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Comparison of suitable pozzolanic material for high grade concrete

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Abstract*— This paper presents the results of an experimental work carried out to evaluate the compressive strength and water permeability and rapid chloride permeability of high grade concrete which cement was partially replaced with superfine fly ash, GGBFS, Microsilica, and Metakaolin. All four pozolanic materials were replaced with three percentages (4%, 6%, and 8%) of pozzolanic material by weight. Tests were performed for properties of fresh concrete, compressive strength, water permeability, rapid chloride permeability was determined at 7,14,28,56, days. Test results indicate significant improvement in the strength properties of High grade concrete by the addition of pozzolanic material as partial replacement of ordinary Portland cement, and can be effectively used in structural concrete.

***Index Terms*—GGBFS, Metakaolin, Micro silica, Rapid Chloride permeability, Water permeability**

I. INTRODUCTION

On the edge of new development strength and durability parameter shows a major contribution in the mix design of concrete. At the same time to find suitable replacement for the ordinary Portland cement to obtained desired strength and durability of concrete. Normal Portland cement concrete may suffer a variety of durability problems depending on the source of cement, the type of aggregates, and the environmental exposure conditions [1] .The advantages of using binary blends instead of normal Portland cement concrete are mostly in terms of improving concretes properties, economy, and sustainability with less environmental impacts. The behavior of these blends depends on the combination of the materials used in the mixture. In a binary blend, one low-reactive pozzolan can be used with normal Portland cement in such a way that all the undesirable effects such as low workability, low-early strength development and high-heat of hydration, could be eliminated. Microsilica and metakaolin are highly reactive pozzolanic materials,[4-5,6] which improved the strength development characteristics of concrete but their presence may lead to reduced workability. Whereas concrete containing fly ash as partial replacement of cement poses problems of delayed early strength development [2]. In the current investigation the effects on the properties of concrete when added with different pozzolanic material are studied.

II. MATERIAL AND METHODS

A. Cement

Ordinary Portland cement of 53 grades available in local market is used in the investigation. The cement used has been tested for various proportions as per IS 4031-1988 .The properties of Cement are shown in the Table 1.

B. Coarse Aggregate

Crushed stone angular metal of 10mm & 20 mm size from a local source was used as coarse aggregate. The specific gravity of 2.98 and fineness modulus 7.55 was used. And found to be confirming to various specifications of as per IS: 383-1970.

C. Fine Aggregate

Artificial sand is used as fine aggregate. The specific gravity and fineness modulus were found to be 2.98 and 3.05 respectively. The properties are tested as per IS 383:1970.[7]

D. Metakaolin

Metacem-85 is available in white powder form having a larger surface area than OPC and it's provided by 20 Micron company Mumbai. The HRM conforms to IS 456:2000.[8]Typical properties given in the Table 1.

E. Microsilica

Micro silica was taken for experimental program are following details Elkem Microsilica Grade EMS- 970D is dry, densified silica fume with a typical bulk density of 500-700 kg/m3.Typical properties given in Table 1.Microsilica was obtained from Elkem chemical Pvt.Ltd

F. Ground Granulated Blast Furnaces Slag

Ground granulated blast furnace slag was obtained from alcofine and properties given in the Table 1.

G. Fly Ash

Super fine fly ash (P-100) is procured from Dirk India Pvt. Ltd, Nashik. Fly Ash is available in dry powder form. The light gray, fly ash under the product name "Pozzocrete 100" is available in 30kg bags. The Fly ash produced by the company satisfies all the requirements of the IS 3812: 1981, BS 3892: Part I: 1997.

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H. Admixture

Viscocrete10R (W) was used for increasing the workability of concrete mix even in case of less water cement ratio .The admixture was used by percentage of mass of cement 1% by mass of the pozzolanic material were used and adopted the same percentage for all four mix proportion for maintaining the slump during the fresh concrete condition.

I. Water

The water used in preparing the specimen was potable water obtained from drinking water source generally; water that is suitable for drinking is satisfactory for use in concrete.

III. MIX PROPORTION

The concrete mix is designed as per IS 10262 – 2009.[9] IS 456-2000 .The Grade of concrete which we adopted was M_{60} with the water cement ratio of 0.29.

IV. TEST SPECIMENS

Cubes of size 150mm X150mm X150 mm were prepared for compressive strength and water permeability of concrete. Core of size 100 mmX50mm was prepared using the standard moulds for rapid chloride permeability test. The samples are cast using the four different pozzolanic materials. The samples are demoulded after 24 hours of casting and kept in a water tank for 28 days curing. A total of 144 specimens are cast for each pozolanic material testing the properties such as compressive strength, water permeability and rapid chloride permeability. The details of the specimen and their notations are given below in the Table 2.

