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Study of High Performance Concrete

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Abstract—*Durability, workability and toughness are the equally important criteria which have to be met by the concrete in addition to the high strength. It is reported that the use of chemical and mineral admixtures in concrete with low water/binder (w/b) ratio shows high performance. The objective of this study is to improve the strength and durability property of concrete by the use of mineral admixtures and chemical admixtures.Strength of the concrete is determined by the compressive and flexure test and the durability of the concrete is studied by means of RCPT.*

Keywords: *high performance concrete, silica fume, fly ash, metakaolin, hyper plasticizer.*

1. INTRODUCTION

Concrete is the most widely used construction material next to water due to the easy availability of its constituents, its versatility and adaptability. Inspite of the technical and economic advantage of the material and the tremendous understanding of its engineering and microstructure, deterioration of concrete has become a major problem and there is widespread concern about the durability of the reinforced concrete structures.

Development of concrete mixtures with enhanced durability properties to avoid premature deterioration of concrete due to environmental effects can be made by the addition of pozzolanic admixture in the concrete mixtures.

The pozzolanic material when used in concrete mixture reacts with calcium hydroxide resulting in C-S-H compounds which, in turn, renders the transition zone between the matrix and aggregates in the concrete mixture, denser and stronger. These pozzolanic materials function as supplementary cementitious materials in concrete mixtures and improve the impermeability of concrete against aggressive chemicals. Low permeability and stronger transition zone are the requirements for long term durability.

Use of mineral admixtures, such as fly ash, silica fume, metakaolin act as pozzolanic materials as well as fine fillers, thereby the microstructure of hardened concrete matrix becomes denser and stronger. Use of chemical admixture such as hyper plasticizer (GleniumB-233 polycarboxylatether) helps to reduce the water content, thereby reducing the porosity within the hydrated cement paste.

Use of finer mineral admixtures having pozzolanic properties can provide a major economic benefit, because it permits a reduction in the amount of Portland cement in the mix.

2. LITERATURE REVIEW

Erhan Guneyisi (2012) in his investigation used metakaolin (MK) as a supplementary cementing material to improve the performance of the concrete. Two MK replacement levels of 10% and 20% by weight of Portland cement were employed in the study at two w/c ratios of 0.35 and 0.55. The performance characteristics of the concretes were evaluated by measuring compressive and split tensile strengths, water absorption, drying. The porosity and pore size distribution of the concrete were also examined by using mercury intrusion porosimetry (MIP). Tests were conducted at different ages up to 120 days.The results revealed that the inclusion of MK remarkably reduced the drying shrinkage strain, but increased the strength of the concrete. Depending mainly on the replacement level of MK, w/c ratio, and age of testing.

Mehmet Gesoglu (2006) in his paper described about the concrete with high strength and low shrinkage by using Portland cement blended with ultrafine MK. His study showed that the MK provided a significant increase in both compressive and split tensile strengths when used as a modifier in concrete. When MK replaces cement, its positive effect on the concrete strength generally starts at early ages and also noticeable increase in the strength was observed at later ages. It was observed that the strength of concrete incorporated with MK was up to 30% greater than that of the plain concretes, depending mainly on replacement level of MK, w/c ratio, and testing age.

Kasum Mermerdas (2007) presents all replacement levels, the MK modified concretes exhibited remarkably lower shrinkage in comparison to the plain concretes, irrespective of w/c ratio. The results demonstrated that the w/c ratio was the dominating factor because both the plain and especially the MK modified concrete with high w/c exhibited relatively low drying shrinkage.The drying shrinkage rates of the concrete had a decreasing tendency with increased drying time, particularly for the MK concrete. The inclusion of MK as a partial cement replacement material provided an excellent improvement in the pore structure of concrete. Irrespective of w/c ratio, the pore size distribution was shifted to the smaller pore size range due to the incorporation of MK. The total porosity decreased substantially with increasing replacement level of MK. The magnitude of this reduction ranged from 22 to 49%, depending mainly onw/c ratio replacement level of MK. Moreover, there was a considerablereduction in the mean (or median) pore diameter of the samples due to theinclusion of MK. The effect was particularly beneficial at 20% MK content,where the lowest porosity and the pore diameter were achieved.

3. MATERIALS

SILICA FUME

Silica fume is amorphous silicon dioxide. The individual particles are extremely small, approximately 1/100th the size of an average cement particle. Because of its fine particles, large surface area and high SiO content, it is a very reactive pozzolona. Quality of silica fume is specified by ASTM C 1240 and AASHTO M 307.

FLY ASH

It is recovered from the gases of burning coal during the production of electricity. It consists primarily of silica, alumina and iron. When mixed with lime and water, the fly ash forms a cementitious compounds with properties very similar to that of Portland cement.

