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STUDIES ON HIGH PERFORMANCE MORTAR MIXES (PART 1 STRENGTH AND FLOW CHARACTERISTICS)

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This paper presents an investigation which examines the effect of silica fume and superplastizer in rich mortar mixes (1:1, 1:1.15 and 1:1.2) using different grades of cement for use in High Performance ferrocement works. Emphasis has been on the compressive strength and flow characteristics, which play an important role in ferrocement applications. The results obtained indicated that use of slag cement, silica fume and superplasticzers have improved the compressive strength and flow characteristics of mortar mixes

INTRODUCTION

Cement mortar forms an important component of cement concrete. Apart from this consideration, studies on cement mortar are required as cement mortar forms an important structural material in applications such as production of ferrocement elements. The porosity of cement mortar can be reduced by decreasing the water cement ratio with the corresponding addition of a super plasticizer to maintain workability[1]. The pore structure can further be modified by addition of pozzolanic admixtures such as silica fume.Thus silica fume and super plasticizer are being employed increasingly for better benefits of handling, placing, compaction and finishing along with other technical and economical advantages. Studies are conducted exhaustively to thoroughly understand the behavior of High Performance Mortar mixes. It is known that if the w/c ratio is slightly controlled to have impervious mortar with good compressive strength and flow, silica fume and super plasticzer have a important role to play. As the matrix in ferrocement has 95% or more pronounced influence on the behavior of the final product[2], the selection of constituent materials such as cement, fine aggregate, mixing and placing of mortars should be done with due care[3]. The chemical composition of cement, nature of aggregates, water-cement ratio and the mineral admixture are the major influencing parameters in determining the porosity of the mortar.An investigation of strength and flow characteristics of these mortars with different grades of cement in addition to silica fume is reported in this Part-I of the work. In Part-II the shrinkage and sorptivity characteristics of these high performance mortars are investigated and presented[4].

EXPERIMENTAL PROGRAM

The experimental investigation was carried in two phases. In the first phase three mortar mixes 1:1/0.34, 1:1.15/0.35 and 1:1.2/0.37 were prepared using different grades of cement (43,53 grade OPC and slag cement). For each mix the w/c ratio was selected in such a way that a minimum of 75%

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flow was attained. Thus the w/c ratios arrived were 0.34, 0.35 and 0.37 for the mortar mixes 1:1, 1:1.15, 1:1.2 respectively. In each mix the parameters varied were the percentage replacement of cement with silica fume (0,5,10,15 and 20% by weight of cement). From this study an optimum percentage of silica fume that gives higher compressive strength was found. The second phase of investigation was aimed at determining the optimum dosage of Superplasticizer (by varying the dosage of superplasticizers 0, 0.2, 0.4, 0.6.0.8 and 1.0).

Materials

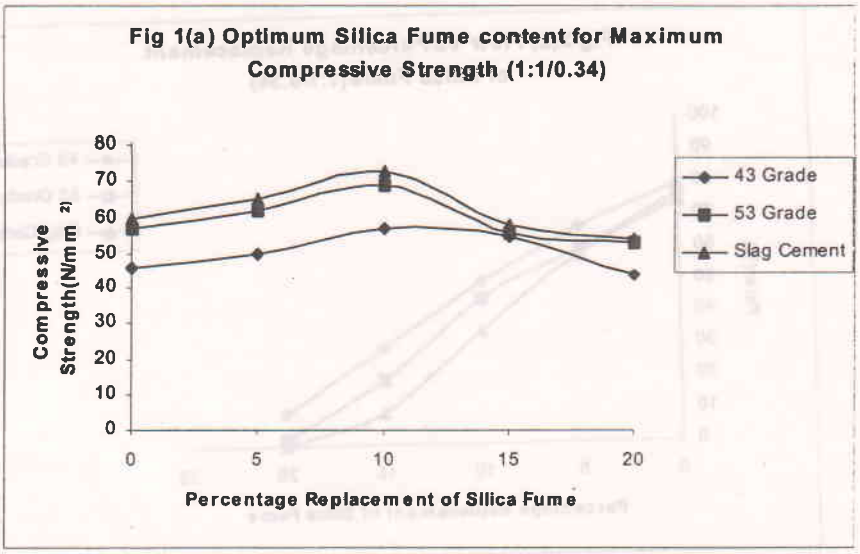
- **Cement**: Three grades of cement 53, 43 grade OPC and slag cement were used. These were according to IS: 12269-Code of Practice confirming to 53 Grade Ordinary Portland Cement[5], IS:8112-Code of Practice confirming to 43 Grade Ordinary Portland Cement[6] and IS:455-Code of Practice confirming to Slag Cement[7] respectively, with specific gravities 3.12,3.15 and 3.161.
- **Sand**: Locally available river sand confirming to IS: 650-Code of Practice confirming to Standard Sand for Testing of Cement[8], passing through sieve size of 1.10 mm was used. The Fineness modulus of sand was 2.4 and specific gravity was 2.44.
- **Water**: Potable water was used for mixing and curing purpose.
- **Silica fume**: The mineral admixture was obtained from a near by Ferro Silicon Alloy Industry. The silica content was about 92% and the lime reactivity 2.34. The compressive strength was 14.35 N/mm^2. The initial and final setting times were 40 minutes and 143 minutes respectively. The specific gravity was 1.84 and the fineness by wet sieving on a 45μm sieve was 5.04%.
- **Superplasticizer**: Sulphonated Naphthalene condensate (SNF) was used as a superplasticizer for the present study. The specific gravity of SNF was 1.18 and at 25°C it has a good compatibility with Portland and slag cements.

