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Influence of Mineral and Chemical admixtures in Ordinary Portland Cement on Physical and Mechanical Properties

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ABSTRACT

The supplementary cementious materials (SCMs) or mineral admixtures like fly ash, silica fume, metakaolin and ground granulated blast furnace slag (GGBS) are used in cement composite by partial replacement of cement about 20%. The effect of SCMs in Ordinary Portland cement (OPC) with regard to water requirement for consistency, setting time and cement mortar cubes with and without addition of super-plasticizer (SP) has been studied. It has been observed from the experimental studies that the cement consistency for OPC is 27.5% and addition of different mineral admixtures demands more water than cement consistency. Particularly, the mix with metakaolin demands 39% water for consistency. It is observed that with the addition of SP, the water required for consistency found reduced to 25% in all the mixes. The use of mineral admixtures influence fast setting time and with the addition of SP, the setting time is much faster. For preparation of mortar cubes demand 1 % more water as compared to IS-1489. XRD test has been conducted on cement and other cementitious materials, such as fly ash, silica fume, metakaolin, GGBS, to know the nature of particles present in that, which have more influence in imparting strength property. River sand and standard sand has been used in the present study. The compressive strength has been determined for these mixes at 3, 7, 28, 56 and 90days and the compressive strength determined at 90 days indicates that all the mixes with mineral admixtures give more or less same strength except the mix with fly ash in both conditions i.e. with river and standard sand, which gives 10.20 % less by using River sand and 16.5% less by using standard sand. With the addition of SP, the compressive strength of cubes prepared using river and standard sand is more compared to the strength of cubes prepared without SP. The compressive strength of the mortar cubes using standard sand gave better results on compared to cubes using river sand. The compressive strength of cubes for silica fume using River sand gave higher strength of about 56.38Mpa and by using standard sand cement with silica fume gave higher strength of about 57.52MPa. With the addition of SP, the compressive strength of the mortar cubes using river and standard sand, silica fume gave higher strength of about 60.25 and 61.11MPa respectively.

Key words: *Cement, Consistency, Compressive strength fly ash, Final Setting time, GGBS Initial setting time, Meta kaolin, Silica fume, Super-plasticizer, XRD.*

1.0 INTRODUCTION

Concrete is one of the most widely used construction material in the world. The most expensive ingredient of ordinary concrete is undoubtedly cement both economically and environmentally. It is also noticed that due to production of cement every year several million tonnes of CO_2 is releasing to environment, in order to overcome all these adverse effect supplementary cementitious materials (SCM) such as Fly ash, Silica fume, Metakaolin, Ground granulated blast furnace slag (GGBS) are used as partial replacement of cement. Several studies are being done to understand the hydration reactions in cement as well as cement with admixtures. Cement contains many ingredients like oxides of calcium (CaO), silica (SiO_2), aluminium (Al_2O_3), iron (Fe_2O_3),

magnesium (MgO) and alkalise like Na2O and K_2O as shown in Fig 1. The main products of hydration of cement are calcium silicate hydrates (C-S-H), calcium hydroxides (CH), and calcium aluminate hydrates (C-A-H). The changes in the chemistry of binder due to addition of an admixture to cement affects the rate, quantity and quality of hydration products which eventually results in changes in the strength of the cement paste.
Mortar consists of fine aggregates in addition to binder. Natural river sand is the commonly used fine aggregate. But standard sand as specified by Bureau of Indian Standards (BIS) is used to make mortar to find the strength. So the study regarding the variation of strength of mortar using the two types of sand is significant.

The purpose of present study is to find out the Physical, mineralogical, mechanical properties of mortar cubes with mineral admixtures such as Fly ash, GGBS, Silica fume and Metakaolin, and Chemical admixture such as super plasticizer (Glenium B-233), this study also includes comparison on mechanical properties between mortar cubes with river sand and mortar cubes with standard sand.

2.0 LITERATURE REVIEW

[1] Every year the production of cement is increasing with increasing demand of construction industries. Therefore the rate generation of co_2 also increases. If one ton of cement is produced then one ton of Co_2 is releasing, it will effects the environment like global warming. Therefore it is necessary to replace the cement from concrete by other supplementary cementious materials called admixtures.