METAKAOLIN

When the kaolin is calcined between 500-800◦ c, dehydroxilization of kaolin to metakaolin occurs. High reactivity metakaolin is a highly processed reactive aluminosilicate pozzolan, a finely-divided material that reacts with slaked limeat ordinary temperature and in the presence of moisture to form a strong slow –hardening cement.

4. MIX PROPORTION

Coarse aggregate of size 20mm confirming to IS 383-1987 is used. Coarse aggregate 12.50mm and 20mm of specific gravity 2.86 and 2.91 are used.

Mix design 1

Grade of concrete	60 MPa
Type of cement	OPC 53 grade
Mix ratio	1 : 1 ½ : 2
W/C ratio	0.29
Cementitious content	OPC -450 kg/cum Fly ash -50 kg/cum Silica fume- 30 kg/cum

Mix design 2

Grade of concrete	60 MPa
Type of cement	OPC 53 grade
Mix ratio	1 : 1 ½ : 2
W/C ratio	0.29
Cementitious content	OPC -480 kg/cum Fly ash -50 kg/cum

Mix design 3

Grade of concrete	60 MPa
Type of cement	OPC 53 grade
Mix ratio	1 : 1 ½ : 2
W/C ratio	0.29
Cementitious content	OPC-540 kg

Mix design 4

Grade of concrete	60 MPa
Type of cement	OPC 53 grade
Mix ratio	1 : 1 ½ : 2
W/C ratio	0.29
Cementitious content	OPC -410 kg/cum Fly ash -50 kg/cum metakaolin-40 kg/cum

5. EXPERIMENTAL PROCEDURE

Four trial mixes of M60 grade were used. Sieve analysis was carried out for both fine and coarse aggregates.

CURING

The most intricate part is HPC has very low w/binder ratio and better particle distribution due to the use of mineral admixtures, which result insignificantly less pore per unit volume of cementations materials in the mixture than the CCC. Filling of the voids by hydration product in HPC ismuch faster than that of CCC as smaller pores needs less hydration products to fill. Therefore, moisture loss due to capillary action *stops earlier* **.**in case of HPC compared to CCC under the same curing conditions. The moisture loss from HPC has been found predominant up to the first 24 hours. Owing to very low water/binder ratio and use of super plasticizer, the early stage hydration rate of HPC is higher than CCC leaving less longterm hydration potential. Curing duration after the initial moisture protectionhas been found to have little effect on long term chloride permeability of HPCcontaining micro-silica or fly-ash. Method of curing has similar effect on HPC both for creep andshrinkage of concrete, which are again influenced by the type and durationof curing.

INITIAL CURING

Curing compound has not been found to be very effective for initialcuring. Immediately after the placement of fresh concrete, water sheen(bleed water) appears on the top of the concrete surface. If curing compoundis spread before this water sheen dries, local ponding of the curingcompound mixed with the water sheen occurs on the concrete surface.Again, allowing the water sheen to be completely evaporated may beharmful for the long-term properties of concrete especially in dry and hotclimate.

FINAL CURING (WET CURING)

For final curing, wet curing as adopted for conventional concretes,such as ponding water on the exposed surface or covering the exposed surface by wet burlap and keeping it wet by continuous sprinkling of water has been found to be effective.

TEST

The concrete is subjected to both fresh and hardened state test. Fresh concrete test involves workability test (slump cone and flow test). Results of workability test are tabulated.

TABLE 1

Workability Slump test	
Time	**Measurement**
@ 5'	230 mm
@ 30'	
@ 60'	135 mm

Tests for high strength
- i. Compressive strength test
- ii. Flexure strength test

Tests for performance are
- i. Sorptitvity
- ii. RCPT

Non destructive tests performed are
- i. UPV test
- ii. Rebound hammer test.

6. RESULTS AND DISCUSSION

COMPRESSIVE STRENGTH TEST

For cube test two types of specimen either cubes of 15 cm X 15 cm X 15 cm or 10cm X 10 cm x 10 cm depending upon the size of aggregates,are used. Cubical moulds of size 15 cm x 15cm x 15 cm is used for the testing. Concrete is poured in the mould and after 24 hours these moulds are removed and test specimens are put in water for curing. The top surface of these specimen should be made even and smooth. This is done by putting cement paste and spreading smoothly on whole area of specimen.These specimens are tested by compression testing machine after 3, 7 and 28 days curing. Load is applied gradually at the rate of 140 kg/cm^2 per minute till the specimens fails. Load at the failure divided by area of specimen gives the compressive strength of concrete. Results of cube compressive tests are presented in graphical format.

