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BEHAVIOUR OF MORTAR CONTAINING SILICA FUME AND FLY ASH USED FOR FERROCEMENT LAMINATES

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ABSTRACT

This paper reports the results from laboratory studies on the compressive strength of mortar for Ferro cement that contains ternary blends of Portland cement, silica fume and super plasticizer as water reducing agent. Cement mortars (1:2, 1: 2.5 and 1:3) incorporating various water cementitious ratios (0.32, 0.35 and0.38) were used. The silica fume content is constant at 5% by weight of cement. Fly ash content varying from 10% to 20% and super plasticizer were used to maintain uniform flow of mortar which varies from 0% to 1% by weight of cement, to ensure that no segregation would occur. Totally 586 mortar cubes for each mix with mineral admixtures were tested for their compressive strength. Finally suggestions were made for the proportion of mineral admixtures to achieve high strength mortar which can be used for rehabilitation of reinforced concrete structures particularly with Ferro cement composites.

INTRODUCTION

In many countries around the world, silica fume and fly ash are used for producing active pozzolanic admixtures. These pozzolanic admixtures are used for reducing the Portland cement content in mortar and concrete production (Cook , 1985; Ruiz Al, 1965). The positive effects exerted by such pozzolanic admixtures on properties of portland cement mortar and concrete have been emphasized in many studies (Babu *et al.* 1993; George *et al.* 1995). In addition to a strength gain, it was shown that such admixtures could improve the surface resistance of the Portland cement mortar and concrete (Akoz *et al.* 1995). The compressive strength of cement paste containing silica fume decreases as the silica fume content increases at low water cementitious materials ratios of 0.25, but plain cement paste exhibited highest strength and greater strength development after 28 days (Akkan and Mazlum, 1993).

The benefits of using either fly ash or silica fume in concrete in partial replacement for portland cement are fairly well established. However both materials have certain short falls. Silica fume, while imparting significant contributions to concrete strength and chemical resistance can create increases in water demand placing difficulties and plastic shrinkage problems in concrete and present handling difficulties in the raw state if not properly used. Deficiencies

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associated with the use of fly ash in concrete depend on the nature of fly ash being considered.

The combination of silica fume and fly ash in a ternary cement system (i.e., Portland cement being the third component) should result in a number of synergistic effects, some of which are obvious as follows.

- Silica fume compensates for low early strength of concrete with low fly ash.
- Fly ash increases long term strength development of silica fume concrete.
- Fly ash offsets increased water demand of silica fume.
- Very high resistance to chloride ion penetration can be obtained with ternary blends.

Ferrocement is a thin walled reinforced concrete which commonly consists of cement mortar reinforced with closely spaced layers of continuous and relatively small wire mesh.

Ferrocement is regarded as highly versatile material possessing a degree of roughness, ductility, durability, strength and crack resistance that is greater than that found in other forms of concrete construction (Naaman, 2000; Memon and Salihuddin, 2006). It is the promising composite material for the prefabrication and the industrialisation of the building industry (Memon and Salihuddin, 2005) which proves an excellent material for low cost housing (Mattone, 1992) and enhancement of light weight core materials for producing high performance light weight structural sandwich panels. The properties of mortar mix like compressive strength, water absorption are very important to consider during the design of thin ferrocement structural elements. The studies have been conducted to investigate the characteristics of mortar mix to use in ferrocement elements. (Arif and Kaushik, 1996) ACI 549 recommends sand cement ratio (S/C)1.5-2.5 and water cement ratio (W/C) 0.35-0.5, for the use in ferrocement (ACI committee 549R-97).

The SF concrete had consistently higher compressive strength than the control concrete. In the case of ternary use of PC, FA and SF, the compressive strength also gradually decreased with the replacement ratio but the rate of reduction was much less compared to the case in the binary use of PC and FA (Mehmet Gesoglu *et al.* 2009). The corrosion resistance of the ternary blend mortar of OPC, RHA and FA is consistently higher than that of mortar containing single pozzolan (Chindaprasirt and Rukzon, 2008). The concrete containing FA had generally lower compressive strength. However, binary (PC+SF and PC+S) and ternary (PC+S+SF) blends of SF and S provided comparably higher compressive strengths (Mehmet Gesoglu and Erdogan Ozbay, 2007).