[2] "A material other than water, aggregate, cement, used as an ingredient of concrete or mortar added to the batch immediately before or during mixing is called admixture". These are also called as supplementary cementious materials. There are two kinds of admixtures they are chemical admixtures and mineral admixtures.

[2] Pozzolanic materials are siliceous or siliceous and aluminous material, which in themselves possess little or no cementitious value, but in finely divided form and in the presence of moisture, chemically react with calcium hydroxide liberated on hydration to form compounds, possessing cementitious properties .

[3] Mineral admixtures are of different types i.e. pozzolanic (low calcium fly ash), cementious (ground granulated blast furnace slag), both pozzolanic and cementious (high calcium fly ash), natural materials (volcanic ash) and by-product material.

3.0 MATERIALS AND METHODOLOGY

3.1Raw Materials Used in the Study

The materials used in the present study are Ordinary Portland Cement (OPC) and four mineral admixtures namely Fly Ash (FA), Ground Granulated Blast Furnace Slag (GGBS), Metakaolin (MK) and Silica Fume (SF), Natural River sand, water and superplasticiser (SP).
The percent replacement of cement was fixed at 20% by weight of cement. Separate set of mixes using SP were also casted. The SP dosage was 0.6% by weight of binder. The binder to fine aggregate ratio was 1:3.

River Sand

Natural river sand was collected from Chengalpettu Local River. The sand was sieved through 4.75 micron IS sieve. The fineness modulus of sand was 2.95.

Standard Sand

Standard sand as specified in IS 650:1991 ie; Ennore sand was used. Three varieties i.e. fine (300micron), medium (900micron) and coarse (2.36mm) sand were mixed in equal proportions.

Superplasticiser (SP)

Glenium B233 type superplasticiser was used. (0.5-0.6 litters per 100 kg of cement).

3.2 Experimental Methodology

3.2.1 Consistency Test

Consistency is the general term to indicate the degree of fluidity or the degree of mobility. The standard consistency of cement paste is defined as that consistency which will permit a Vicat plunger having 10mm diameter and 50mm length to penetrate to a depth of 33-35 mm from the top of the mould.

3.2.2 Initial Setting Time of Cement

It is defined as the time elapsed between the moments that water is added to the cement, to the time that the paste starts losing its plasticity. As per laboratory procedure, initial setting time is the time elapsed between the moments that water was added to the cement, to the time when the needle of a Vicat apparatus penetrates 5 mm measured from the bottom of mould.

3.2.3 XRD and Chemical composition of Raw Materials

Brucker's D2 –phaser, a desk top XRD have been used for analysis of sample. The scans were performed with 2θ ranging from 5-70° at a rate of 0.01° per minute. All spectra were analyzed by using EVA software for qualitative analysis and Rietveld refinements was carried out by using pattern analysis software namely TOPAS (Total pattern analysis software). Copper Kα radiation (λ=1.5418 Å) was used and the power of X-ray gene ration is 30KV and 10mV.

Fig. 1, X-ray Diffractometer Fig. 2,Sampling tray with powdered

3.2.4 Compressive Strength

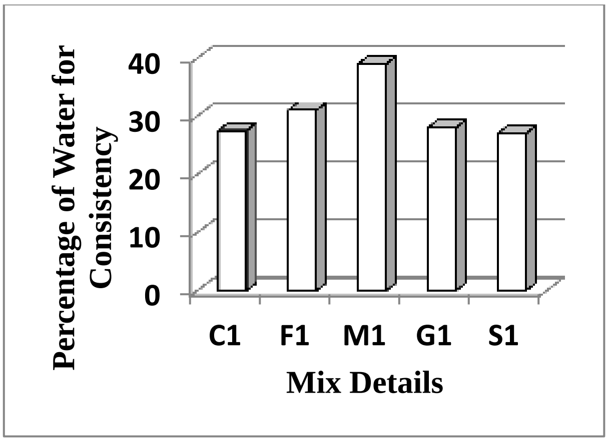
The cement is always tested for strength at the laboratory before it is used for important works. Strength tests are not made on neat cement paste because of difficulties of excessive shrinkages and subsequent cracking of neat cement. Strength of cement is found on a cube cast using cement mortar, sand in specific proportions. The fine aggregate as river sand is used for cement mortar. A total of 70.6 mm size mortar cubes are cast and are tested at different ages (3, 7, 28, 56 and 90 days) for compressive strength.