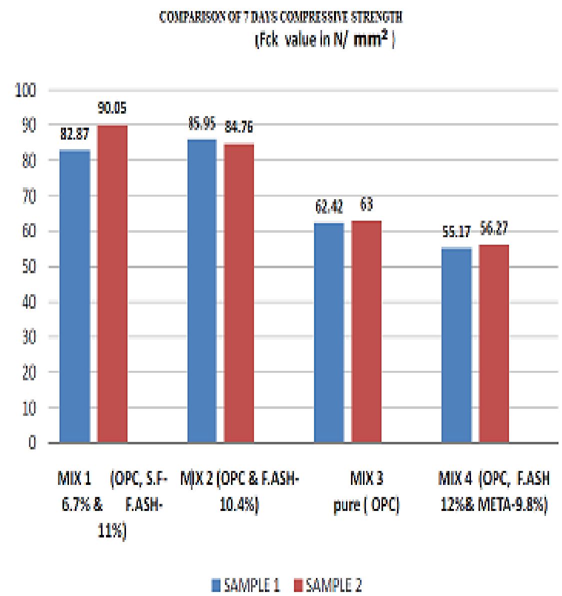

Fig. 1

From the graph, the compressive strength of the mix1 is nearly 20% higher than the other mix 3. Both the mix1 and mix2 possess higher compressive strength than mix3 while mix4 shows less strength.

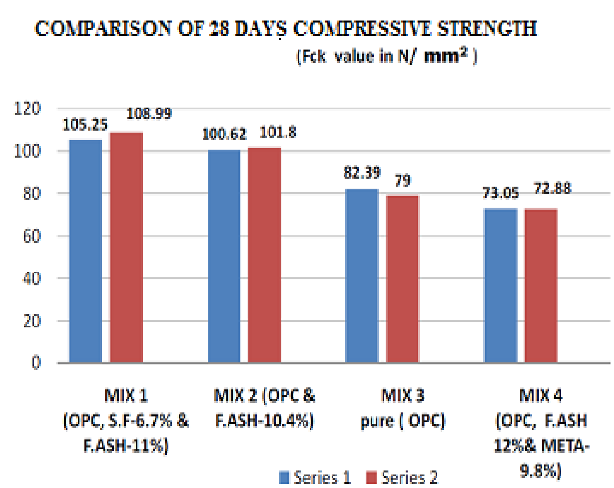

Fig. 2

The above graph shows the 28 days compressive strength of the concrete. From the graph it can be interpreted that the mix1 possess high compressive strength (nearly 20% greater) when compared to the other mix 3. Both mix1 and mix2 show higher compressive strength than the nominal mix. While mix4 shows less value than the mix3.

FLEXURE STRENGTH

Flexural strength is the measure of the tensile strength of concrete. An unreinforced concrete beam of 150 x 150mm with a span length at least three times the depth cast using the mix is tested The flexural strength is expressed as Modulus of Rupture (MR) in psi (MPa) and is determined by standard test methods ASTM C 78 (third-point loading) or ASTM C 293 (centre-point loading). The results are presented in graphical format.

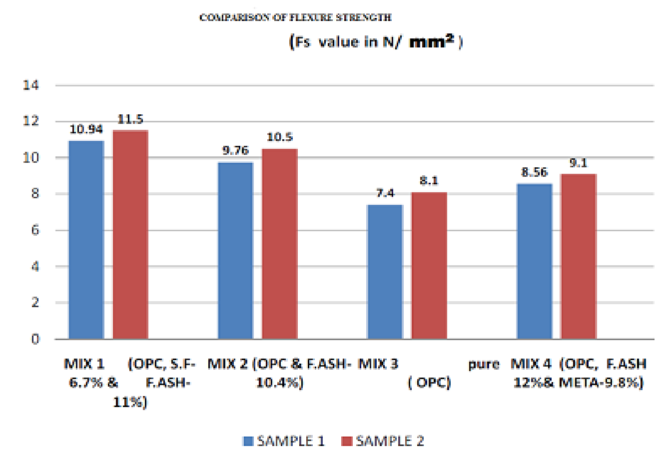

Fig. 3

From the graph it can be interpreted that the flexure strength of mix1 is nearly 25% higher than that of the OPC mix. The flexure strength of mix4 is also found to be 10% higher than that of mix 3.

SORPTIVITY

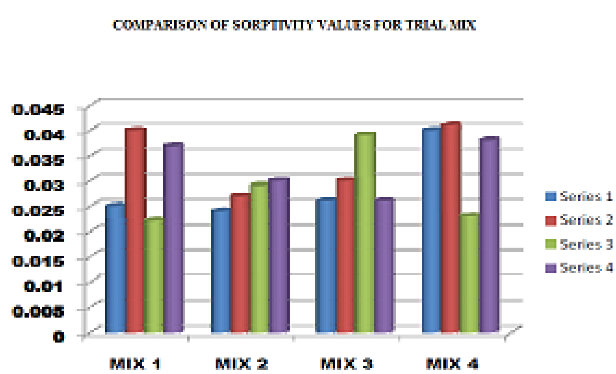

Fig. 4

A concrete core specimen is placed in a pan and exposed to a liquid on one plane. The level of liquid in the pan is kept constant to avoid discrepancies due to pressure gradients. At regular intervals, the mass of the concrete core specimen is weighed and the amount of fluid absorbed is normalized by the cross-sectional area of the exposed surface. Results of the test are presented in graphical format.