It is apparent that ternary cementitious blends of Portland cement, silica fume and fly ash offer significant advantages over binary blends and even greater enhancements over ordinary Portland cement. In some cases, price differences between the individual components may allow the ternary blend to compete with ordinary Portland cement on the basis of material costs (Hariharan *et al.* 2011).

This paper particularly aims to assess the trial mixes the extent to which the Portland cement can be blended by silica fume and fly ash with super plasticizer in the production of durable mortar by means of a test program.

MATERIALS AND METHODS

Materials

All the materials used during this experimental program comply with the standard specifications.

Cement

The physical and chemical properties of the used Ordinary Portland cement (OPC) are tabulated in Table 1 and Table 2 respectively.

Fly ash

High calcium fly ash (ASTM class C) from NLC limited, Neyveli, India was used in this investigation. The physical and chemical compositions of the fly ash are shown in Table 1 and 2 respectively.

Silica fume

Uncompacted silica fume from Elkern, India was incorporated in this study. The physical properties and chemical analysis of the silica fume are shown in Table 1 and 2 respectively.

Fine aggregate

The natural river sand passing through 2.36mm sieve was adopted as fine aggregate in mortar.

Super plasticizer

The super plasticizer of trade name Fosroc Conplast SP430 conforming to IS 9103-1999 and ASTMC-494 was used as the chemical admixture during this study. It is available as a medium brown coloured

Table 1. Physical properties of cementitious materials

Description of test	ASTM Type I Portland cement	Flyash ASTM Class C	Silica Fume
Physical Test			
Specific gravity	3.15	2.04	2.02
Fineness-passing 45µm	94.1	--	85
Initial setting time (min)	150	--	--
Final setting time (min)	265	--	--
Specific surface (m^2/g)	329	--	19
Bulk density (kg/m3)	--	--	602

Table 2. Chemical analysis of cementitious materials

Description of test	ASTM Type I Portland cement	Flyash ASTM Class C	Silica Fume
Silicon dioxide (SiO_2)	20.32	60.09	85.72
Aluminium oxide (Al_2O_3)	4.94	18.63	0.06
Ferric oxide (Fe_2O_3)	2.55	-	0.45
Calcium oxide (CaO)	62.58	-	-
Magnesium oxide (MgO)	1.18	1.10	-
Sulphur trioxide (SO_3)	3.46	1.54	-
Sodium oxide (Na_2O_3)	0.19	0.31	-
Potassium oxide (K_2O)	0.86	0.05	-
Loss of ignition (LOI)	1.28	2.41	1.96

Table 3. Compressive strength of Mix 1:2 & w/b ratio 0.32, 0.35 and 0.38

Mix & W/B	% of SP	5%SF & 10% FA	5%SF & 15% FA	5% SF & 20% FA
	0	69.5	70.06	71.9
	0.2	73.67	75	76.62
1:2	0.4	79.13	80.01	81.63
0.32	0.6	83	84.58	84.60
	0.8	76.6	78.18	79.60
	1	66.11	67.45	63.46
	0	67.96	69.45	71.61
	0.2	76.67	78.55	79.82
1:2	0.4	79.93	80.33	82.34
0.35	0.6	86.67	88.97	89.42
	0.8	76.4	78.52	79.95
	1	71.13	73.19	74
	0	64.28	63.1	62.99
	0.2	64.48	64.55	63.06
1.2	0.4	67.37	66.12	65.62
0.38	0.6	74.66	70.94	69.68
	0.8	62.05	61.59	60.72
	1	63.05	62.82	61.03

aqueous solution and its specific gravity is 1.18.It is from group sulphonated naphthalene formaldehyde condensates in dry powder form.