4.0 RESULTS AND DISCUSSIONS

The results obtained from the various tests are given below with a brief discussion about them

4.1 Standard Consistency Values

The standard consistency test was carried out for each of the different mixes a. The results are shown in Fig, 3 and 4.



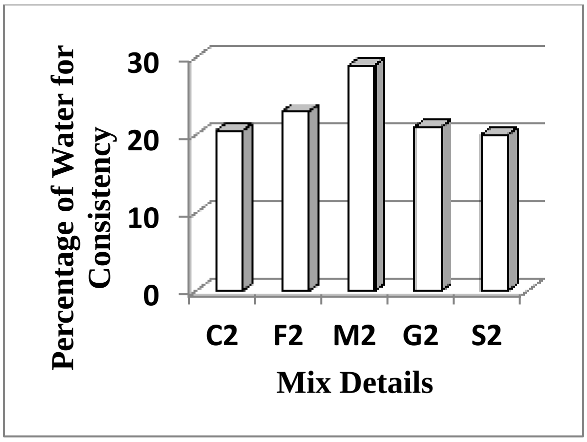


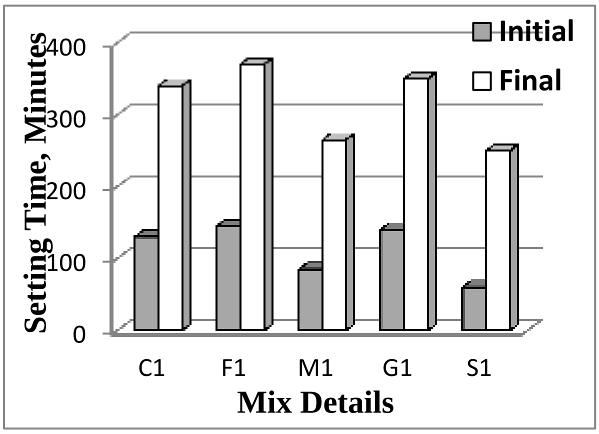
Fig. 3, Standard Consistency (without SP) Fig. 4, Standard Consistency (with SP)

From the Fig.3 it clearly indicates that the consistency of cement without any admixtures is 27.5%, and by addition of mineral admixtures except silica fumes other mineral admixtures consumes more water for consistency, particularly Metakaolin consumes about 39%, i.e. 41.80 % more than that of consistency of cement.

Fig. 4.2 clearly indicates that, by addition of chemical admixture (super plasticizer) there is a reduction of water consumption for consistency. The cement with SP alone consumed 20.5% of water only for consistency and by addition of mineral admixtures the water consumption for consistency is observed more except Silica fume. When compare the mixes without SP to with SP, there is almost 25% reduction in water requirement with SP.

4.2 Initial and Final Setting Time

The initial and final setting time for mixes with and without admixtures is given in Fig.



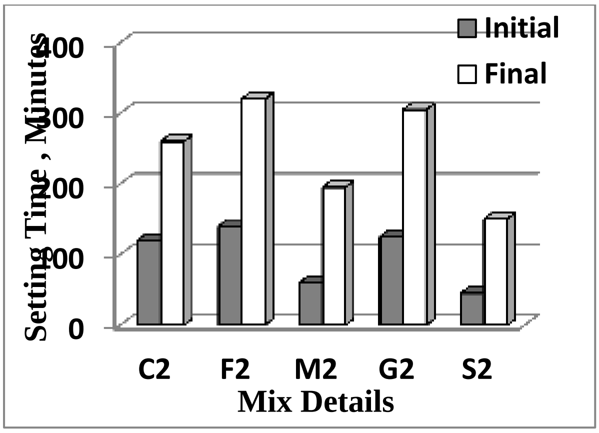
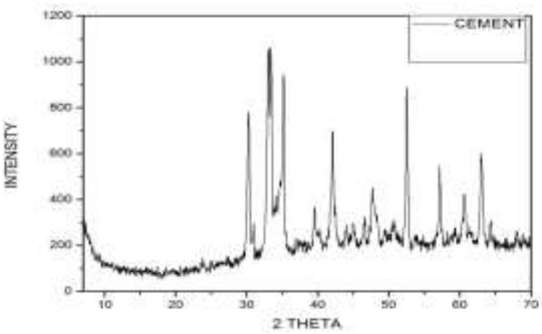


