Study on Strength Characteristics for M 60 Grade Concrete Using Fly Ash, Silica Fume, Metakaolin, and Steel Fibers

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***Abstract*-The present paper aims to study the performance by using supplementary cementitious materials to achieve high strength multi blended concrete mixes.An attempt is made to compare the performance of multi blended concrete mixes with ordinary Portland cement (OPC) concrete. In the OPC concrete mixes cement was partially and separately replaced by Fly Ash (FA), Silica Fume (SF), Metakaolin (MK)in different proportions of 5%, 10% and 15% and also in combination of these materials in proportions of 15% Fly Ash (FA) + 10% Silica Fume (SF), 15% Fly Ash (FA) + 10% Metakaolin (MK) and also 10% Fly Ash (FA) + 7.5% Silica Fume (SF) + 7.5% Metakaolin (MK) by weight of cement. A constant water binder ratio of 0.34 is maintained for compressive strength and split tensile strength evaluation for M60 grade of concrete. In order to achieve the required degree of workability and to gain tensile strength, Super plasticizer and steel fibers of required proportion were added for all the mixes. The Compressive and Split Tensile Strengths are determined at 3, 7 and 28 days. The multi blended concrete mixes exhibited higher compressive strength than OPC mix concrete and also better performance in short term strength development.**

***Keywords*-Multi blended, Cementitious materials, Compressive strength, Tensile strength, Steel Fibers, admixture, super plasticizer, mineral admixture, chemical admixture, Fly ash (FA), Silica fume(SF), Metakaolin (Mk), Ordinary Portland cement(OPC).**

I. INTRODUCTION

Concrete is the second most consumed material in the world that is considered as durable and strong material, and has relatively high compressive strength and significantly low tensile strength i.e. about 10% of the compressive strength and as a result concrete always fails from tensile stresses which must be reinforced. On this property concrete has to be reinforced with steel bars, mesh, or fibers to produce reinforced concrete. The ultimate strength of concrete is related to water/cement ratio, size, shape and strength of aggregates used. While the lower water cement ratio concrete makes a stronger concrete than a higher ratio.

Cementitious Materials are by-product materials and the use of these materials in mortar and concrete leads to reduction in waste and savings in energy consumption during the production of cement and multi blended mixes. Most recently blended and multi-blended concretes produced with the addition of industrial by-products/pozzolanic materials are becoming an active area of research due to their improved performance in both strength and durability. The common Cementitious Materials used are fly ash (FA), rice husk ash (RHA), slag, silica fume (SF), calcined clay (Metakaolin) etc, and it is observed that the combination of two or more kinds of Cementitious materials has emerged as a better choice over single mineral admixture to improve concrete properties.

In here an attempt has been made to study the effect of the use of Indian fly ash (FA), silica fume (SF) and Metakaolin (MK) on the short term (early age) strength development of multi blended concrete and compared with the conventional concrete mix, provided the multi blended concrete mixes containing each cementitious materials fly ash (FA), silica fume (SF), metakaolin (MK) separately and in combination mixes were combined to partially replace OPC along with the use of steel fibers in percentage of volume. Obtaining workability, with mixes containing admixtures, low water cement ratio i.e., 0.34 often requires super plasticizers. The class F fly ash, silica fume, metakaolin are used in different proportions of 5%, 10% and 15%, and combinations in proportion of 15% fly ash (FA) + 10% silica fume (SF), 15% fly ash (FA) + 10% metakaolin (MK) and finally 10% fly ash (FA) + 7.5% silica fume (SF) + 7.5% metakaolin(MK) by weight of cement. A constant water binder ratio of 0.34 for M60 was maintained for compressive strength and split tensile strength evaluation.

The compressive strength decreased at early ages as the amount of cement replaced by fly ash (class C) increased beyond 30% [2]. The addition of two or more kinds of SCMs in one mix has shown better results over single mineral admixture and achieved better concrete properties and found that the addition of 8-12% SF as cement replacement yielded the optimum strength ([3], [4]). The concrete mixes containing FA beyond 30% with or without SF were not able to achieve the strength of OPC concrete ([5]). In general, each of SCMs possesses different properties and reacts differently in the presence of water at early age.

The significance of this research is to evaluate performance of concrete with the combinations of fly ash, silica fume and metakaolin by conducting compressive strength and split tensile strength.

II. EXPERIMENTAL PROGRAM

A. *Mix proportion:*

The IS 10262:1982 mix design was adopted for concrete mix. For determining the compressive strength of concrete cubes of size 150 mm were cast and tested as per IS 516:1959, while 150 mm diameter and 300 mm long cylinders were used for determining the split tensile strength in accordance with IS: 5816-1970.