Water

Water is one of the most important constitutes without which concrete cannot be produced. It should not contain substance which can be harmful to the process of hydration of cement and durability of concrete. In general, water, which is acceptable for drinking, is also suitable for the concrete mixing. In this study tap water is used for the manufacture of

Table 4. Compressive strength of Mix 1:2.5 & w/b ratio 0.32, 0.35 & 0.38

Mix & W/B	% of SP	5%SF& 10% FA	5%SF & 15% FA	5%SF & 20% FA
	0	74.16	66.43	65.06
	0.2	75.99	72.43	66.75
1.2.5	0.4	79.20	76.10	67.83
0.32	0.6	85.79	76.69	72.49
	0.8	73.90	66.25	62.56
	1	72.89	62.14	57.71
	0	65.24	70.95	64.26
	0.2	68.55	71.50	66.79
1:2.5	0.4	72.84	75.89	68.25
0.35	0.6	75.06	77.93	69.24
	0.8	64.23	64.02	63.45
	1	62.91	62.32	61.04
	0	61.36	60.19	56.89
	0.2	66.65	65.51	60.24
1:2.5	0.4	70.56	67.12	62.08
0.38	0.6	74.94	72.07	65.51
	0.8	72.03	64.88	56.80
	1	68.57	58.38	56.12

Table 5. Compressive strength of Mix 1:3 & w/b ratio 0.32, 0.35 & 0.38

Mix	% of SP	5% SF & 10% FA	5% SF & 15% FA	5% SF & 20% FA
	0	57.14	55.45	53
	0.2	60.71	60.45	57.18
1:3	0.4	64.28	65.83	60.43
0.32	0.6	70.10	71.67	63.99
	0.8	68.86	69.98	57.12
	1	64.84	66.87	56.57
	0	59.30	57.62	53.83
	0.2	63.51	61.76	54.33
0.35	0.4	69.27	67.58	59.04
	0.6	73.43	71.75	62.17
	0.8	69.94	67.66	58.85
	1	64.93	59.69	57.75
	0	59.28	59.71	57.77
	0.2	63.92	60.62	61.22
1:3	0.4	64.63	62.82	65.84
0.38	0.6	69.42	65.90	66.68
	0.8	59.53	57.19	53.79
	1	50.51	50.42	49.34

the concrete.

Methods

The cement was replaced with silica fume at three proportions (5%, 10% and 15%) and dosage of super plasticizer ranging from 0%-1% by the weight of total binder with an increment of 0.2% was adopted.5% silica fume as a cement replacement shows a good increase in compressive strength at 28days. The addition of 5% silica fume with different flyash replacements were adopted. Visual inspections showed that there is bleeding problems with water binder ratio of 0.39 and 0.4.Hence w/b ratio of 0.32, 0.35 and 0.38 were adopted.

Three principal mixes 1:2, 1:2.5 and 1:3 were considered with three different water cementitious ratios 0.32, 0.35 and 0.38 were used. At every water binder ratio, partial replacement of cement with 5% silica fume and fly ash content varied from 10%, 15% and 20% by weight of cement. Dosage of super plasticizer ranging from 0% - 1% by the weight of the total binder with an increment of 0.2% was adopted.

Thus 162 mixes were developed and 486 cubes of standard size 70.6 x 70.6 x 70.6 mm were casted and tested for compressive strength in 28 days duration.

The specimens were cured in water for 28 days and tested for compressive strength. A survey of the mix proportions along with the dosage of super plasticizer, water binder ratio and the determined values of compressive strength are presented in Table 3, 4 & 5. The test aimed at revealing the level and the development of compressive strength resulting from variations in the water binder ratio.

EXPERIMENTAL RESULTS AND DISCUSSION

The results obtained from the experimental investigations are tabulated in tables and comparisons are presented in the form of graphs. All the values are the average of three specimens tested in each case during the testing program of this study. The results are discussed as follows.

