Strength and Durability Study on High Performance Concrete Replacing Cement by Mineral Admixtures

N. Ezhilarasi[1], Dr. K. Jagadeesan[2], M. Soundararajan[3], Dr. K. Nirmal Kumar[4]
[1.] PG student, Department of Civil Engineering, Sona College of Technology, Salem.
[2.] Professor, Department of civil engineering, Sona College of Technology, Salem.
[3]. Research scholar and Assistant Professor, Sona College of Technology, Salem.
[4.] Professor, Department of civil engineering, Kongu Engineering College, Perundurai.

Abstract: **In the modern world, most of the natural resources are depleting rapidly due to their excavation at a high rate. Hence, alternative materials should found out for the construction materials, especially cement, whose manufacture is highly hazardous to the environment due to the emission of large quantity of CO_2 into the atmosphere. Some of the alternative materials for cement are GGBS, silica fume, Metakaolin, etc. These materials are used to produce high performance concrete (High Performance Concrete). High Performance Concrete is define as the concrete which possesses high strength and high durability. This paper deals with the strength and durability characteristics of high performance concrete using mineral admixtures. Many trials were conducted to find out the optimum mix ratio for the high performance concrete. The use of high performance concrete should be encouraged in order to reduce the environmental effects of cement manufacture, and also to produce the concrete with high strength. Test on compressive strength and non-destructive test at 7 and 28 days were conducted. It was concluded that possible optimum replacement of mineral admixtures was found to be $C_{75}G_5M_{10}S_{10}$ .Split Tensile Strength and Flexural Strength and durability characteristics were carried out for conventional and optimum concrete mix to study the properties of concrete with mineral admixtures.**

Keywords: Aggregates, Silica fume, Metakaolin, GGBS, Compressive strength, ultrasonic pulse velocity, High Performance Concrete, Split Tensile, Flexural Strength and durability characteristics.

1. INTRODUCTION:

Concrete is the most important material used for construction. In the modern world, the use of concrete has be increasing and hence demand for special types of concrete is also in large quantity. One among those special types of concrete is High Performance Concrete (HPC). HPC is define as a concrete meeting special combination of performance and uniformity requirements that cannot always be achieved routinely using conventional constituents and normal mixing, placing, and curing practice. The term High Performance concrete (HPC) is suggested for concrete mixtures that possess high-workability, high-strength, and high-durability. But the proportions are designed or engineered to provide the strength and durability needed for the structural and environmental requirements.

The raw materials needed for the manufacture of Portland cement (PC) are available in many places, and the energy requirements for its production may be considered to be relatively modest.

They are responsible for substantial “environmental unloading” because their disposal can be hazardous to be environment and higher utilization of them can result in reduction of greenhouse gas emission from cement industry. Some of them or condensed silica fume (SF), Metakaolin (MK), and ground granulated blast slag (GGBS). In this paper these three mineral admixtures are replacing cement by certain percentage.

2. REVIEW OF LITERATURE:

M. Vijaya Sekhar Reddy, I.V.Ramana Reddy. There is a growing awareness all over the world about the extensive damages being caused to the environment due to accumulation of waste material in the form of pulverized fuel ash from thermal power plants, silica fume, blast furnace slag etc. Abhishek Anand, Abhinav Daalia, Acceptance testing on site has to be more than cube testing at28 days. Where durability of concrete is the driving force for adoption of high performance concrete, in-situ permeability tests are performed as a matter of routine**.** B.B.Patil, P.D.Kumbhar**,** The results of the study indicate that the workability and strength properties of HPC mixes improving by incorporating HRM up to desirable content of 7.5% by weight of cement. Asma.K.C, Meera.C.M, A conventional concrete without any mineral admixtures having a compressive strength was designed of 60MPa and two other mixes are prepared one by replacing cement by 10% Metakaolin and other by replacing cement with 10% Metakaolin + 30% fly ash respectively. A.Islam Laskar and S.Talukar, The paper deals with the monitoring of workability is a critical issue for High Performance Concrete (HPC) since HPC is susceptible to small change in mixture proportions that have a direct impact on hardened properties.

3. EXPERIMENTAL INVESTIGATION:

The materials used are Ordinary Portland cement, natural river sand tested and conforming to the specifications IS 2386 (Part II)-1963, IS 2386 (Part III)-1963 , IS 2386 (Part IV)-1963 and IS 2386 (Part VI)-1963. The fines modulus of sand used is 2.76 with a specific gravity 2.65. Concrete mixes are designed for M_{60} to study the compressive strength of concrete. The mineral admixtures (GGBS, Metakaolin, Silica fume) are replacing cement up to 30%. The optimum mix ratio with mineral admixtures and without mineral admixtures in High Performance concrete is obtained by trial and error method.

