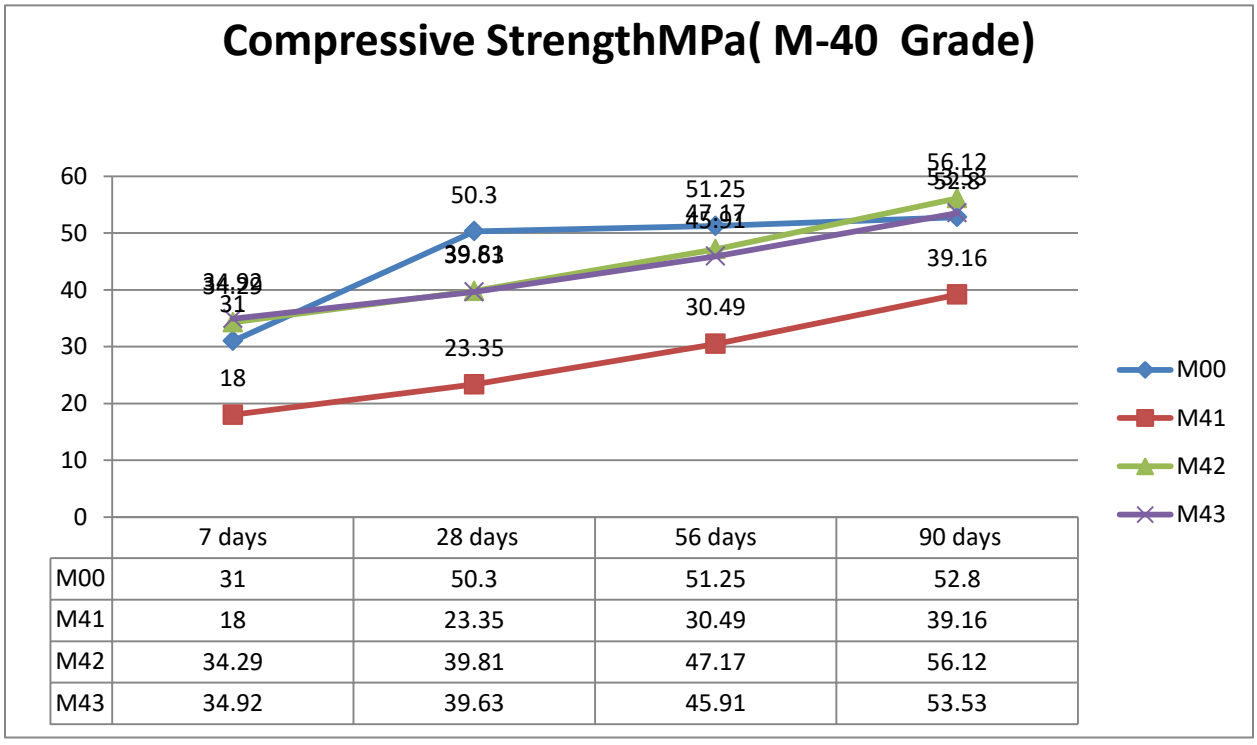
Table 4.5 shows compressive strength of M40 grade of concrete at the Age of 07, 28, 56 and 90days and Table 4.6 shows compressive strength of M50 grade of concrete at the Age of 07, 28, 56 and 90days

Table 4.5 Compressive strength test results for M40 grade.

Mix		(Cement +UFFA) (%)	Mineral Admixture Metakaolene (%)	Compressive strength at curing of			
				7 days	28 days	56 days	90 days
M00	0.38	100 % OPC	00 %	31	50.3	51.25	52,80
M41	0.30	50% OPC+40% UFFA	10 %	18	23.23	30.49	39.16
M42	0.30	40% OPC+45% UFFA	15 %	34.29	39.81	47.17	56.12
M43	0.30	40% OPC+40% UFFA	20 %	34.92	39.63	45.91	53.53

Table 4.6 Compressive strength test results for M50 grade.

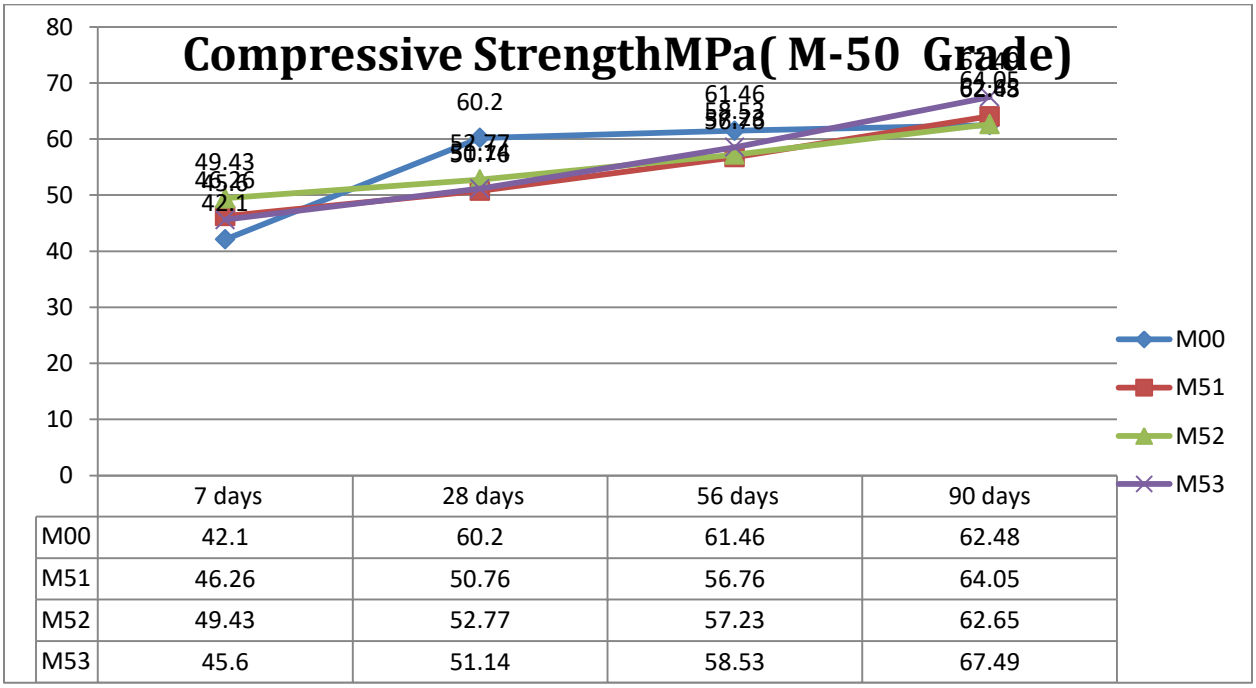
Mix	W/C Ratio	(Cement +UFFA) (%)	Mineral Admixture Metakaolin (%)	Compressive strength at the age of			
				7 days	28 days	56days	90 days
M00	0.33	100 % OPC	00 %	42.10	**60.20**	**61.46**	62.48
M51	0.28	50% OPC+40% UFFA	10 %	46.26	50.76	56.76	64.05
M52	0.28	40% OPC+45% UFFA	15 %	49.43	52.77	57.23	62.65
M53	0.28	40% OPC+40% UFFA	20 %	45.60	51.14	58.53	67.49



