An Experimental Investigation on Strength Properties of Concrete with Partial Replacement of Cement by Fly Ash and Metakaolin & with M. Sand as Fine Aggregate

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Abstract – Construction activities have been increasing rapidly worldwide resulting in tremendous increase in use of concrete that has resulted in heavy production of cement and depletion of river sand. Production of cement leads to environmental pollution due to emission of carbon dioxide (Co_2). Extraction of river sand results into lowering of the water head affecting ground water level. It also leads to erosion of nearby land and gradual destruction of flora & fauna in the surrounding areas. An attempt has been made in the present investigation to evaluate the compressive strength and split tensile strength properties by replacing cement partially with fly ash and metakaolin and by using M.Sand instead of river sand. An experimental study has been carried out by replacing cement with 15% fly ash and metakaolin at 5%, 10%, 15% and 20% and using M.Sand as fine aggregates. The results indicated that there was an improvement in the strength properties and the optimum improvement was found to be in case of mix having cement replaced with 15% fly ash and 15% metakaolin.

Key Words: Cement concrete, Metakaolin, Fly ash, M.Sand Compressive Strength, Split tensile strength.

1. INTRODUCTION

A lot of research and modifications are being carried out to produce concrete with desired characteristics, since the usage of concrete is next only to water. With the advancement of technology and increased field of application of concrete and mortars, the strength, workability, durability and other characteristics of the ordinary concrete needed modification to make it more suitable for various situations. This has led to the use of cementitious materials such as fly ash, silica fume, metakaolin etc. which have contributed towards higher performance, energy conservation and economy .

The use of fly ash and metakaolin partially replacing the cement in concrete results in reduction of cement used, reduction in the emission of carbon dioxide (Co_2), conservation of existing resources along with the enhancement in the strength and durability properties of concrete.

Depletion of natural sand deposits in our country is already causing serious threat to the environment as well as society. This along with shortage in natural good quality sand has made researchers to look for an alternative to river sand. The M.sand produced under controlled and well supervised conditions can a better substitute for river sand. In use of fly ash for partially replacing the Portland cement in concrete not only reduces the amount of cement used, but also significantly enhances the properties of concrete, reduces the emission of CO_2, conserves the existing resources and greatly improves consistency. The addition of fly ash in concrete improves certain properties such as workability, later age strength development and a few durability characteristics .

Blending metakaolin with Portland cement improves the properties of concrete by increasing compressive and flexural strength, providing resistance to chemical attack, reducing permeability substantially preventing alkali silica reaction, reducing efflorescence and shrinkage preventing corrosion of steel.

2. MATERIALS AND METHODS

2.1. Materials

2.1.1 Cement: Ordinary Portland cement of 43 grade confirming to Indian Standards was used in the present investigation and the specific gravity of the sample was evaluated. The results have been tabulated in table2.1.

2.1.2 Fine aggregates: M.Sand with fineness modulus 3.2 conforming to zone II was used in the present investigation and the specific gravity of the sample was evaluated. The results have been tabulated in table2.1.

2.1.3 Coarse aggregates: Crushed granite with fineness modulus 6.9 having size between 20 mm and 4.75 mm was used in the present investigation and the specific gravity of the sample was evaluated. The results have been tabulated in table 2.1.

2.1.4 Water: Drinking water was used for the experimental study

2.1.5 Fly ash: The specific gravity of fly ash was evaluated for the experimental study. The results have been tabulated in table2. 1.

2.1.6 Metakaolin: The specific gravity of metakaolin was evaluated for the experimental study. The results have been tabulated in table 2.1.

Table 2.1: Significant properties of materials used

Materials	Specific gravity
Cement	3.15
Fine aggregates (M.Sand)	2.61
Coarse aggregates	2.59
Fly ash	2.28
Metakaolin	2.41

Table 2.2: Mineral Composition of metakaolin

Major Minerals	Percentage
Lime (Cao)	0.7
Silica (SiO_2)	60.92
Alumina (Al_2O_3)	39.0
Iron oxide (Fe_2O_3)	0.93
Magnesium oxide (MgO)	0.66
Sodium oxide (Na_2O)	0.4

2.2 Mix Proportion

M40 grade of concrete was considered for the present study. The proportion of ingredients was determined in compliance with IS 10262-2009. The various mix proportions for conventional concrete (Control specimen) as well as fly ash based metakaolin concrete wth M.Sand (by partially replacing OPC with fly ash and metakaolin) are presented in Table2.3.