Table 3.1: Properties of cement

S.No	Description	Values
1	Specific gravity	3.15
2	Fineness (by sieve analysis)	4.60%
3	Consistency	29%
4	Initial setting time	30 minutes

Table 3.2: Properties of coarse aggregate

S.No	Description	Values
1	Specific gravity	2.75
2	Bulk Density	1765.0kg/m³
3	Surface moisture	0.086%
4	Water absorption	0.5%
5	Fineness modulus	6.45
6	Impact Value	13.3%
7	Cushing Value	17.3%
8	Abrasion Value	26.5

Table 3.3: Properties of fine aggregate

S.No	Description	Values
1	Specific gravity	2.64
2	Fineness modulus	2.76
3	Water absorption	1.0%
4	Bulk Density	1668.0kg/m³

Table 3.4: Properties of silica fume

S.No	Description	Values
1	Specific gravity	2.1
2	Specific surface area	8340m²/kg
3	Mean grain size	0.15µm

Table 3.5: Properties of GGBS

S.No	Description	Values
1	Specific gravity	2.9
2	Bulk Density	1200 kg/m³

Table 3.6: Properties of Metakaolin

S.No	Description	Values
1	Specific gravity	2.5
2	Mean grain size	2.54

Table 3.1 shows the properties of cement are within the allowable limits. From Table 3.2 it was observed that the properties of coarse aggregate values satisfy the standards. Table 3.3 gives the properties of natural river sand. It is noticed that the surface moisture content of fine aggregate was increased. Tables 3.4, 3.5 and 3.6 are the properties of mineral admixtures. Mineral admixtures replacing cement up to 30% in concrete mix. Super plasticizer is used in concrete mix to improve the workability of concrete.

4. CONCRETE MIX DETAILS:

Two sets of mixes are prepared for M_{60} grade concrete. First Mix ordinary conventional concrete. Second mix replacing mineral admixtures for cement. For each trial 3 cubes were cast, in which 3 cubes for testing the compressive strength at 7 days and 28 days.

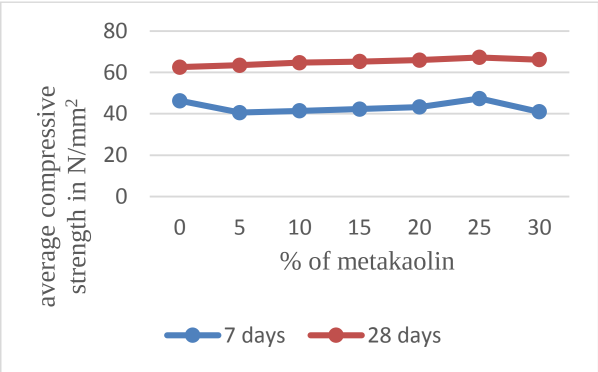
Cement	Fine aggregate	coarse aggregate	water	Super plasticizer
1	1.2	2.4	0.28	1%

5. TESTING DETAILS:

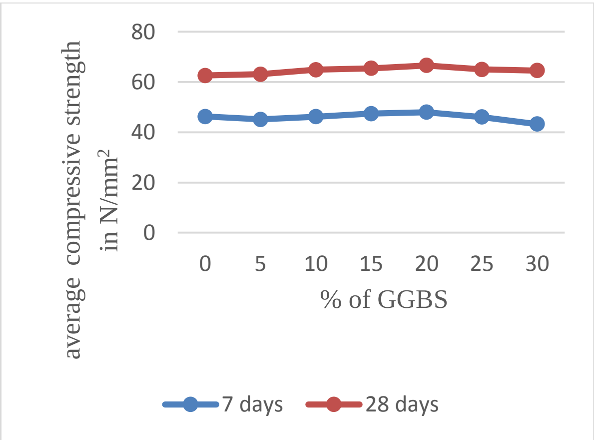
5.1. Compressive strength

Workability test was conducted by using slump cone to measure the slump value of fresh concrete. The Compressive strength of the concrete was determined by cubes Table 5.1 shows the compressive strength of concrete.

