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Experimental Study on High Performance Concrete and High Volume Flyash Concrete using Polypropylene Fibre

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Abstract : India is the second largest cement producer in the world. In India, 420 million tonnes of cement was produced in previous year[7]. By 2025, cement production will reach up to 550 million tones. One tonne of cement produces 1.25 tonnes of CO_2. Cement replaced by the other cementitious materials to reduce the effects of CO_2 emission on environment. This experimental study was carried out to study on flexural behavior of high Performance concrete of Grade M60 by the cement replacement with Fly ash and polypropylene fibre. The total production of fly ash is nearly as much as production of cement. But utilization of fly ash is only about 5% of the population in India. The disposal of fly ash is one of the major issues as dumping of fly ash as a waste material may cause severe environmental problems. Present study is aimed to obtain high durability and high strength concrete by replacing cement with 40% & 50% of fly ash and 10% of Silica fume & Metakaolin. As Per ACI method the various mix designs are prepared for various proportions. Respective tests are conducted. Based on the results, 50% replacement of fly ash and 10% of silica fume with cement gave better compressive strength.
Keywords : High volume fly ash, silica fume, Metakaolin, super plasticizer, polypropylene fiber.

1.0 Inroduction

Concrete is the most extensively used material in construction so that considerable attention is taken for improving the properties of concrete with respect to strength and durability[1]. Cement production consumes huge energy and causes about 7% of total greenhouse gas emission in the world[8-10]. Each one ton of Portland cement production generates about one ton of CO2 emissions, which is a green-house gas. The environmental issues related with green-house gases emissions and depletion of natural resources play an important role in the sustainable development of concrete and construction industry[4,6]. Concrete Normal and special materials are used to make these specially designed concretes that must meet a combination of performance requirements. Special mixing, placing, and curing practices may be needed to produce and handle high-performance concrete. A substantial reduction of quantity of mixing water is the fundamental step for making HPC.

High performance concrete is not a special type of concrete[3,5]. It comprises of the same materials as that of the conventional cement concrete. The use of some mineral and chemical admixtures like Silica fume and Metakaolin enhance the strength, durability and workability qualities to a very high extent. High Performance concrete works out to be economical, even though its initial cost is higher than that of conventional concrete because the use of High Performance concrete in construction enhances the service life of the structure and the structure suffers less damage which would reduce overall costs.

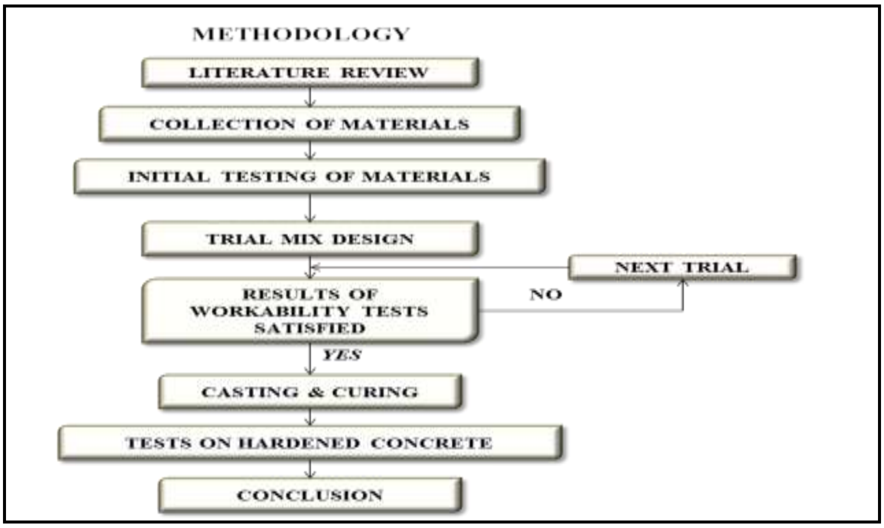
1.1 High Performance Concrete

1. It gives high workability, durability, strength, density, dimensional stability, modulus of elasticity and abrasion resistance.
2. It gives resistance to chemical attack, Toughness , frost and deicer scaling damage
3. Low permeability and diffusion
4. Ease of placement
5. Compaction without segregation