Table 2.3: M40 Mix proportion

Mix Proportion	Cement content (Kg/m^3)	Metakaolin (MK) (Kg/m^3)	Fly ash (Kg/m^3)	F.A (Kg/m^3)	C.A (Kg/m^3)	W/C
Control specimen	495	…….	…….	561	1086	0.4
MK 5% Fly ash 15%	396	24.75	74.25	561	1086	0.4
MK 10% Fly ash 15%	371.25	49.5	74.25	561	1086	0.4
MK 15% Fly ash 15%	346.5	74.25	74.25	561	1080	0.4
MK 20% Fly ash 15%	321.75	99.0	74.25	561	1086	0.4

3. Experimental Program

The experimental program consisted of casting and testing of M40 grade concrete specimens of cube (150 mm) and cylinder (150 X 300 mm).

3.2 Compressive strength

Nine numbers of cubes were cast for each mix and tested using 200T capacity Compression Testing Machine (CTM).

3.3 Split Tensile strength

Nine numbers of cylinders were cast and tested using 200T capacity Compression Testing Machine (CTM).

4. Results and discussions

4.1 Compressive strength: The compressive strength was determined after normal curing for 3days, 7 days and 28 days. The results are presented in Table 4.1 and are also depicted graphically in figure 4.1.

Table 4.1 Compressive Strength Test results

Specifications	Compressive strength (N/mm²)		
	3 days	7 days	28 days
Control specimen	14.33	28	41
MK 5% Fly ash 15%	20.7	29.26	41.9
MK 10% Fly ash 15%	20.83	32.34	43.4
MK 15% Fly ash 15%	26.6	34.60	44.2
MK 20% Fly ash 15%	18.0	44.20	40.8

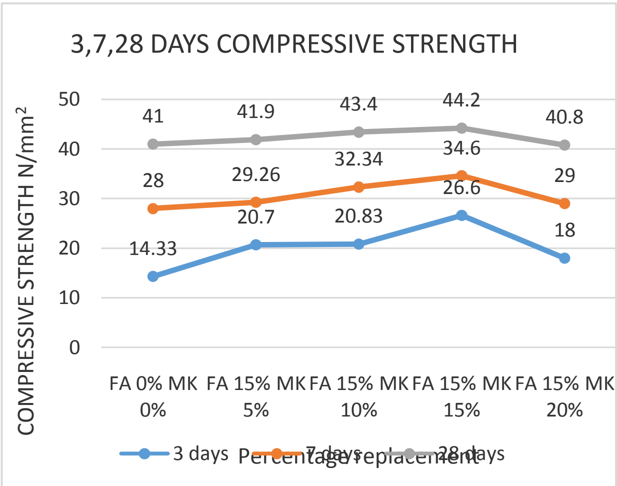

Fig. 4.1 Compressive strength test results

4.2 Split Tensile strength

The split tensile strength was determined after normal curing for 28 days. The results are presented in Table 4.2.

Table 4.2 Split tensile test results

Specifications	Split Tensile Strength (N/mm²)
Control specimen	2.8
MK 5% Fly ash 15%	2.82
MK 10% Fly ash 15%	2.98
MK 15% Fly ash 15%	3.0
MK 20% Fly ash 15%	2.84

From the graph and table, it can be observed that the strength of concrete increases as the percentage of metakaolin increases till 15% and starts reducing beyond 15% addition of metakaolin. The minimum strength obtained by all the mixes is greater than the target strength of the mix design. The maximum compressive strength has been attained for mixes containing 15 % of Fly ash and 15% of metakaolin at 28 days.

5. Conclusions

The following conclusions have been arrived from the study:

1) Addition of Metakaolin and flyash has resulted in enhanced early strength and ultimate strength of concrete.
2) Partial replacement of cement by 30% pozzalonic material (15% metakaolin and 15% flyash) is the most optimum replacement, enhancing the compressive strength and split tensile strength at all ages of concrete.
3) Addition of flyash and metakaolin partially replacing cement in the concrete mix results in achieving economy as well as reducing green gas emission.

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