B. *Materials Used*:

The concrete mix was designed as per of IS 10262-1984 and it was prepared by using the following materials,

- ***Cement***- The 53 grade Ordinary Portland cement conforming to IS: 12269-1987 was used in the research with a specific gravity of 3.15.
- ***Coarse Aggregate***- Crushed stone aggregate with combinations of 12 mm and 10 mm in 60% and 40% respectively from a local source having the specific gravity of 2.74 conforming to IS: 383-1970 was used.
- ***Fine Aggregate***- Locally available river sand passing through 4.75 mm IS sieve conforming to grading zone-II of IS: 383-1970 was used with a specific gravity of 2.74.
- ***Water***- Potable water is used for mixing and curing concrete.
- ***Chemical Admixture***- The chemical admixture used is Poly-Carboxylic Ether which is brown in colour with a specific gravity is 1.02 and the recommended dosage is for 1kg of cement is 0.015 lit of Varaplast PC 100 which is used for effective workability.
- ***Mineral Admixture***-

  Fly ash: Fly ash is available in dry powder form and is procured from ULTRA TECH CEMENT in Nellore. The fly ash produced by the company satisfies all the requirements of the IS: 3812-1981.

  Silica Fume: Silica fume is being used increasingly as a supplementary cementing material for concrete and is formed from submerged-arc electric furnaces. SF is also known as silica dust, condensed silica fume, micro silica or volcanized silica and is usually grey or premium white colour. Majority of SF particles are very small and less than 1µm in diameter with specific gravity of 2.22.

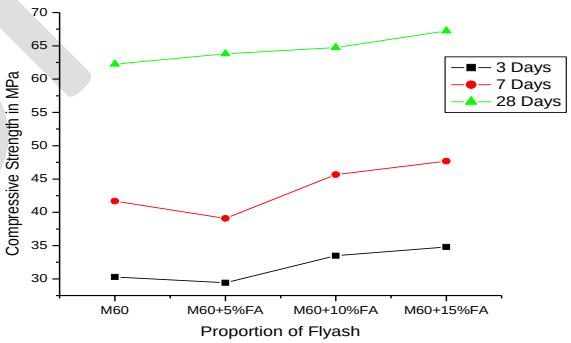
  Metakaolin: Metakaolin is obtained by the calcinations of pure or refined Kaolinite clay at a temperature between 650 ^{o}C and 950 ^{o}C. Metakaolin is used as a Supplementary Cementitious Material (SCM) in concrete to reduce cement consumption, to increase strength and the rate of strength gain, to decrease permeability, and to improve durability. Metakaolin reduces the porosity of concrete. Its specific gravity is 2.6.

  Steel Fibers: High tensile steel fibers, crimped type were used with a volume fraction of 0.5% with aspect ratio 100 is used in the mixes. As concrete fails on tension fibers play a major role.

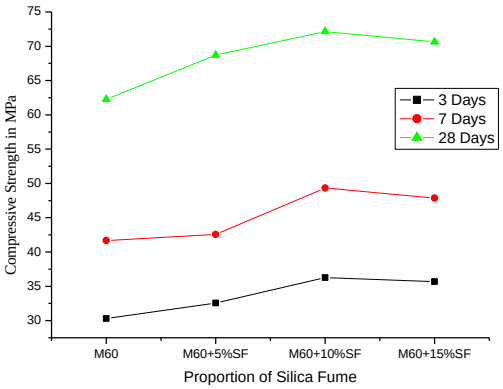
III. RESULTS AND DISCUSSIONS

The effect of Fly ash, silica fume and metakaolin at various proportions along with inclusion of steel fibers are studied with help of compressive strength, split tensile strength

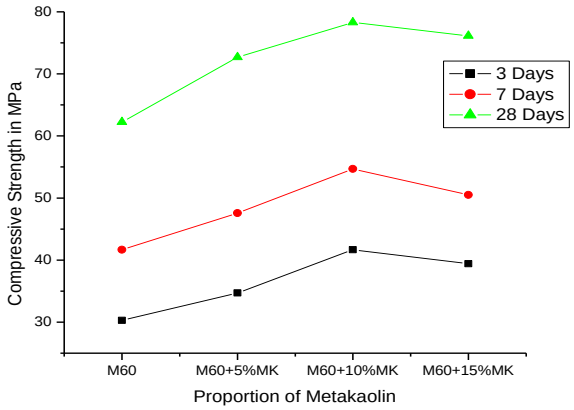
Results obtained for the high strength concrete are compared with the individual percentage replacements and different combinations of admixtures for M60 and these observed results are presented below.



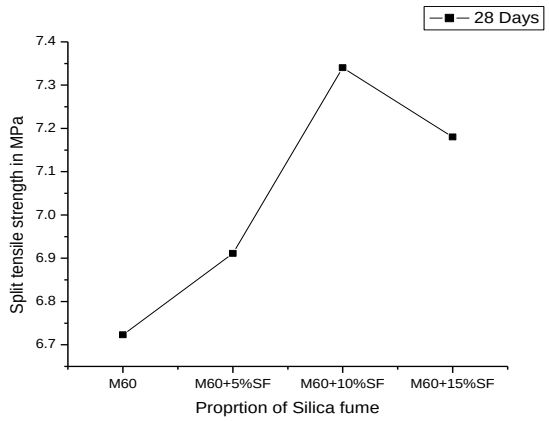
Graph 1: Fly Ash Compressive strength results