Fig.5, Initial and Final setting Time (no SP) Fig.6, Initial and Final Setting Time (SP)

From the table 4.2 and Fig, 4.3 it has been clearly observed that cement alone, without any mineral and chemical admixtures both initial and final setting time is 130 and 340 Min. With the addition of mineral admixture i.e. fly ash the setting time is delayed than setting time of cement alone, it is about 145 and 370 Min, initial and final setting time. With GGBS it is also some more are equal to that of cement. But in the case of metakaolin and silica fume it is observed that both initial and final setting times are in faster rate when compared to cement alone. Silica fume is showing much faster rate of initial and final setting time 60 and 250 Min, when compared to all other mixes.

From the table 4.2 and Fig, 4.4 it has been observed that with addition of chemical admixture i.e. super-plasticizer, the rate of setting time is comparatively faster than the mixes without chemical admixtures. It is observed that cement alone with SP the initial and final setting time is 120 and 260 Min. With the addition of mineral admixture i.e. fly ash the setting time is delayed than setting time of cement alone, it is about 140 and 320 Min, initial and final setting time. But in the case of metakaolin and silica fume it is observed that both initial and final setting times are in faster rate when compared to cement alone. Silica fume is showing much faster rate of initial and final setting time 45 and 150 Min, when compared to all other mixes.

4.3 XRD and Chemical compositions of Raw Materials



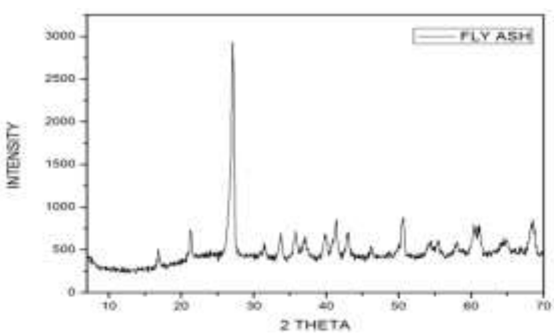
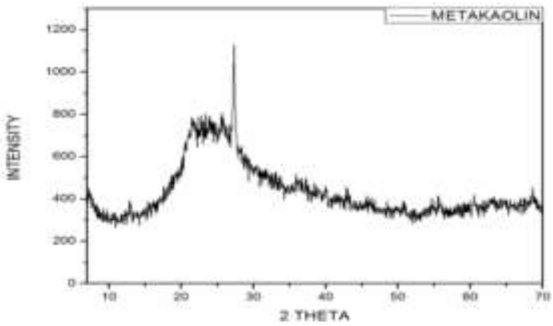
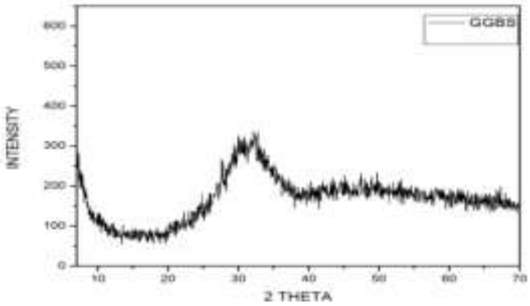


Fig. 7, XRD of OPCFig. 8, XRD of Fly Ash





Fig, 9, XRD of MetakaolinFig, 10, XRD of GGBS

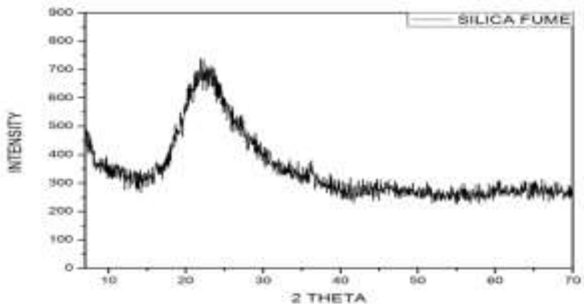


Fig. 11, XRD of Silica Fume

Table.1, Chemical Composition of Cement, fly ash, metakaolin, GGBS, silica fume

Chemical Constituents	Cement(OPC)	Fly ash	Metakaolin	GGBS	Silica fume
CaO	63.1	40	0.09	-	1.6
SiO_2	19.8	35	54	52.52	90
Al_2O3	4.9	12	46	32.56	0.4
Fe_2O_3	2	1	1.2	6.16	0.4
MgO	2	-	0.03	-	-
Na_2O	0.85	0.3	0.03	0.02	0.5
K_2O	-	0.4	0.1	0.11	2.2
SO_3	3.8	9	-	4.95	0.4