2.0 Objectives of This Project

1. To Study the Physical and Chemical properties of Fly ash, silicafume, Metakaolin, Super plastizers and polypropylene fibres.
2. To investigate the effect of replacing cement by fly ash and silicafume and Metakaolin to compare the effect of presence of the replacement material on the strength of specimens to the conventional specimens.
3. To determine the suitability percentage of replacement by fly ash, silicafume and metakaolin, cubes cylinders and prisms are to casted and tested. Various mix proportions are to be designed such as normal concrete mix (M1), 50% replacement of cement with fly ash (M2), 50% of fly ash + 10% of silicafume (M3), 50% of fly ash + 10% of Metakaolin (M4) and 50% of fly ash + 5% of silicafume + 5% of metakaolin (M5).
4. 4.To determine the suitable mix proportion and to find maximum strength obtained in concrete compare all test results such as compressive, tensile and flexural strength.

2.1 Methodology



3.0 Material Properties

3.1 Cement:

Ordinary Portland cement 53 grade confirming to IS 12269 – 1989.

Table 1.Properties of Cement

Properties	Test Result
Specific Gravity	3.18
percentage of Fineness	<10%
Initial Setting Time	34 minutes
Final Setting Time	260 minutes

3.2 Fly Ash:

Fly ash includes substantial amounts of silicon dioxide (SiO_2) (both amorphous and crystalline), Aluminum oxide (Al_2O_3) and calcium oxide (CaO), the main mineral compounds in coal-bearing rock strata[8-11]. For this investigations Class F Fly ash from Mettur thermal power plant are used.

Table 2 Properties of Fly ash

Presentation	Finely divided dry Powder
Colour	Light grey Bulk
Weight	1.0 metric ton per cubic meter
Specific Density	2.3 metric ton per cubic meter
Particle size	Max 18 % ROS
Particle shape	Spherical

3.3 Fine Aggregate

Fine aggregates are entirely passing the 4.75 mm sieve, and predominantly retained on the 75 µm sieve. Locally available river sand confirming to grading zone II of IS 383 -1970.

Table 3 Properties of fine aggregate

Properties	**Test result**
Specific gravity	2.7
Bulk Density	1726
Fineness modulus	3.91
Water Absorption	0.7%

3.4 Coarse Aggregate

Those particles that are predominantly retained on the 4.75 mm sieve. Locally available Coarse Aggregate confirming to graded aggregate of nominal size 12 mm as per IS 383 -1970.

Table 4.Properties of coarse aggregate

Properties	**Test result**
Specific gravity	2.75
Bulk Density	1628
Water Absorption	0.5%

3.5 Silica Fume

Silica fume, which has a similar function as fly ash, is very effective in lowering the water-to-cement ratio needed for workable concrete in conjunction with super plasticizers because its sub-micron particle size allows it to pack between the cement grains.

Silica fume is an ultrafine material with spherical particles less than 1 µm in diameter, the average being about 0.15 µm. This makes it approximately 100 times smaller than the average cement particle. The bulk density of silica fume depends on the degree of densification in the silo and varies from 130 to 600 kg/m3.

The specific gravity of silica fume is generally in the range of 2.2 to 2.3. The specific surface area of silica fume ranges from 15,000 to 30,000 m2/kg

Silica Fume (Grade 920 D)

Silica fume used was confirming to ASTM- C (1240-2000) and was micro silica 920 D.

3.6 Metakaolin

Metakaolin is a dehydroxylated form of the clay mineral kaolinite. Stone that are rich in kaolinite are known as china clay or kaolin, traditionally used in the manufacture of porcelain.

Table 5 Physical properties of Metakaolin

Specific Gravity	2.40 to 2.60
Physical Form	Powder
Color	Off white Gray to Buff
Brightness	80-82 Hunter L
Specific Surface	8 – 15 m2 /g.