V. DETERMINATION OF MODULUS OF ELASTICITY

For found out the modulus of elasticity of concrete using the analytical method adopted in IS: 456-2000 & CEB-FIP model code -1990.IS:456-2000 given the standard equation as $EC=5000\ f_{ck}^{(0.5)}$ ---------- (1)

And CED-FIP model code given the standard equation as $E=\alpha.2100(628/10)^{0.33}$----------(2)

VI. RESULT AND DISCUSSION

A. Compressive Strength

The factors that influence the compressive strength of High grade concrete when increased the percentage of pozzolanic Material increased the compressive strength of High grade concrete. The test results are presented in Table 4, 5, &6. The variables of % pozzolanic material with ordinary Portland cement and Compressive strength are presented in figure. 1, 2&3.

B. Water permeability of concrete

The depth of penetration into the concrete is decreased at an increasing percentage of pozzolanic material. Out of this Pozzolanic material metakaoline gave the best result. The results are presented in Table 8 and the results showed in figure. 4.

C. Rapid chloride Permeability Test

The rapid chloride permeability [3] determined in coulombs for control concrete & OPC with 8% Pozzolanic material are presented along with compressive strength in Table 7 and Figure.5.

D. Modulus of elasticity of concrete

Modulus of elasticity was determined by IS: 456-2000 & CEB-FED model code -1990. The results are presented in figure. 6.

Table 1: Oxide Composition of Cementitious Materials

Material	Oxide composition percent by weight					
	CaO	SiO_2	Al_2O_3	Fe_2O_3	MgO	SO_3
OPC	63.00	20.00	6.30	3.60	2.40	1.50
GGBFS	42.20	32.30	13.30	0.30	6.40	2.10
Fly ash	2.50	52.50	28.20	10.50	1.60	0.20
Micro Silica	0.20	98.30	0.20	0.05	0.07	0.01
Meta Kaolin	2.00	51.52	40.18	1.23	0.12	0.00

Table 2: Mix Proportion for OPC with Pozzolanic Material

Sr. No	Material	Quantity in kg		
		PC+PM (4 %)	PC+PM (6 %)	PC+PM (8 %)
1	OPC+ Fly Ash	480+20	470+30	460+40
2	OPC+ GGBFS	480+20	470+30	460+40
3	OPC+ MK	480+20	470+30	460+40
4	OPC+ MS	480+20	470+30	460+40
5	Artificial Sand	907	907	907
6	CA	1023	1023	1023

Table 3: Water Binder Ratio for different Mix Proportion

Sr. No	Material	Quantity in kg	Water in Lit.	W/B Ratio	Admixture 1%
1	OPC	500	152	0.30	5
2	OPC+ Fly Ash	500	135	0.27	5
3	OPC+ GGBFS	500	140	0.28	5
4	OPC+ Metakaolin	500	145	0.29	5
5	OPC+ MS	500	155	0.31	5

Table 4: Compressive strength results of Control concrete &OPC with 8% Pozzolanic Material

Material	1 d	3 d	7 d	28 d	56d
CC	18.5	55.0	69.5	82	92
OPC+ 8%Fly Ash	18.6	56.0	81.5	99	106.1
OPC+8% GGBFS	16.5	58.5	82	100	102
OPC+ 8% MK	21.3	57.7	82	106	112
OPC+ 8% MS	25.5	55.5	72	90	98.2

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Table 5: Compressive strength results of Control concrete &OPC with 4% Pozzolanic Material

Material	1 d	3 d	7 d	28 d	56d
CC	18.50	55.00	69.50	82.00	92.00
OPC+ 6%Fly Ash	18.57	55.30	78.00	93.00	98.50
OPC+6% GGBFS	16.90	56.30	77.50	94.20	98.00
OPC+ 6% MK	20.70	56.00	78.42	98.40	104.15
OPC+ 6% MS	24.00	54.50	72.00	87.50	96.00

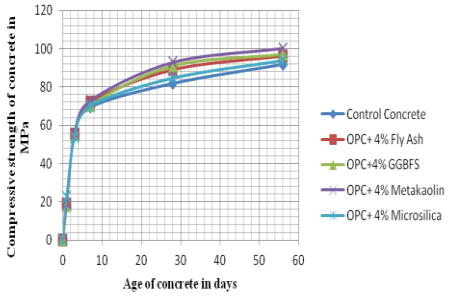

Fig 1 :compressive strength of concrete &OPC with 4% Pozzolanic material

Table 6: Compressive strength results of Control concrete &OPC with 4% Pozzolanic Material