From the fig. 6, 7, 8, 9, 10, 11 the studies related to identification of mineralogical phases present in the cement and mineral admixtures have been conducted and studied by using XRD technique.

The cement used is an Ordinary Portland Cement (Bharathi cement of 43grade) which surpasses the requirements of IS12269-1987 Grade. From the studies it has been recognized for its High early strength and excellent ultimate strength because of its optimum particle size distribution, superior crystalline structure and balanced phase composition.

Fly-ash of Type F from Ennore Thermal Power plant was used for the study. X-ray diffraction was done for the Fly ash and the image was as shown in Fig. 8 and the percentage compositions are given in Table 2.

Metakaolin was collected from local market. X-ray diffraction was done for metakaolin as shown in Fig. 9 and the percentage composition is given in Table 1.

GGBS was obtained from Vizag steel plant. XRD results shows that the crystalline nature of the material is less in GGBS. If GGBS is added to cement paste the resulting hardened cement paste using GGBS is also more chemically stable. It contains much less free lime, which in concrete with Portland cement. In addition, GGBS contains no C_3A making GGBS cement much less reactive sulphites as given in fig. 10 and Table 2.

Silica fume was collected from local market. X-ray diffraction was done for the silica fume as given in Fig, 11 and the percentage compositions are given in Table 2.

4.4 Compressive Strength

Compression test has been conducted on mortar cubes without SP and with river sand at 3, 7, 28, 56, and 90 days and results were tabulated. From the fig. 12 it is observed that cement alone without any admixtures giving 28 days compressive strength of 44.77MPa. It is alsoobserved that all the mixes with mineral admixtures except Metakaolin and fly ash are giving compression strength is same range. At 28 days mix with GGBS showing higher compressive strength than all other mixes, but at 90days test Silica fume and GGBS are giving almost same compressive strength. Fly ash and Metakaolin are giving almost same compression strength at all 3, 7, 28, 56 and 90 days. On 28 days test those two mixes are giving 16.20% lesser strength when compare with normal cement mortar cubes alone.

Table 2 Compression Strength of Mortar Cubes with River Sand (without SP)

Materials	3Days (MPa)	7Days (MPa)	28Days (MPa)	56Days (MPa)	90Days (MPa)
C1	31.86	38.44	44.77	50.77	54.56
F1	24.85	27.41	37.44	47.08	49.61
M1	24.12	29.61	37.63	42.4	48.24
G1	28.42	36.44	46.50	51.26	56.46
S1	28.91	38.78	44.73	50.43	56.38

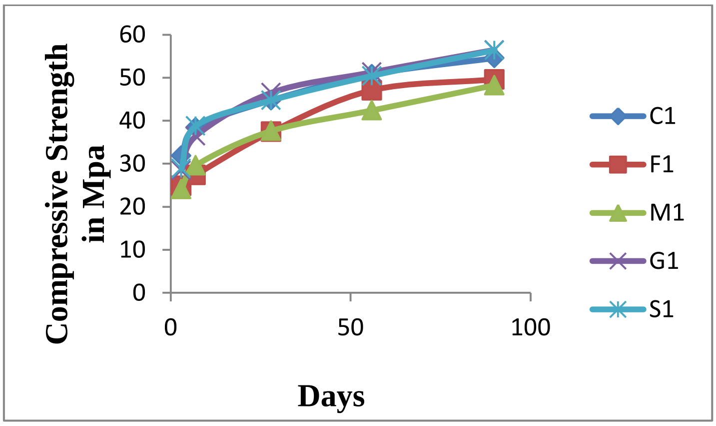


Fig. 12, Compression Strength Values of cubes with River Sand (without SP)

