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Experimental Investigation on Strength Characteristics of Concrete containing Fly Ash and Micro silica

Latika Manchanda
Chandigarh College of Engineering and Technology,
Panjab University, Chandigarh, India

***Abstract*— Due to growing urbanisation, use of concrete has increased to a great extent. Also, the materials used in making concrete are non-renewable; therefore there is a great need of finding and utilizing supplementary raw materials for making concrete. Waste materials like fly ash, lime stone quarry, micro silica, blast furnace slag etc are seen as partial replacements for cement to deal with this issue. It would not only provide an alternative to an expensive raw material but also decrease the threat to the environment due to waste accumulation.**

For discovering the economical alternatives for cement, comparison of compressive strength of concrete by adding fly ash and micro silica in different proportions is done. For compensating the loss in strength of concrete because of adding fly ash in higher percentage, micro silica has been added in concrete.

In the study conducted, results revealed that compressive strength of concrete has increased on addition of fly ash and micro silica.

Keywords*— Compressive Strength, Concrete, Fly Ash, Micro silica, Cement.

1. INTRODUCTION

With increasing rate of inflation, construction cost has been highly affected. Cement is one of the most expensive and highly used materials in construction. Increasing industrialization has also posed a serious threat to environment. Management and removal of waste emitted from industries is also a rising problem for us. Therefore using waste materials as partial replacement of cement will protect environment from waste accumulation and also helps in improving overall economy. On adding Fly Ash, durability of concrete is increased and there is reduction in heat of hydration. Thus using Fly Ash shows improved performance of concrete at equal or lower cost.

Micro silica reduces the volume of voids in concrete. Micro fine particles of silica fume react with lime present in cement and thus reduce capillary action and porosity of concrete. Micro silica increases the strength at early stages and reduces the setting time of concrete. Fly ash delays the early age strength and provides strength at later stages.

Tarun R Naik, Frederick H Gustin and Shiw S Singh (1996) made various mixes with varying percentage of Fly Ash and silica fume. His findings suggested that there was significant difference between the compressive strength and chloride resistance of fly ash concrete and fly ash free mixture at later ages (90 days). During initial stages (3 and 7 days) much difference was not observed. Concrete mixes containing Fly Ash and Silica Fume showed even better results. Silica fume helps in increasing the performance of concrete.

Verma Ajay, Chandak Rajeev and Yadav R.K. (2012) studied the effect of micro silica at replacement levels 5, 10, 15, 20% and reported that Silica fume increases the strength of concrete by 25%. Addition of silica fume in concrete reduces capillary, absorption and porosity because of the fine particles of silica fume which react with lime present in cement. Silica fume is a by-product of industries which causes Air Pollution; therefore if it is used in replacement of cement then it would not only improve the performance of concrete but also reduce air pollution.

Aditya Dhagat and Manav Mittal (2013) has replace cement with 43% fly ash and 5% micro silica and analysed that the strength of concrete has visibly increased and made the concrete manufacturing process cheaper and more eco-friendly. He also reported that by adding mere 5% micro silica to concrete gives better strength as compared to fly ash and micro silica concrete.

Amar Devendra Shitole and Sandhya Mathapati (2014) investigated the effect of silica fume additions of 7.5%, 10% as binder replacement. They concluded that when 7.5% of cement is replaced by micro silica, maximum increase in the compressive and flexural strength is seen. Thus micro silica can be used to achieve greater strength of concrete and it will also reduce air pollution.

BLP Swami, P Srinivasa Rao and PSS Narayana (2015) studied the properties of concrete on mixing micro silica at replacement levels 5%, 10%, 15%, 20%, 30%, 40% and reported that at higher percentage of micro silica, water demand increases to keep the workability constant and using plasticizer becomes necessary. Dosage of 10% micro silica gives better results among all mixes. Micro silica concrete gains more strength with age, provides durability because of having better sulphate resistance.

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2. NEED AND OBJECTIVE

In past, many studies have been carried out to investigate the effect of fly ash, rice husk, blast furnace slag, etc. However very few studies are available regarding using fly ash and micro silica as partial replacement of cement to achieve economy and greater standard of performance. Present study is conducted to identify following objectives:

- To investigate the appropriateness of Fly Ash from Rajpura Thermal Power Plant as partial substitute of cement.
- To enquire the effect of partially replacing cement with fly ash in different percentages (10%, 20%, 30%, and 40%) on compressive strength of concrete at moist curing age of 7 and 28 days.
- To study the effect of partial replacement of cement with micro silica in varying percentages (5%, 10%, 15%, 20%) on compressive strength of concrete at moist age of 7 and 28 days.
- To investigate the effect of partial replacement of fly ash with micro silica (at percentage which was most suitable for concrete) on compressive strength of concrete at moist age of 7 and 28 days.
- To compare the compressive strength of concrete without fly ash, with fly ash, with micro silica, with fly ash and micro silica both.
- To compare and conclude the best mix according to economy and strength.