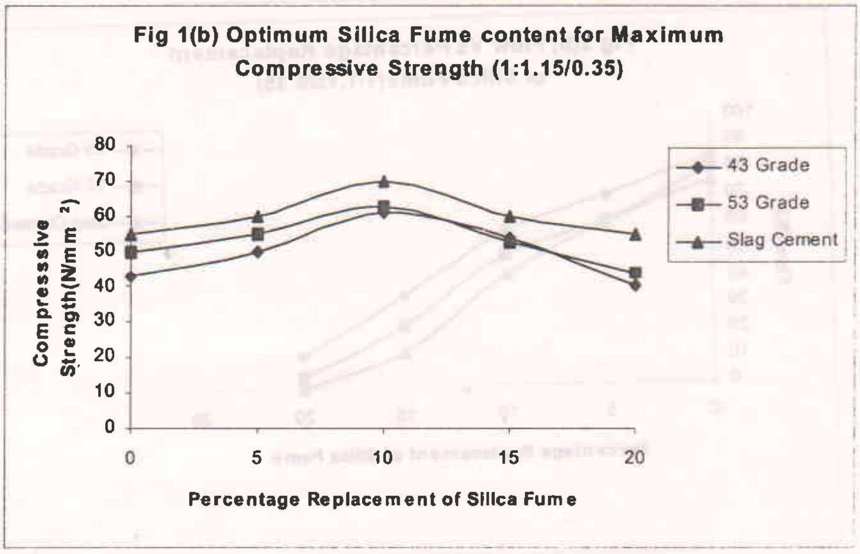
Casting and Testing

A total of 135 mortar cubes of standard size were cast. In the first phase of investigation both flow and strength were measured by varying the silica fume content. The flow was measured as per IS:1199-Code of Practice for methods of Sampling and analysis of concrete[9]. The cured specimens were tested using Tinius Olsen testing machine of capacity 1810KN as per IS: 516-Code of Practice for Testing the Strength of Concrete[10]. The results are presented in Table-1 for different grades of cement at 28 days. The variation of compressive strength and flow for different silica fume contents are shown in Fig.1 and 2 respectively.

INTERPRETATION AND DISCUSSION OF TEST RESULTS

The results obtained from the experimental investigations were tabulated in Tables 1, 2 and 3. From the results obtained the effects of silica fume and superplasticizers on the flow and compressive strength were analyzed.