Table 6 Chemical properties of metakaolin

SiO_2	51-53 %	Na_2O	< 0.05%	P_2O_5	< 0.2 %
Fe_2O_3	< 2.20%	L.O.I.	< 0.50%	MgO	< 0.10%
SO_4	< 0.5%	Al_2O_3	42-44%	K_2O	< 0.40%
CaO	< 0.20%	TiO_2	< 3.0%		

3.7 Super Plasticizer

Super plasticizer also known as high range water reducers is used to reduce the water-cement ratio without affecting the Workability. A commercially available polycarboxylated either based super plasticizer under the name Master Glenium sky 8233 is used. Properties of Super Plasticizer

Table 7. Properties of Super Plasticizer

Aspect	Light brown liquid
Relative density	1.08± 0.01 at 25°C
pH	6
Chloride ion content	<0.2%

3.8 Polypropylene Fibre:

Polypropylene (PP), also known as polypropene, is a thermoplastic polymer was used as a concrete additive to increase tensile strength and to reduce plastic shrinkage and cracking. In this investigation, Recron 3s polypropylene fibres are used.

Table 8 Properties of polypropylene fibre

Length	6-12cm
Tensile strength	4000-6000kg/cm2
Melting point	> 250°C

4.0 Mix Proportion And Preparation Of Specimens

In the present study Mix Design for M60 (Design value at the age of 28 days) grade concrete is done according to ACI211.4R. The various mix proportions of the concrete are shown in Table 4. In the present investigation w/c ratio used is 0.32. The cement was replaced by 50% & 40% of fly ash and 10% silica fume and metakaolin respectively.

Five various concrete mixes were cast, at a 0.32% w/b ratio. The cubes, cylinders and prisms are casted and cured in curing pond at 7 days, 28 days, 56 days respectively and tested for compressive strength, Tensile strength and flexural strength. The results are shown below.

Table 9.Mix Proportion

.Mix Designation		M1	M2	M3	M4	M5
Cement	%	100	50	40	40	40
	kg	503	252	201	201	201
Fly ash	%	0	50	50	50	50
	kg	0	252	252	252	252
FA	kg	700	700	700	700	700
CA	kg	1114	1114	1114	1114	1114
W/C	%	0.32	0.32	0.32	0.32	0.32
Water	kg	161	161	161	161	161
Super plasticizer	%	0	0.8	0.8	0.8	0.8
	kg	0	4.02	4.02	4.02	4.02
Fibre	%	0	0.2	0.2	0.2	0.2
	kg	0	1.8	1.8	1.8	1.8
Silica fume	%	0	0	10	0	5
	kg	0	0	50.3	0	25.1
Meta kaolin	%	0	0	0	10	5
	kg	0	0	0	50.3	25.1

5.0 Results and Discussion

5.1 Compression Test

After the curing period of 7days, 28 days and 56 days all casted cubes are tested respectively for compressive strength. The values are shown in table 10. The graph indicates the compressive strength of all mix proportion as shown in fig 1. In this various mix proportion, the mix proportion of M3 Such as the replacement of cement with 50% of fly ash +10% silicafume obtained the maximum compressive strength 44.3, 54.9 & 64.3 for the curing period of 7days, 28 days and 56days respectively.

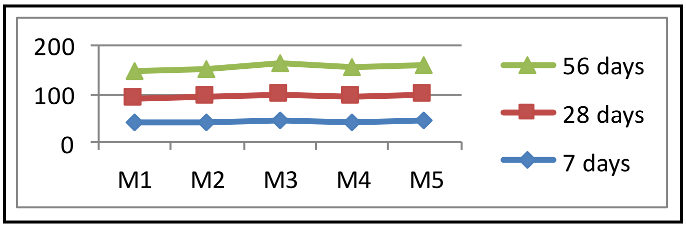


Fig1.Comparison of Compressive strength

Table 10. Compressive strength

Concrete Specimen	**Compressive strength (N/mm^2)**		
	7days	**28days**	**56days**
Concret **(M1)**	41.7	50.9	57.3
50%FA **(M2)**	42.5	51.5	57.9
50%FA+10%SF **(M3)**	44.3	54.9	64.3
50%FA+10%MK **(M4)**	43.4	52.7	58.6
50%FA+5%SF +5%MK **(M5)**	43.9	53.8	63.5