Compressive strength

The results presented in the Table 3, 4, & 5 show the higher compressive strength of almost all the mortars with 5% SF and 10% FA and 5% SF & 15% FA as cement replacement ranging between 5% and 15% over their control OPC mortar at various dosage of super plasticizer. Figures 1, 2 & 3 depict the enhancement of compressive strength at different dosage of the super plasticizer. The trend of the curves presented in Figures1, 2 & 3 for all the three mixes 1:2, 1:2.5 and 1:3 seems to be identical. From the Figures 1, 2 & 3, it is obvious that the compressive strength increases with the increase in the dosage of super plasticizer. Upto 0.6% of the super plasticizer, the enhancement in compressive strength is remarkable and it lowers with the further addition of super plasticizer beyond 0.6%.

From Table 3, 4 & 5 it is also apparent that the compressive strength as high as about 89.42Mpa was achieved for mortar 1:2 w/b ratio 0.35 with 5% silica fume, 20% flyash and 0.6 % super plasticizer while the lowest compressive strength obtained is 49.34Mpa in case of mortar 1:3 w/c ratio 0.38 with 5% silica fume and 20% flyash and 1% super plasticizer. This shows that a high workability flyash, silica fume and cement mortar with a wide range of compressive strength can be produced depending upon the level of cement replacement with silica fume, fly ash and the dosage of super plasticizer as the water reducing admixture. However as cited in the literature review, the end product of thin ferrocement elements depends upon the properties of mortar particularly compressive strength.

Thus on the basis of this study and from compressive strength point of view high workability mortar 1:2 with 5% silica fume, 20% flyash and 0.6% super plasticizer exhibiting high strength seems to be reasonably suitable for the casting of thin ferrocement laminates.

CONCLUSION

Based on the experimental study conducted and the results presented herein, following conclusions can be drawn.

1. It is apparent that ternary cementitious blends of Portland cement, silica fume and fly ash offer significant advantages over binary blends and even greater enhancements over plain Portland cement.

2. In some cases price differences between the individual components may allow the ternary blend to compete with straight Portland cement on the basis of material cost.

3. The Combination of silica fume and fly ash results with improved early age and long term strength development.

4. Compressive strength of high workability mortars enhances with the application of silica fume, fly ash and super plasticizer as cement replacement and water reducing agent respectively. The enhancement ranges between 5% and 15% of control OPC mortars depending upon the mix proportion, replacement level and dosage of super plasticizer.

5. Compressive strength as high as about 89.42Mpa was achieved for mortar 1:2 w/b ratio 0.32 with 5% silica fume, 20% flyash and 0.6% super plasticizer. While the lowest compressive strength obtained is 49.34Mpa,the lowest value obtained for mortar is 1:3 w/b ratio 0.38 with 5% silica fume, 20% flyash and 1% super plasticizer.

6. Mineral admixtures silica fume and fly ash adopted as cement replacement did not affect the flow properties in all the mortars and at all the dosages of super plasticizer applied.