Material	1 d	3 d	7 d	28 d	56d
CC	18.50	55.00	69.50	82.00	92.00
OPC+ 4%Fly Ash	18.60	55.20	72.00	89.20	96.40
OPC+4% GGBFS	18.00	55.30	70.30	91.00	97.00
OPC+ 4% MK	19.20	55.80	72.92	92.98	100.36
OPC+ 4% MS	22.50	53.80	70.00	84.50	93.70

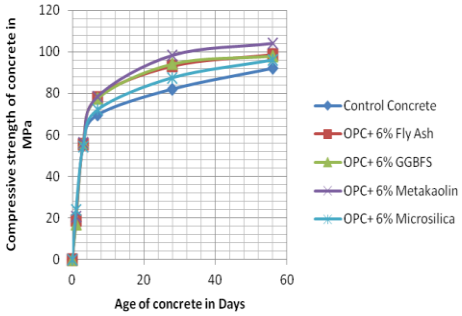

Fig 2 :Compressive strength of control concrete & OPC with 6% Pozzolanic material

Table 7: Rapid Chlorides Permeability Test Result & compressive strength result control concrete & OPC with 8% Pozzolanic material

Mix No.	Combinations	RCPT Values in Coulombs	Compressive Strength in MPa (28 days)
1	Control Concrete	2985	82
2	OPC+8%Fly ash	1323	99
3	OPC+8%GGBFS	1538	100
4	OPC+8%Metakaolin	1303	106
5	OPC+8%Micro Silica	1250	90

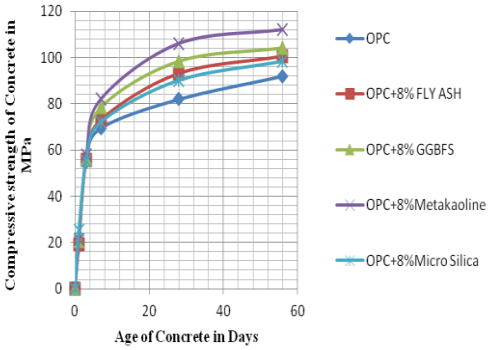

Fig 3:Compressive strength of control concrete & OPC with 8% Pozzolanic material

Table 8: Water Permeability Test results& compressive strength result control concrete & OPC with 8% Pozzolanic material

Mix No.	Combinations	Compressive Strength in MPa (28 days)	Water Permeability in mm
1	Control Concrete	82	22
2	OPC+8%Fly ash	99	8
3	OPC+8%GGBFS	100	15
4	OPC+8%Metakaolin	106	7
5	OPC+8%Micro Silica	90	10

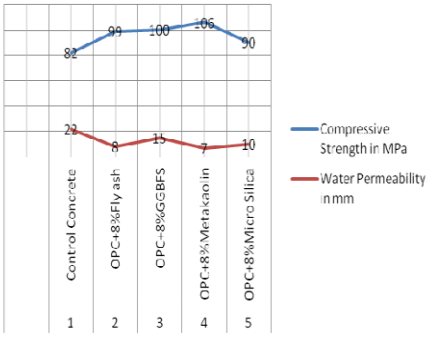

Fig 4: Water permeability & compressive strength of control concrete & OPC with 8% Pozzolanic material

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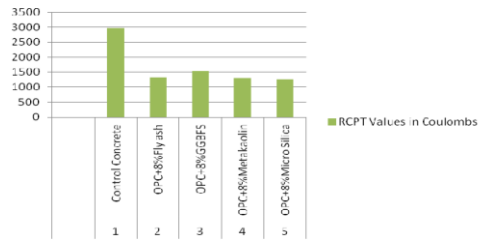

Fig 5: Rapid chloride permeability values of control concrete & OPC with 8% Pozzolanic material

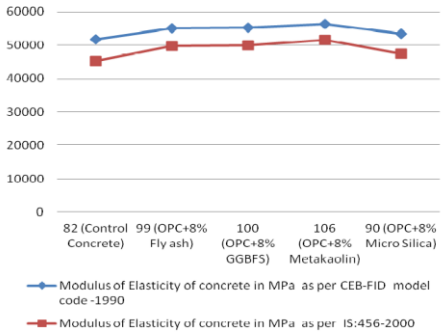

Fig 6: Modulus of elasticity of concrete

VII. CONCLUSION

The following conclusions can be drawn from the present Investigation

1. Compressive strength of ordinary Portland cement replaced pozzolanic material concrete specimens was higher than the plain concrete (control mix) specimens at all the ages.
2. Depth of water penetration reduced for metakaoline higher than other pozzolanic material.
3. Rapid chlorides permeability values in coulombs of control concrete are higher than other pozzolanic material.
4. Out of these four pozzolanic material metakaolin proved the suitability as a replacement material for cement at a level of 8 %

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AUTHOR BIOGRAPHY

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