5.2 Tensile Strength

After the curing period of 28 days and 56 days all casted cylinders are tested respectively for compressive strength. The values are shown in table 11. The tensile strength graph as shown in the fig 2 which indicates the mix proportion of 40% and 50% of cement with 50% of fly ash + 10% of silica fume obtained the maximum Tensile strength of 5.61 & 7.12 for the curing period of 28 days and 56 days respectively compared to other mixes.

Table 11. Tensile strength

Concrete Specimen	**Tensile (N/mm^2)**	
	28days	**56days**
Concrete **(M1)**	4.9	6.17
50%FA **(M2)**	5.16	6.35
50%FA+ 10%SF **(M3)**	5.61	7.12
50%FA+10%MK **(M4)**	5.32	6.54
50%FA+5%SF+5%MK (**M5)**	5.54	6.86

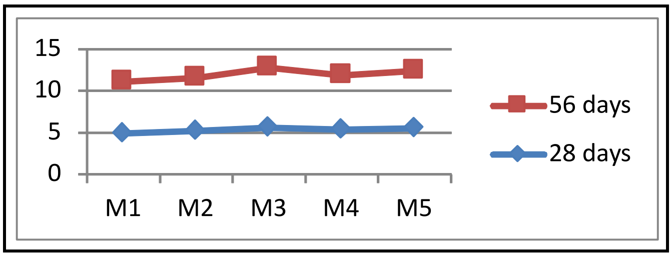


Fig 2.Comparison of tensile strength

5.3 Flexural Strength

After the curing period of 28 days all casted prisms are tested respectively for flexural strength. The values are shown in table 12. The Flexural strength graph as shown in the fig 3 which indicates the mix M3 such as 50% of fly ash + 10% of silica fume obtained the maximum flexural strength compared to other mixes such as M1, M2, M4 and M5.These test results are indicates differentiation of various mix proportion. By comparing these results the suitable mix are selected for high strength and high durability concrete.

Table 12. Flexural strength

Concrete Specimen	Flexural (N/mm^2)
	28days
Concrete **(M1)**	5.18
50%FA **(M2)**	5.27
50%FA+ 10%SF **(M3)**	5.63
50%FA+10%MK **(M4)**	5.41
50%FA+5%SF+5%MK **(M5)**	5.54

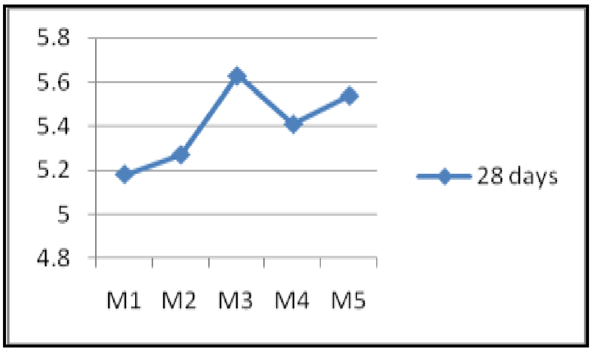


Fig 3.Comparison of Flexural strength

6.0 Conclusion:

From the experimental study on high performance concrete and high volume fly ash concrete using polypropylene fibre it is concluded that High performance concrete with 50 % of fly ash + 10 % of silica fume has obtained higher strength in all the strength parameters such as Compressive strength, Tensile strength and Flexural strength ,when compared to other mix designs such as 50 % fly ash, 50 % of Fly ash + 10 % of metakaolin,50 % fly ash + 5 % silica fume + 5% metakaolin and the conventional mix.

7.0 Reference

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