7. Partial replacement of cement with silica fume and flyash is maximized at 5% and 20%.

8. The results of this research study reveal that,

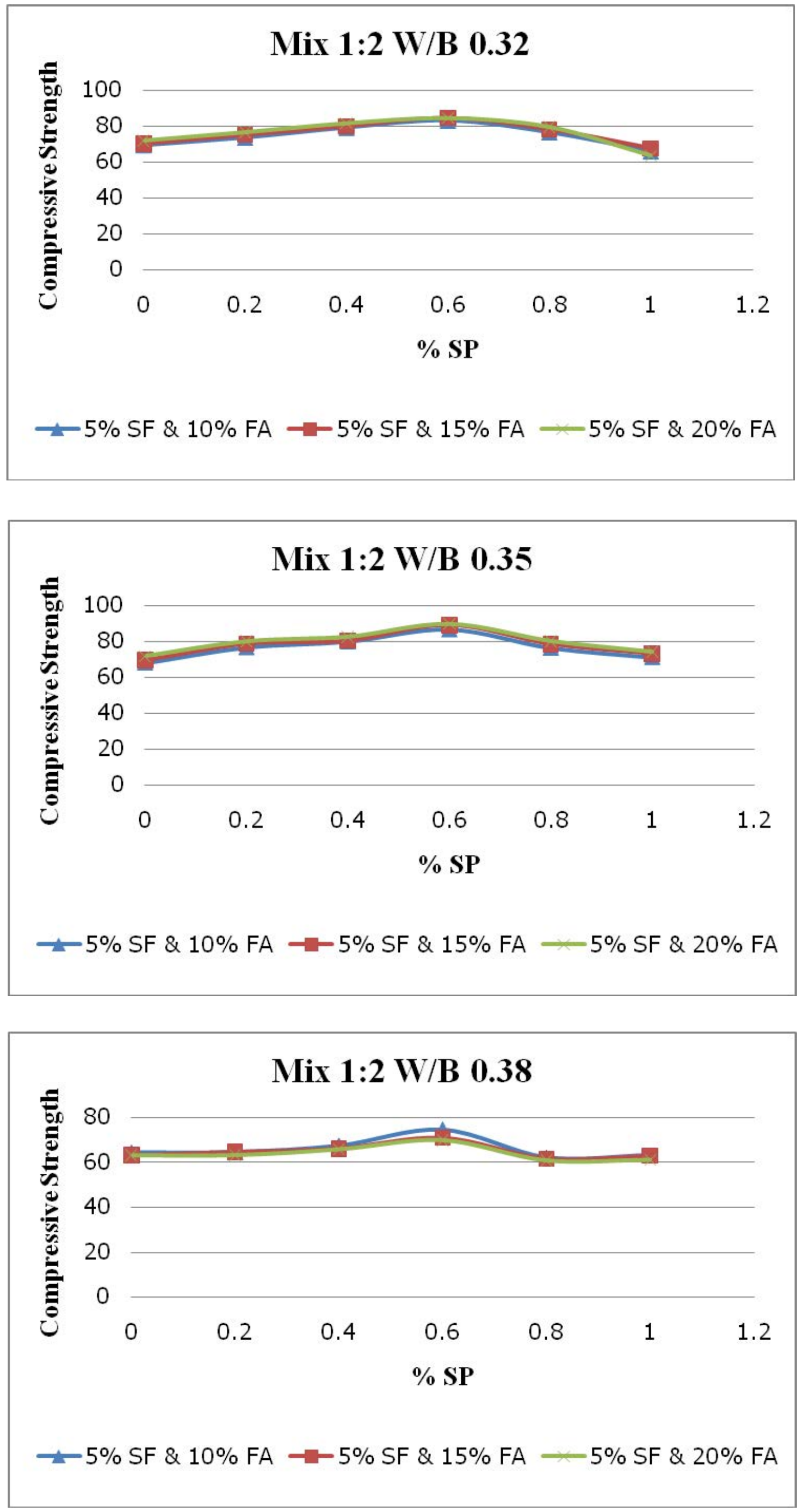

Fig. 1 Variation of compressive strength vs dosage of super plasticizer for mix 1:2