3. MATERIALS USED

A. *Cement*

All the cubes for each concrete mix were made from a single batch of 43 Grade of Ordinary Portland cement. IS:8112-2013 was followed to test the physical properties of cement. Fresh cement was used.

B. *Fine Aggregates*

In this experimental programme, locally procured sand conforming to grading Zone II was utilised. To remove any particles greater than 4.75 mm, the sand was sieved through 4.75 mm sieve and then sand was washed to remove ant foreign material. The fineness modulus of the sand used was 2.18.

B. *Coarse Aggregates*

In the present work, locally available crushed stone aggregates passing through 20 mm is sieve is used. Maximum size of aggregates used is 20 mm. The aggregate were first sieved through 10 mm sieve and then through 4.75 mm sieve. IS: 383-1970 was followed for the requirements of properties of aggregates.

Table 1: Properties of Cement

SN	Particulars	Test Results	Requirements as per IS 8112-2013
1	Fineness (m^2/kg)	264	225 (Min)
2	Standard Consistency (%)	24.3	
3	Setting Time (minutes) Initial Final	 50 265	 30 (Min) 600 (Max)
4	Soundness Le-Chat Expansion Autoclave Expansion (%)	 1.0 0.130	 10.0 (Max) 0.8 (Min)
5	Compressive Strength (MPa) 72 +/-1 hr. (3 days) 168 +/-2 hr. (7 days) 672 +/-4 hr(28 days)	 25.05 37.30 46.90	 23 (Min) 33 (Min) 43 (Min) 58 (Max)

Table 2: Properties of Fine Aggegates

S N	Characteristics	Results Obtained (IS:383-1970)
1	Grading Zone	Zone II
2	Bulk Density (gm/cc)	1.89
3	Fineness Modulus	2.18
4	Specific Gravity	2.63
5	Water Absorption (%)	0.52%
6	Free Moisture Content (%)	Nil

Table 3: Properties of Coarse Aggregates

Sr. No.	Characterisics	Values
1	Colour	Grey
2	Type	Crushed
3	Shape	Angular
4	Bulk Density (kg/litre)	1.62
5	Specific Gravity	2.65
6	Water absorption	1%
7	Fineness Modulus	6.64
8	Moisture Content (%)	Nil
9	Elongation Index (%)	23.8%
10	Flakiness Index (%)	13.5%
11	Aggregate Impact Value (%)	13.7%
12	Aggregate Abrasion Value (%)	19.7%
13	Aggregate Crushing Value (%)	15.8%

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C. *Fly Ash*

Fly Ash was procured from Rajpura Thermal Power Station, Rajpura and supplied to UltraTech RMC Plant, Mohali in one lot. Chemical and Physical properties are shown in table 4.

D. *Micro silica*

Elkem Micro silica Grade 920 D is a dry silica fume powder. Micro silica particles are less than 1 micron in diameter, generally 100 times finer than average cement particles. It improves the performance of concrete. It optimises particle packing of the concrete. Micro silica increases durability, ompressive strength and reduces segregation and bleeding in following ways:

- Micro silica imparts uniform distribution and produces more volume of hydration products.
- Micro silica decreases the size of pore in concrete.

Properties of Elkem Micro silica are listed in table 5.

Table 4: Properties of Fly Ash

S N	Tests	Result	Requirements (as per IS :3812:2013)
1	SiO_2+Al_2O_3+Fe_2O_3, % by mass	92.78	70 (Min)
2	Silicon Dioxide as SiO_2, % by mass	62.55	35 (Min)
3	Magnesium Oxide as MgO, % by mass	0.13	5 (Max)
4	Total Sulphur as SO_3, % by mass	0.22	3 (Max)
5	Available Alkali's as Na_2O, % by mass	0.20	1.5 (Max)
6	Total Chlorides as Cl, % by mass	0.024	0.05 (Max)
7	Loss on Ignition, % by mass	0.52	5(Max)

Table 5: Properties of Micro silica 920D

S N	PARAMETERS	ANALYSIS	SPECIFICATIONS
A	CHEMICAL REQUIREMENTS		
1	SiO_2 (%)	85.50	85.0 (Min)
2	Moisture Content (%)	0.55	3.0 (Max)
3	Loss of Ignition (%)	2.30	6.0 (Max)
B	PHYSICAL REQUIREMENTS		
4	>45 micron (%)	0.84	10 (Max)
5	Pozz. Activity Index (7d) (%0)	139	105(Max)
6	Sp. Surface m^2/g	18.0	15(Min)
7	Bulk Density (KG/m^3)	510	500-700