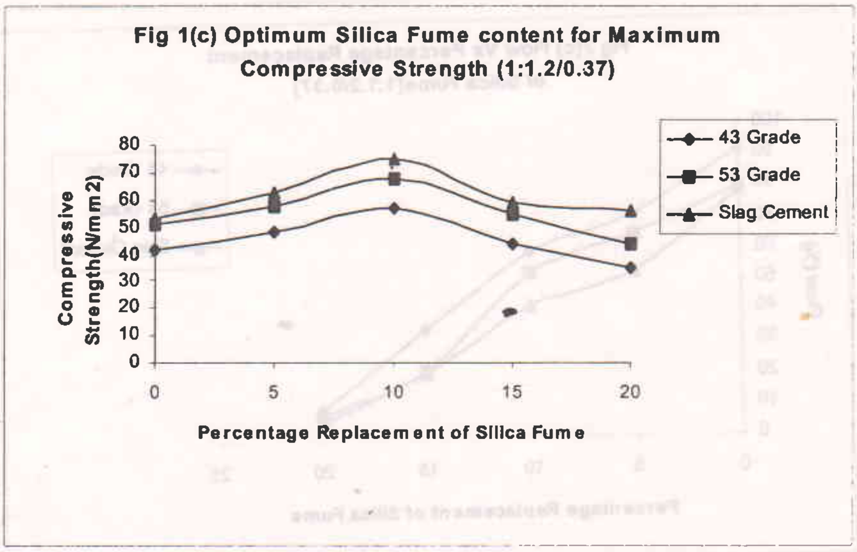


Fig. 1. The variation of compressive strength for different silica fume contents

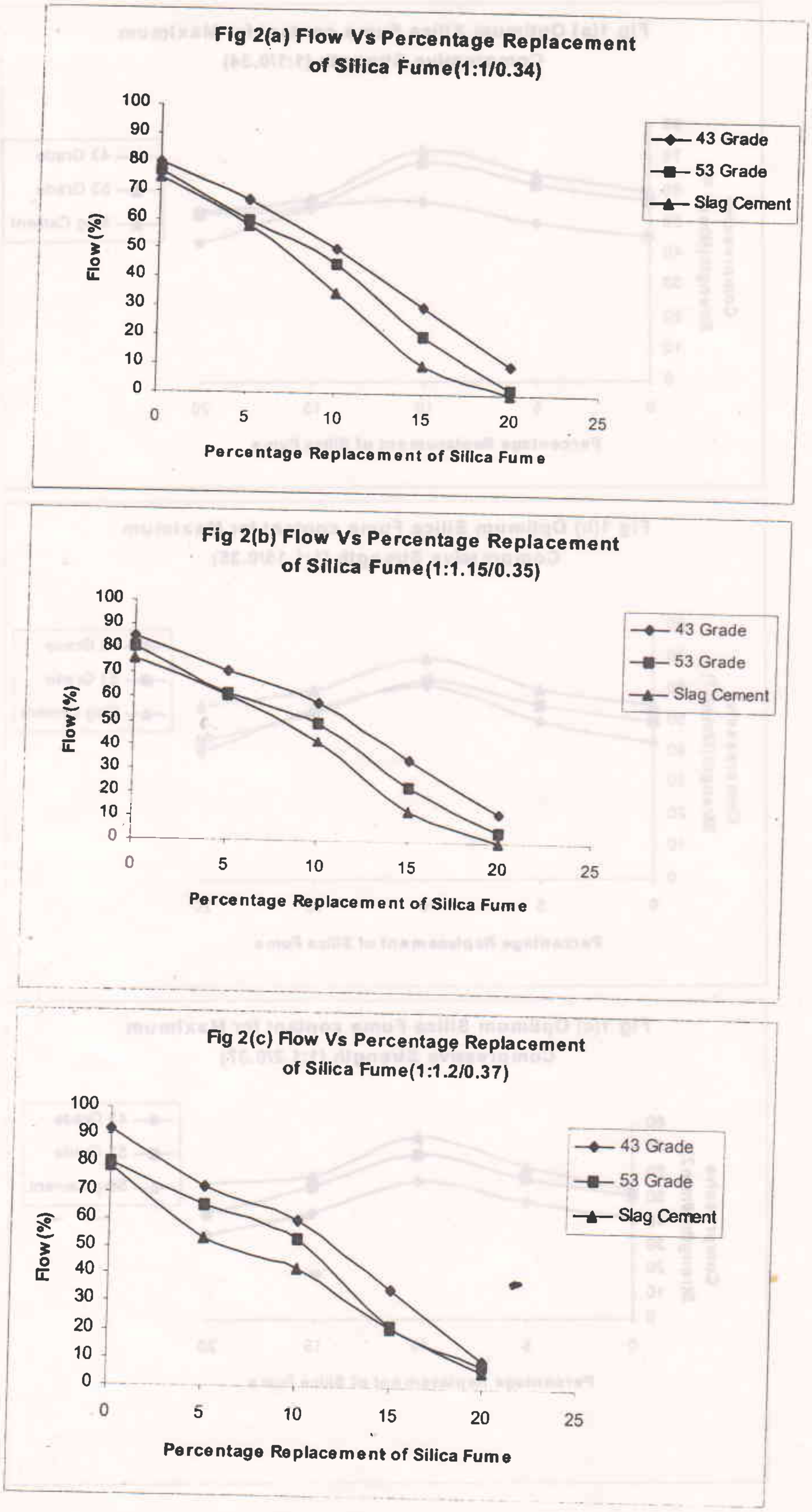


Fig. 2. The variation of flow for different silica fume contents

Effect of Variation of Silica Fume on Compressive Strength and Flow

From Table 1 and Fig. 1, it is evident that with an increase in the dosage of silica fume content, for the three different mixes and for all the three grades of cement, there is a gain in the compressive strength upto about 10% replacement and beyond, there is a decrease. The optimum dosage for replacing silica fume in cement can hence be fixed at 10%. However, the dosage of silica fume can be increased to 15% as the compressive strength of silica fume concrete was more than that of ordinary concrete for all the mixes adopted. From Table 1 and Fig. 2 it is clear that there is a general decrease in the flow for different grades of cement and for different mixes. Further, it was observed that use of slag cement has resulted in a higher decrease in flow as compared to 43 and 53 grades for all the three mixes. At the optimum dosage of 10% silica fume replacement in cement, though there is a higher compressive strength of slag cement mortar this material was not found suitable for ferrocement work due to low flowability. However, this can be overcome by using suitable superplasticizers. In the second phase of investigation the optimum dosage of superplasticizers was obtained by maintaining a minimum of 75% flow for silica fume mortars.

Table 1 28-Day Compressive strength and Flow values for variation in silica fume content

Mix	% of Silica Fume	43 grade cement		53 grade cement		Slag cement	
		28day Compressive Strength(Mpa)	Flow (%)	28day Compressive Strength(Mpa)	Flow (%)	28day Compressive Strength(Mpa)	Flow (%)
1:1/0.34	0	46	80	57	77	60	75
	5	50	67	62	60	65	58
	10	57	50	69	45	73	35
	15	55	30	56	20	58	10
	20	44	10	53	2	54	0
1:1.15/0.35	0	43	85	50	81	55	76
	5	50	71	55	62	60	61
	10	61	58	67	50	70	42