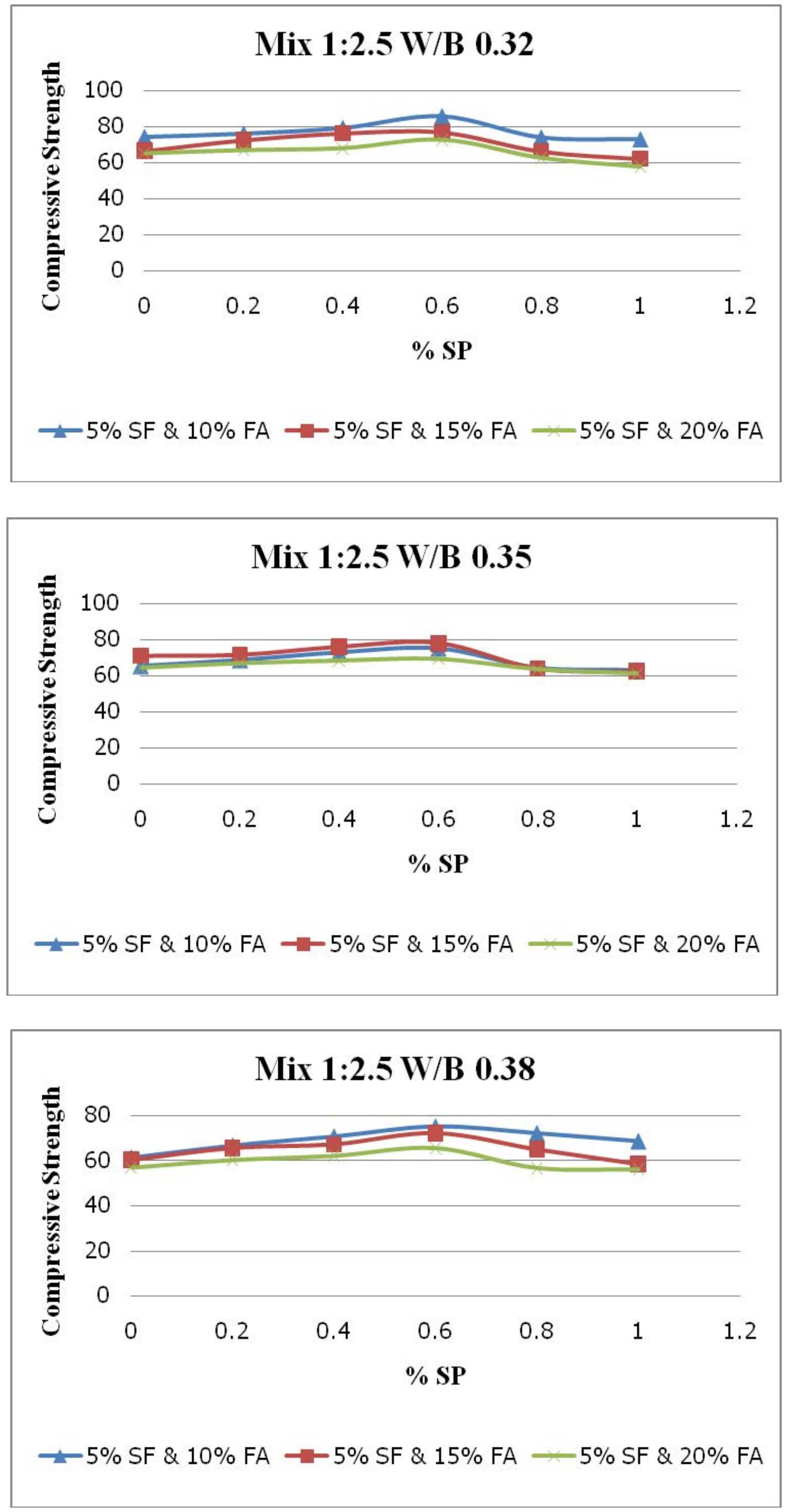

Fig. 2 Variation of compressive strength vs dosage of super plasticizer for mix 1:2.5

the compressive strength of silica fume, fly ash, cement mortar ranging between 89.42Mpa and 49.34Mpa depend upon the mix ratio, water binder ratio, replacement level of cement with silica fume and flyash dosage of super-plasticizer. Nevertheless mortar 1:2, water binder ratio 0.35 with 5% silica fume, 20% flyash and 0.2% to 0.6% super plasticizer could be considered as suitable mortar for the casting of thin ferrocement elements.