E. *Superplasticizer*

In the present study, Superplasticizer "Forsoc Conplast SP430G8" procured from M/s Forsoc Chemicals Pvt Ltd. Chandigarh. It is based on Sulphonated Napthalene Formaldehyde Polymers and is supplied as a brown liquid which instantly disperses in water. It is a specially formulated superplasticizer to give 25% water reductions without loss in workability, yielding greater strength, denser quality and closely textured concrete with lesser porosity and increased durability.

Table 6: Properties of superplasticizer

SN	Test	Result	Limit as per IS 9103:1999
1	Specific Gravity	1.236	±0.02 of the value stated by manufacturer
2	pH	7.36	Min. 6.00
3	Dry Material Content	43.78	±5% of the value stated by manufacturer (% by mass)
4	Chloride Content	0.029	Within 10% of the value or within 0.2% whichever is greater as stated by manufacturer (% by mass)

4. EXPERIMENT

Proportioning and Casting of Mix

Concrete mixes were designed as per IS: 10262-2009 Concrete Mix Proportioning Guidelines. Four trial mixes were designed, casted and tested for selecting control mix. Trial mix which achieved the target mean strength was selected as control mix.

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Table 7: Detail of Control Mix

Mix	M35	
Water	155	0.44
Cement	349	1
Fine Aggregates	721	2.065
Coarse Aggregates	1223	3.5
Superplasticizer	2.44	0.006
Water cement ratio	0.44	

5. RESULTS AND DISCUSSIONS

Compressive Strength Test: The test was conducted as per IS code 516-1959. Cubes of dimension 150*150*150mm^3 were kept in tanks for curing for 7 and 28 days. Cubes were tested immediately after removal from water. The results shown in the table and figure reveal that compressive strength of concrete decreases on increasing the dosage of fly ash. But on addition of micro silica, strength of concrete increases visibly. When micro silica is added at 10%, maximum increase in compressive strength was noticed. Therefore in mix M9, M10, M11, M12, 10% dosage of micro silica is given. At higher dosages of micro silica, fly ash and micro silica together, compressive strength of concrete did not show much improvement. M9 mix containing 10% fly ash and 10% micro silica exhibited better results among all the mixes and it is also much economical than control mix.

Table 8: Result of Compressive Strength at moist curing of 7 and 28 days

Sr. No.	Mix	% replacement of cement by fly ash	% replacement of cement by micro silica	Compressive Strength N/mm^2	
				7 Days	28 Days
1	M0	0	0	30.55	42.3
2	M1	10	0	25	35
3	M2	20	0	21.09	33.5
4	M3	30	0	16.88	28.51
5	M4	40	0	12.25	25.53
6	M5	0	5	30.0	40.8
7	M6	0	10	32.5	42.7
8	M7	0	15	32.1	41.3
9	M8	0	20	30.7	40.6
10	M9	10	10	28.71	44.48
11	M10	20	10	20.84	36.43
12	M11	30	10	19.21	32.3
13	M12	40	10	17.53	30

6. COST ANALYSIS

Compressive strength of concrete cubes containing fly ash and micro silica revealed better results than M0 cubes. They are safe for using in various structural applications. The cost of the materials used in the cube are considered for comparing the cost of concrete, because rest all costs like labour and miscellaneous are same. Cost of Mix containing 10% fly ash and 10% micro silica is compared with reference mix. Quantity of aggregates, superplasticizers etc are equal in both mix, only the quantity of fly ash, cement and micro silica vary.

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Table 9: Comparison of cost of materials used in M0 and M9 mix

Mix Designation	Rate (Rs/Kg)	M0 (reference mix)		M9 (10% fly ash and 10% micro silica)	
Compressive Strength (N/mm^2)		43.48		44.40	
Material		Quantity Kg/m^3	Amount Rs	Quantity Kg/m^3	Amount Rs
Cement	7	349	2443	279.2	1954.4
Fly Ash	1.2	0	0	34.9	41.88
Sand	0.53	721	382.13	721	382.13
Aggregates 10 mm	0.6	489	293.4	489	293.4
Aggregates 20 mm	0.6	734	440.4	734	440.4
Micro silica	10	0	0	34.9	349
Water	-	155	-	155	-
Super plasticizer	38	2.44	92.72	2.44	92.72
Total			3651.65		3553.93
% Saving					2.676% for 1 m^3