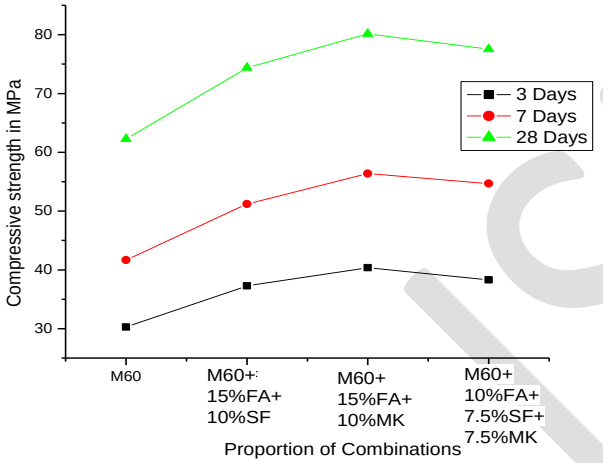
Graph 2: Silica Fume Compressive strength results



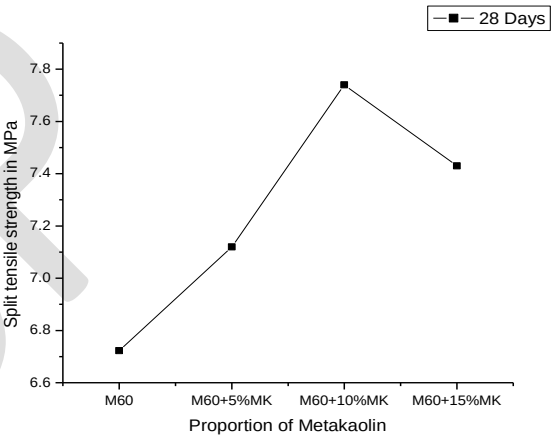
Graph 3: Metakaolin Compressive strength results



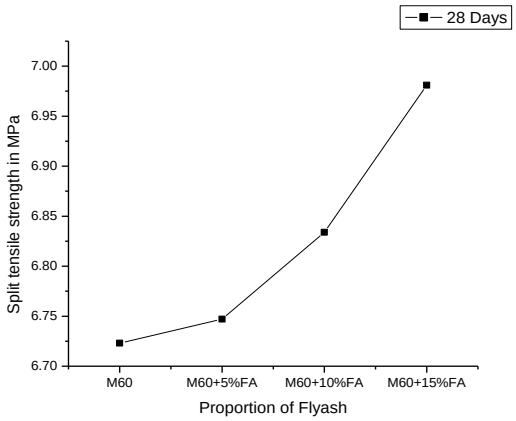
Graph 6: Silica Fume Split Tensile strength results



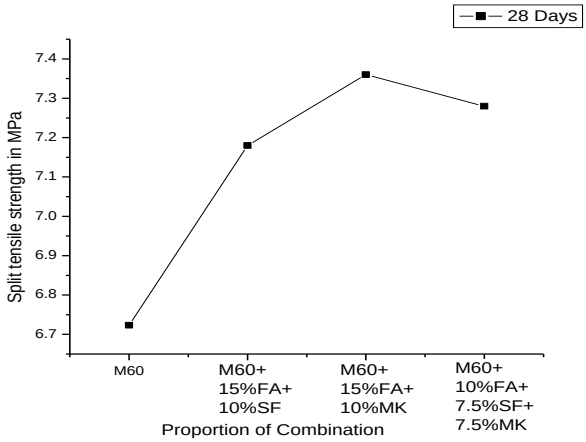
Graph 4: Combination Compressive strength results



Graph 7: Metakaolin Split Tensile strength results



Graph 5: Fly Ash Split Tensile strength results



Graph 8: Combination Split Tensile strength results

IV. CONCLUSIONS

1) The optimum performance was observed with the addition of plasticizer for thorough mixing and to obtain the desired strength and workability of the concrete mixes.
2) The maximum compressive strength attained for M60 grade concrete is 80.14 MPa for the combination of 15% Fly ash + 10% Metakaolin.
3) The steel fibers contribute effectively for achieving high strength along with mineral admixtures Fly ash, Silica fume and Metakaolin.
4) As soon as micro crack appears, sudden failure is observed in high strength concrete cubes.
5) The utilization of by-product mineral admixtures is the best alternative for now-a-days since it not only makes the concrete accomplish the proper performance but also reduce the concrete cost and environmental problems. Incorporating such materials further enhances the fresh properties of concrete.
6) Compacting factor (workability) decreases as the % addition of S.F/M.K increased. Workability (Compaction Factor) increases by addition of Flyash (FA) in both cases.
7) The maximum split tensile strength achieved is 7.74 MPa for replacement of 10 % Metakaolin.
8) The compressive strength has reached optimum upto the 10% replacement of admixtures and strength decreases beyond 10% addition of Silica Fume and Metakaolin, whereas for Fly ash increases upto 15% replacement.

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