DURABILITY TEST – RCPT

Cores are usually cut by means of a rotary cutting tool with diamond bits. In this manner, a cylindrical specimen is obtained usually with its ends being uneven, parallel and square. The core should then be soaked in water, capped with molten sulphur to make its ends plane, parallel, at right angle and then tested in compression in a moist condition as per BS 1881: Part 4: 1970 or ASTM C 42-77.

The procedure of this test method for measuring the resistance of concrete to chloride ion penetration has no bias because the value of this resistance can be defined only in terms of a test method. The method relies on the results from a test in which electrical current passes through a concrete sample during a six-hour exposure period. The interpretation is that the larger the Coulombnumber, or the charge transferred during the test, the greater the permeability of the sample. The more permeable the concrete, the higher the coulombs; the less permeable the concrete, the lower the coulombs

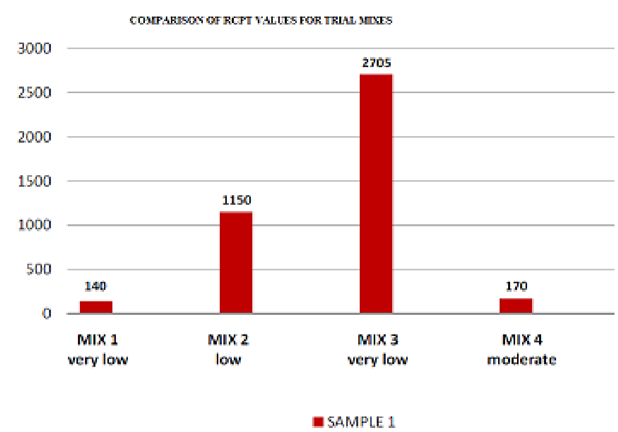

Fig. 5

From the results of RCP test, all the mixes show comparatively less charge passed through them when compared to the mix3. It can be seen that the mix1 with fly ash and silica fume show less conductivity which means less porosity in the structure, thus better durability.

UPV

Ultrasonic scanning is a non destructive test to qualitatively assess the homogeneity and integrity of concrete.The test essentially consists of measuring travel time T of ultrasonic pulse of 50 to 54 kHz, produced by an electro-acoustical transducer, held in contact with one surface of the concrete member under test and receiving the same by a similar transducer in contact with the surface at the other end. With the path length L, (i.e. the distance between the two probes) and time of travel T, the pulse velocity (V=L/T) is calculated. Higher the elastic modulus, density and integrity of the concrete, higher is the pulse velocity. The ultrasonic pulse velocity depends on the density and elastic properties of the material being tested. The results of the test are tabulated.

TABLE 2: UPV RESULTS

SAMPLE	DISTANCE ($X10^{-6}$)	TIME ($x10^{-3}$)	Velocity (km/sec)
1	150	00.01	15 >4.5 very good
2	150	00.01	15>4.5 very good
3	150	00.02	7.5>4.5 very good
4	150	00.02	7.5>4.5 very good

REBOUND HAMMER TECHNIQUE

A spring controlled mass that slides on a plunger within a tubular housing. When the plunger of rebound hammer is pressed against the surface of concrete, a spring controlled mass with a constant energy is made tohit concrete surface to rebound back. The extent of rebound, which is a measure of surface hardness, is measured on a graduated scale. This measured value is designated as Rebound Number (rebound index). A concrete with low strength and low stiffness will absorb more energy to yield in a lower rebound value. The result of the rebound hammer tests is tabulated.

TABLE 3 - REBOUND HAMMER TEST

sample	Readings	Average	Remarks
1	52 50 52	52	>40 high surface hardness
2	50 48 50	50	>40
3	48 46 46	46	>40
4	46 44 48	46	>40

From the table it can be interpreted that all the mixes show high surface hardness.

7. CONCLUSION

1. The study predicts that the more finer the particle size of SCM, theITZ becomes minimum and the aggregates are well reinforced with thecement paste.It is very cost effective when taking into account the cost required for repairs and rehabilitate of conventional concrete structures.
2. The results of the compressive strength test and flexure test, shows that the mix1 (combination of OPC, fly ash and silica fume) possess higher strength than nominal and other mixes.
3. In terms of higher durability, the results of sorptivity test and RCP test shows that the mix1 possess much durability when compared to the other mixes.
4. High performance workable concrete can be produced with very low water content.

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