Compressive strength for M40 grade of concrete.

It is observed from the graph that replacement of cement using UFFA with metakaolin results in reduction in compressive strength initially. But thereafter there is significant improvement in performance of compressive strength. Compressive strength for control mix (M00) were found 31.00, 50.30, 51.25 and 52.80 N/mm2 at the age of 7 days, 28 days, 56 days and 90 days. Compressive strength reduces initially when cement is replaced with UFFA and Metakaolin at all ages. Compressive strength for mix (M41) were found 18.00, 23.35, 30.49 and 39.16 N/mm2 at the age of 7 days, 28 days, 56 days and 90 days. After that there is increase in compressive strength for mix M42 and M43. Compressive strength for mix (M42) were found 34.29, 39.81, 47.17 and 56.12 N/mm2 at the age of 7 days, 28 days, 56 days and 90 days. Similarly compressive strength for mix (M43) were found 34.92, 39.63, 45.91 and 53.53 N/mm2 at the age of 7 days, 28 days, 56 days and 90 days. The maximum compressive strength 56.12 Mpa was observed for mix M42 at (45FA+15M)% replacement of Fly ash at 90 days curing.

It was found that compressive strength of concrete mixtures with (40FA+10M)%, (45FA+15M)% and (40FA +20M) % of fly ash as cement replacement was lower initially at all ages and that the strength of all mixtures continued to increase with the age. Maximum percentage of increment in compressive strength for mix M42 and M43 was found 6.28 % and 1.42 % at the age of 90 days as compared to control mix.



	7 days	28 days	56 days	90 days
M00	42.1	60.2	61.46	62.48
M51	46.26	50.76	56.76	64.05
M52	49.43	52.77	57.23	62.65
M53	45.6	51.14	58.53	67.49

Compressive strength for M50 grade of concrete

It is indicated from the above graph that compressive strength at the age of 7 days and 90 days shows excellent improvement for grade 50. Maximum percentage of increment in compressive strength for mix M51, M52, and M53 were found 2.51%, 0.27% and 8.01% respectively at the age of 90 days when compared with control mix.

Compressive strength for control mix (M00) were found 42.10, 60.20, 61.46 and 62.48 N/mm2 at the age of 7 days, 28 days, 56 days and 90 days. Compressive strength for mix (M51) were found 46.26, 50.76, 56.76 and 64.05 N/mm2 at the age of 7 days, 28 days, 56 days and 90 days. Compressive strength for mix (M52) were found 49.43, 52.77, 57.23 and 62.65 N/mm2 at the age of 7 days, 28 days, 56 days and 90 days. Similarly compressive strength for mix (M53) were found 45.6, 51.14, 58.53 and 67.49 N/mm2 at the age of 7 days, 28 days, 56 days and 90 days. The maximum compressive strength 67.49 Mpa was observed for mix M53 at (40FA+20 M)% replacement of Fly ash at 90 days curing.

VII. CONCLUSIONS

On the basis of experimental investigation carried out in the laboratory following conclusion can be drawn in regard of concrete produced with Ultra-fine fly ash (UFFA) and Metakaolin (M).

1. The replacement of cement with UFFA and Metkaolin reduces the compressive strength initially (mix M41) at all the ages for grade M40.
2. Further compressive strength improves for mix M42 concrete and shows better performance than M41 concrete and the maximum compressive strength 56.12 Mpa was observed at (45FA+15M)% replacement of UFFA and Metakaolin at 90 days curing.
3. Compressive strength at the age of 7 days and 90 days shows excellent improvement for grade M50.The maximum compressive strength 67.49 Mpa was observed for mix M53 at (40FA+20 M) % replacement of Fly ash at 90 days curing.
4. Combination of UFFA and Metakaolin shows excellent improvement in compressive strength for both grade. Maximum percentage of increment in compressive strength was found 6.28 % for M40 grade at the age of 90 days and 8.01 % for M50 grade at same age.
5. Concrete produced with combination of UFFA and Metakaolin can be used in different civil engineering structures, beam, column, foundations and other construction work. It can be also used in high-rise building, tall structure, road pavement etc.

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