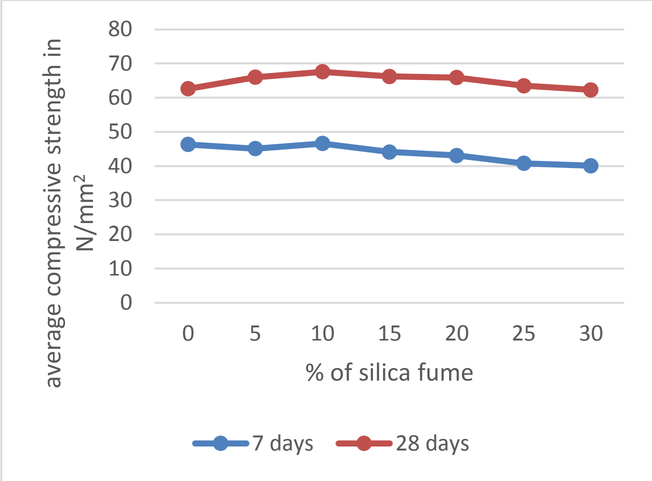
Figure 5.1: Compressive Strength test



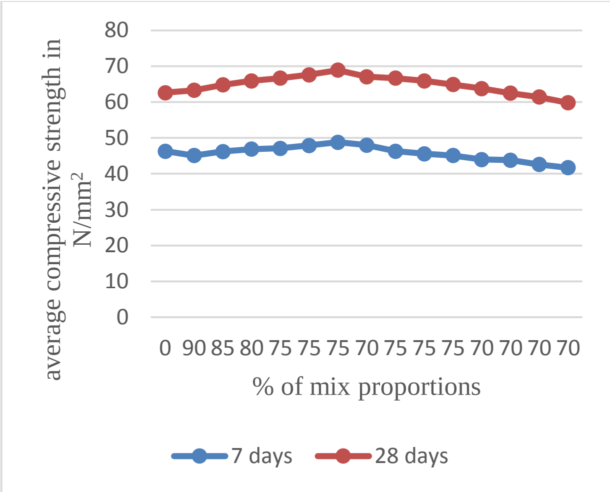
Graph 5.1: Compressive Strength for metakaolin



Graph 5.2: Compressive Strength for GGBS



Graph 5.3: Compressive Strength for silica fume



Graph.5.4: Compressive Strength for mineral admixtures

5.2. Ultrasonic Pulse Velocity Test

In ultrasonic pulse velocity test, three methods are there. In this paper, direct method is used. The test was conducted for all the mixes for both 7 days and 28 days for M60 grade of concrete. Three specimens was cast for each replacement of blast furnace steel slag aggregate. From the following table 5.1.2, the quality of concrete is determine with reference to the velocity obtained.

Table5.2: Quality of concrete using Ultrasonic pulse velocity

Pulse velocity (km/sec)	Concrete quality (Grading)
Above 4.5	Excellent
3.5 to 4.5	Good
3 to 3.5	Medium
Below 3	Doubtful

Figure 5.2: ultrasonic pulse velocity

5.3. Split Tensile Strength Test

The test was conducted as per IS 5816:1999. For tensile strength test, cylindrical specimens of dimension 100 mm diameter and 300 mm length were cast.

In each category, three cylinders were tested and their average value was reported. The split tension test was conducted by using digital compression machine having 2000 KN capacity.

Split tensile strength was calculated as follows:

Spilt Tensile strength (MPa) = 2P / π DL
Where, P = Failure Load (KN)
D = Diameter of Specimen (100 mm)
L = Length of Specimen (300 mm)

Test Results of splitting tensile strength for conventional and optimum percentage of mineral admixtures concrete of M_{60} grade concrete as shown in table 5.3.below.

Figure .5.3: Split tensile Test

Table 5.3: Test Results of Split Tensile Strength

S.No	Mix ID (%)	Average Split tensile strength in (Mpa)
1.	CC	5.44
2.	$C_{75}G_5M_{10}S_{10}$	6.78

From the table 5.3, Split tensile test results of cylinder at 28 days have been observed. $C_{75}G_5M_{10}S_{10}$ is 25% higher than the control mix.

5.4. Flexural strength test

The test was conducted as per IS 5816:1999. For Flexural strength test, cylindrical specimen of 100 mm X 100 mm X 500 mm were cast. In each category, three prisms were tested with single point load was applied and their average value was reported.

The flexural strength test was conducted as shown in figure 5.4

Figure.5.4: Flexural Strength of Concrete

A beam specimen is placed in the ultimate testing machine of 2000kN capacity for testing. Rollers are placed at a center to center distance of the beam specimen. The load is increased until the specimen fails and the maximum load applied to the specimen during the test is recorded.
The Flexural strength is calculated by using the formula

$\sigma = P\, l / bh^2$

Where,
P = load in Newton shown in dial gauge
l = length of rectangular prism in mm i.e. 500 mm
b = breadth of rectangular prism i.e. 100 mm
h = height of rectangular prism i.e. 100 mm.