From the Fig, 13 with SP and with river sand it has observed that in the earlier stage i.e. at 3 days Fly ash is giving lesser compressive strength when compared to other mixes. It is about 28% lesser than mix with cement cubes. At 7 days also fly ash is giving lesser strength i.e. almost 22% lesser strength than the cement cubes. Up to 7days it is observed that Metakaolin is showing lesser strength when compare to other mixes except Fly ash, but at 28 days there is lot of variation in strength, there is almost 27% increment in strength. At 28 days also fly ash is giving lesser strength. At 28 days cement mortar cubes are giving higher strength i.e. 53.21MPa. Other mixes except Fly ash also behaving in the same range. At 90 days silica fume is giving higher strength i.e. 60.25MPa, and all other mixes are in less or equal range.

Table 3 Compression Strength of Mortar Cubes with River Sand (with SP)

Materials	3Days (MPa)	7Days (MPa)	28Days (MPa)	56Days (MPa)	90Days (MPa)
C2	40.41	46.11	53.21	55.31	59.69
F2	29.34	35.98	42.41	48.71	53.96
M2	32.58	38.42	52.07	56.81	59.18
G2	39.79	46.32	53.19	56.08	57.63
S2	38.14	44.08	49.80	56.90	60.25

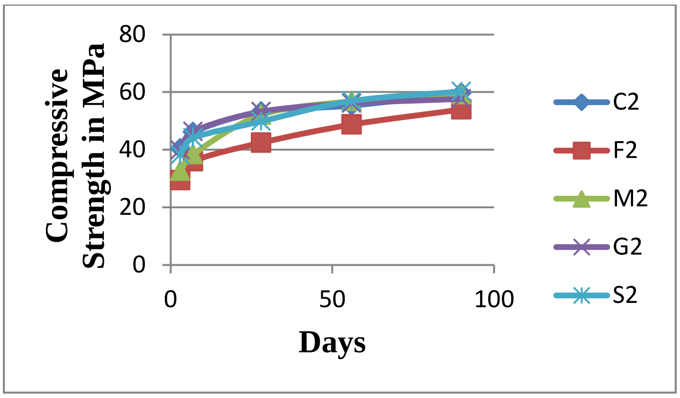


Fig.13, Compression Strength Values of cubes with River Sand (with SP)

From fig.14, without SP and standard sand it is clearly observed that initially Metakaolin is giving lesser strength when compare with other mixes. It is about 22.05MPa at 3days test. At 7 days also same pattern is observed i.e. Metakaolin giving lesser strength of about 24.17MPa. And cement mortar cubes alone giving 39.07MPa. At 28 days it is observed that Metakolin and fly ash are in same range, cement mortar cubes are giving higher strength of 47.12MPa. At 56 days GGBS is giving higher strength of 53.20MPa. At 90 days silica fume is giving 57.42MPa.

Table 4 Compression Strength of Mortar Cubes with Standard Sand (without SP)

Materials	3Days (MPa)	7Days (MPa)	28Days (MPa)	56Days (MPa)	90Days (MPa)
C1	30.72	39.07	47.12	51.10	56.25
F1	27.25	30.65	39.15	43.61	48.44
M1	22.03	24.17	38.35	45.05	50.36
G1	26.98	33.35	43.25	53.20	54.35
S1	29.74	36.78	46.85	48.91	57.52

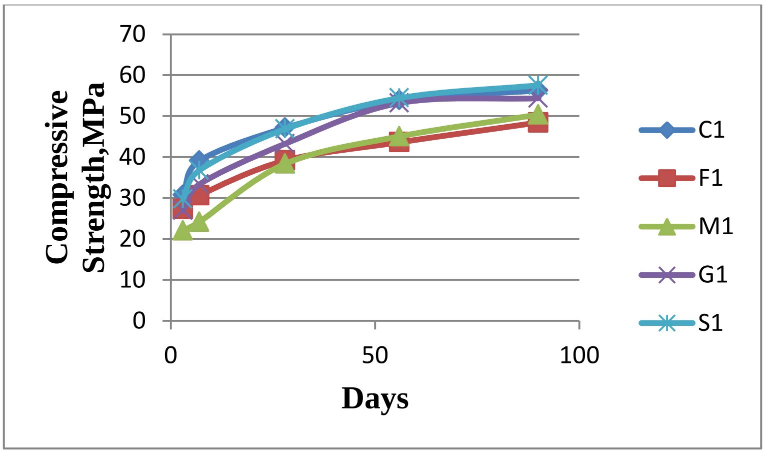


Fig.14, Compression Strength Values of cubes with Standard Sand (without SP)