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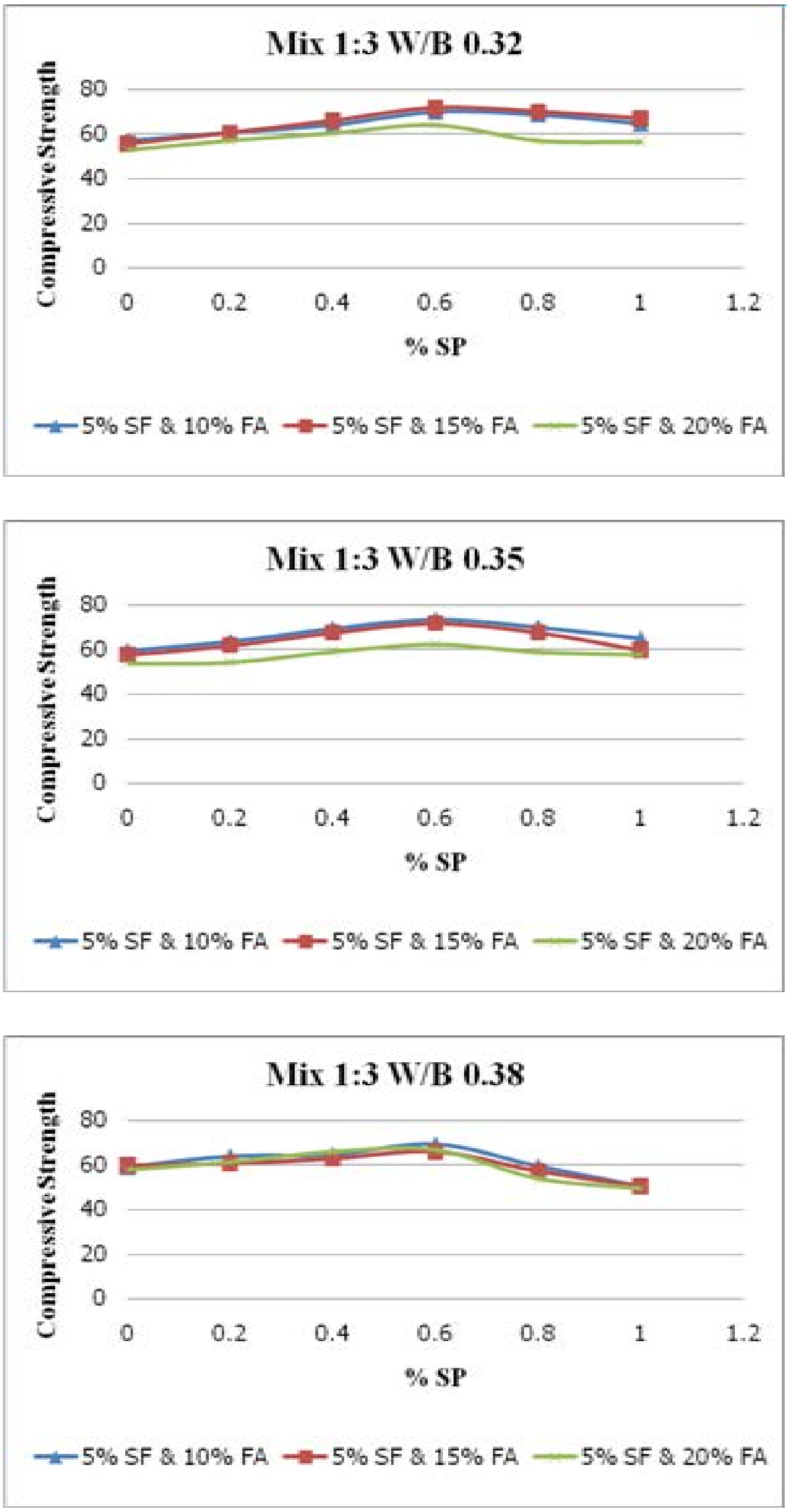

Fig. 3 Variation of compressive strength vs dosage of super plasticizer for mix 1:3

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