	15	54	34	53	23	60	13
	20	40	12	44	4	55	0
1:1.2/0.37	0	42	92	51	80	53	79
	5	48	72	58	65	63	53
	10	57	60	68	53	75	42
	15	44	35	55	22	59	21
	20	35	10	44	8	56	6

Effect Of The Dosage Of Superplasticizer On Flow

Maintaining the optimum dosage of silica fume at 10% the variation in the dosages of superplasticizers (0.2, 0.4, 0.6, 0.8 and 1.0 % by weight of cement) were studied on flow for all the three mixes and all the three grades. The results are shown in Table 2 and plotted in Fig. 3. From the figure it is very much evident that as the superplasticizers dosage exceeds 0.6% the variation in the flow has almost reached a constant value. Hence the optimum dosages of superplastizer for achieving the desired flow may be kept at 0.6%.

Table 2 Flow values for optimum silica fume dosage

% SP	FLOW TABLE VALUES(%)								
	43 GRADE			53 GRADE			SLAG CEMENT		
	1:1/0.34	1:1.15/0.35	1:1.2/0.37	1:1/0.34	1:1.15/0.35	1:1.2/0.37	1:1/0.34	1:1.15/0.35	1:1.2/0.37
0	50	55	60	50	52	58	35	42	53
0.2	87	91	112	77	97	95	75	82	91
0.4	100	111	120	107	111	120	92	97	112
0.6	110	120	127	120	122	128	118	130	132
0.8	113	122	128	122	128	130	121	125	128
1.0	115	124	130	126	131	134	123	132	131

Effect of optimum silica fume and Superplasticizer on Strength and Flow

The compressive strength of 100mmx100mm mortar cubes for optimum silica fume and superplastizer additions are presented in Table 3 and shown in Fig. 4 for 3, 7 and 28 days. The flow values are also shown in the same table for optimum values of silica fume and superplasticizers and the variation for all the three grades and mixes are plotted in Fig. 5.

In general, the use of slag cement, optimum silica fume and suitable superplasticizer content has resulted in a compressive strength of 81 Mpa with a flow value of 118% for mix 1:1/0.34. Hence high strength mortars with a good performance with respect to flow can be developed. The high strength and high flowability mortar mixes for use in ferrocement applications can be developed and these mortars are High Performance Mortars.