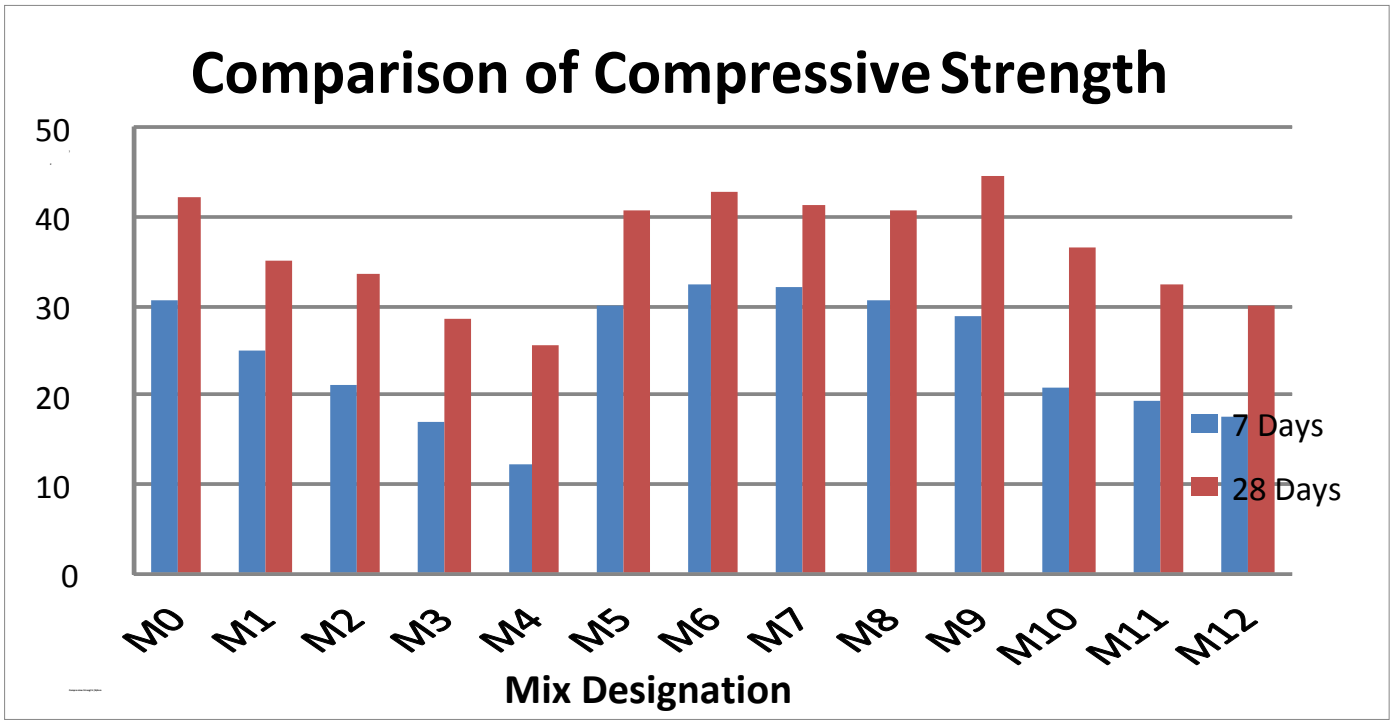

Fig1: Comparison of Compressive Strength of Mixes at 7 ad 28 days

Thus, it is clearly evident that on adding fly ash and micro silica, there is a visible increase in workability, permeability, durability and early strength. Further there is additional advantage in economical point of view. Therefore, replacement of cement by fly ash and micro silica is a practical proposition.

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7. CONCLUSIONS

Based on the results obtained in this study, following conclusions can be made:

I. On replacing cement by fly ash in different percentages (10%, 20%, 30%, 40%) and testing for compressive strength on 7th and 28th days, it is revealed that with increase in dosage of fly ash compressive strength of mix decreases. When 40% of cement is replaced by fly ash, there is a maximum of 59.9% decrease in compressive strength at 7 days and 39.64% decrease at 28 days. This is a clear confirmation that substitution of fly ash results in higher strength at later age.

II. On replacing cement with micro silica at varying percentages (5%, 10%, 15%, 20%) and testing for compressive strength showed that there is a maximum increase in compressive strength of concrete at replacement level of 10%.

III. On replacing cement with fly ash and micro silica in varying percentages and testing for compressive strength, maximum increase in strength is recorded at replacement level of 10% fly ash and 10% micro silica.

IV. On adding 10% fly ash and 10% micro silica in concrete, economy and high strength both of the objectives are achieved.

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