Test Results of flexural strength for M_{60} grade of concrete with mineral admixtures for given volume fractions as shown in table 5.4below.

Table 5.4: Test Results of Flexural Strength

S.NO	Mix ID	Average flexural strength in (Mpa)
1.	CC	5.31
2.	$C_{75}G_5M_{10}S_{10}$	6.91

From the table 5.4, optimum mineral admixtures replacement shows higher flexural strength results compare to the conventional mix at 28 days.$C_{75}G_5M_{10}S_{10}$ is 30.13% higher than the control mix.

5.5 Water Absorption Test:

First the concrete specimen are immersed in water for several days of 7days, 28 days. After that the specimen is taken out and weighed which is the wet weight of concrete. Then the specimen is dried in oven up to 105º C and then weighed which is the dry weight of concrete.

From this Water absorption of concrete is calculated by using the formula.

% of Water absorption = [(W1-W2) / W1] ×100

Where,

W1 = Weight of the wet specimen

W2 = Weight of the dry specimen

Table 5.5: Water absorption test results

SI No	Type of concrete	Wet weight of concrete in kg (W_w)	Dry weight of concrete in kg (W_d)	Water absorption of the concrete (%)
1	CC	8.90	8.39	6.07
		8.92	8.40	6.20
		8.86	8.35	6.10
2	$C_{75}G_5M_{10}S_{10}$	8.91	8.52	4.61
		8.84	8.36	5.74
		8.81	8.41	4.75

5.6. Chloride Attack

Chloride attack is primarily cause's corrosion of reinforcement. To test the effect of chloride on concrete, 150 mm x150 mm x150 mm size conventional as well as mineral admixtures concrete cubes were cast and kept at a room temperature. After 24 hours the specimens were cured in clean fresh water for 28 days. After curing the cubes were immersed in sodium chloride solution and tested for their compressive strength and there by durability were assessed.

Table 5.6: Loss of weight of specimen subjected to Chloride Attack

SI NO	Type of concrete	Initial Weight in Kg	Weight after 28days curing Kg	% of weight loss
1	CC	8.90	8.80	1.02
		8.92	8.83	1.01
		8.90	8.81	1.03
2	$C_{75}G_5M_{10}S_{10}$	8.86	8.77	1.03
		8.84	8.76	0.93
		8.87	8.79	0.93

SI.NO	Mix ID	Compressive strength MPa
1	CC	**59.4**
2	$C_{75}G_5M_{10}S_{10}$	**66.6**

6. RESULTS & DISCUSSION:

From graph:5.1, 5.2 and 5.3, it was noticed that the compressive strength gradually increases as the percentage of metakaolin, GGBS and silica fume corresponding optimum value is 25%, 20% and 10% respectively.

From graph: 5.4 three admixtures are combined together for replacing the cement. From this results the optimum value is 5% of GGBS, 10% of metakaolin, and 10% of silica fume.

From the ultra-sonic pulse velocity results we can see that the quality of concrete at 7 days is in medium range whereas for 28 days the quality of concrete comes under excellent and good range for the M60 grade of concrete.

From split tensile strength test, flexure strength test and also durability test results shows, the mineral admixtures concrete is better than the conventional concrete.

7. CONCLUSION:

1. In ultra-sonic pulse velocity test, the quality of concrete was excellent up to $C_{75}G_5M_{10}S_{10}$ mix for replacement of cement.
2. The compressive strength of the concrete was increased about 2.34% of Metakaolin, 3.7% of GGBS and 1% of silica fume at 7 days curing compare to the conventional concrete.
3. The compressive strength of the concrete was increased about 7.5% of Metakaolin, 6.4%of GGBS and 8% of silica fume at 28 days curing compare to the conventional concrete.
4. Three admixtures are combined together for replacing the cement. The compressive strength is increased about 5.4% 7 days.
5. Three admixtures are combined together for replacing the cement. The compressive strength is increased about 9.6% 28 days.
6. Split tensile test results of cylinder at 28 days have been observed. $C_{75}G_5M_{10}S_{10}$ is 25% higher than the control mix.
7. Optimum mineral admixture replacement shows higher flexural strength results compare to the conventional mix at 28 days. $C_{75}G_5M_{10}S_{10}$ is 30.13% higher than the control mix.
8. The durability characteristics such as resistance to water penetration, resistance to chloride attacks of

mineral admixtures concrete are better than that of the controlled mix concrete

9. The chloride acid resistance of mineral admixtures concrete is significantly better than that of natural aggregate. Mineral admixtures concrete is Eco-Friendly.

8. ACKNOWLEDGEMENT:

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