From fig.15, with SP and standard sand it is clearly observed that initially fly ash is giving lesser strength when compare with other mixes. It is about 26.09MPa at 3days test. At 7days also same pattern is observed i.e. fly ash giving lesser strength of about 33.95MPa. And cement mortar cubes alone giving 40.50MPa. At 28 days it is observed that Metakaolin mix is giving higher strength of 48.95MPa. And all other mixes are less or equal to strength of Metakaolin except fly ash. At 56days GGBS is giving higher strength of 55.67MPa. At 90 days silica fume is giving 61.11MPa. It is also noticed that with river and standard sand silica fume is attaining higher strength at later ages i.e. at 90 days.

Table 5 Compression Strength of Mortar Cubes with Standard Sand (with SP)

Materials	3Days (MPa)	7Days (MPa)	28Days (MPa)	56Days (MPa)	90Days (MPa)
C2	35.10	40.50	48.32	53.81	58.45
F2	26.09	33.49	40.89	46.59	51.25
M2	30.52	38.93	48.95	55.67	58.25
G2	29.27	35.78	49.47	52.67	55.04
S2	32.05	38.83	47.49	53.92	61.11

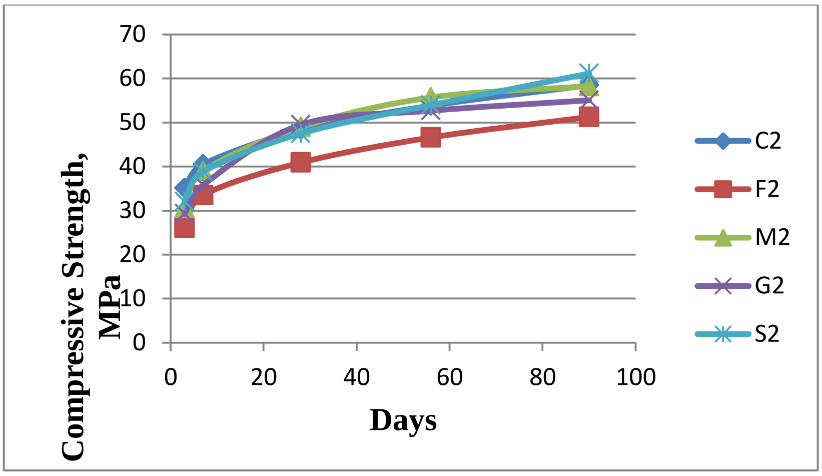


Fig. 15, Compression strength values of cubes with standard sand (with sp)

4.0 CONCLUSION

From this study, it is observed that the supplementary cementious materials used in the present investigations can be used in cement composite. The strength obtained by addition of these materials is more or less in the same range as compared to the control mix. However, with the addition of SP, maximum increment in strength was noticed with the reduction in water consumption.

The following conclusions may be drawn from this study

- Water requirement for standard consistency was increased by the addition of mineral admixtures.
- Metakaolin was observed to be consuming maximum water for consistency.
- There is almost 25% reduction in water requirement for consistency observed with the addition of super-plasticizer for all the mixes.
- The use of mineral admixtures influence fast setting time and with addition of SP, the setting time is much faster
- As per IS1489, the water required for preparation of mortar cubes by addition of these materials demands 1% more water with both river and standard sand.
- The compressive strength at 90 days using River and Standard sand indicates that all the mixes with mineral admixtures give more or less same strength except the mix with fly ash, which gives 10.20 % less.
- The compressive strength at 90days for mortar cubes with silica fume with SP is giving higher compressive strength in both the cases i.e. is using river and standard sand. And all other mixes are giving lesser equal to the silica fume except Fly ash.
- With the addition of super-plasticizer the compressive strength of mixes increased by 10-15%.

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