The Shrinkage and Sorptivity observations were reported in Part-2[4] and it was concluded that the superplasticized silica fume mortars are less porous and also there was a general decrease in shrinkage with addition of silica fume and superplasticizer. The sorptivity also decreased with the use of such a combination

Table 3 compressive strength and flow values (optimum dosages of superplasticizer and silica fume)

Grade	Mix	Compressive Strength(Mpa)			Flow(%)
		3 Day	7 Day	28 Day	
43 Grade cement	1:10/0.34	26	40.0	62.0	110
	1:1.15/0.35	24	38.0	58.0	120
	1:1.2/0.37	21	31.0	55.0	127
53 Grade cement	1:10/0.34	27	42.0	70.5	120
	1:1.15/0.35	23	38.5	63.0	122
	1:1.2/0.37	23	33.0	61.0	128
Slag cement	1:10/0.34	38	58.0	81.0	118
	1:1.15/0.35	38	63.0	76.0	130
	1:1.2/0.37	34	53.0	78.0	132

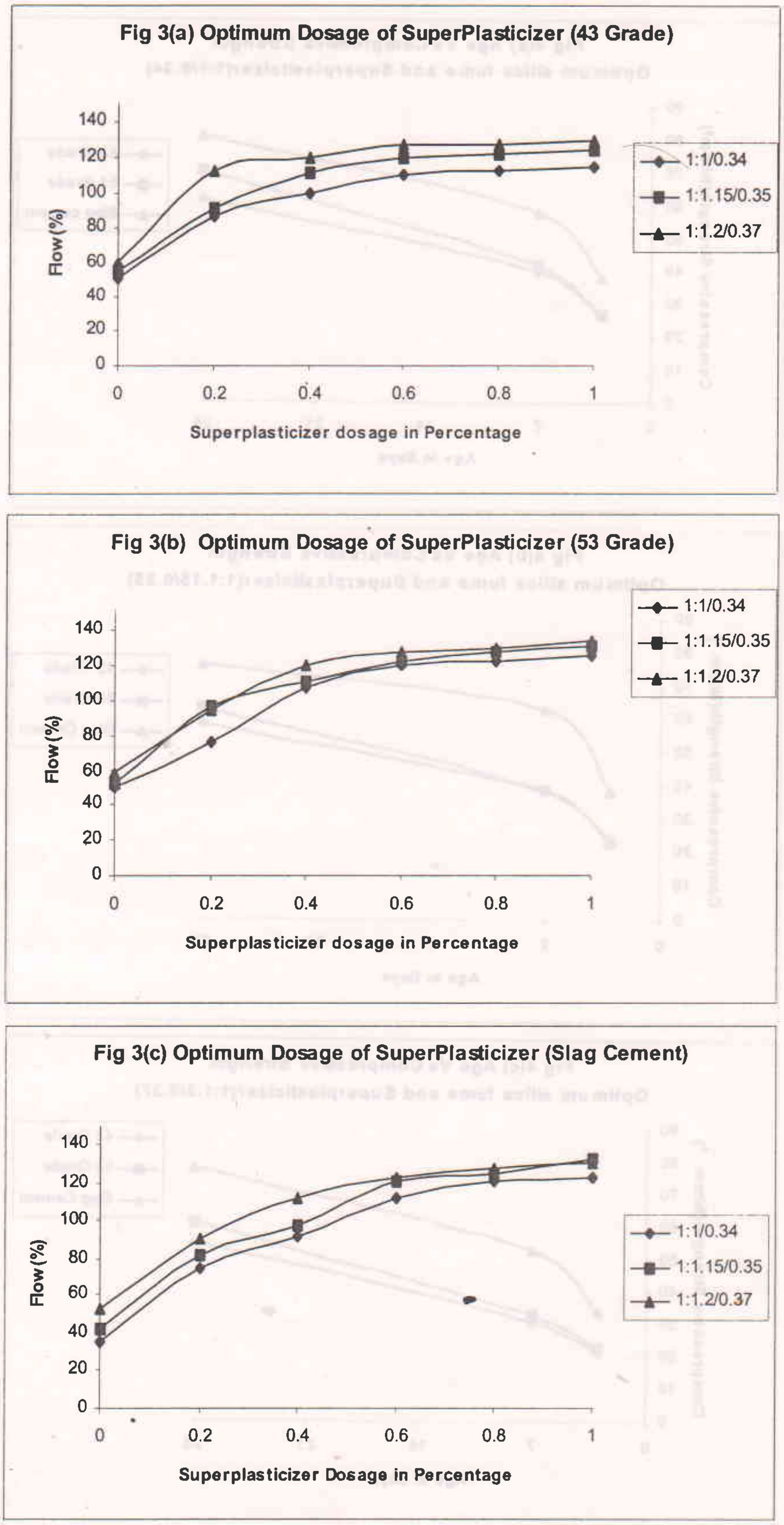


Fig. 3. Optimum Dosage of SuperPlasticizer

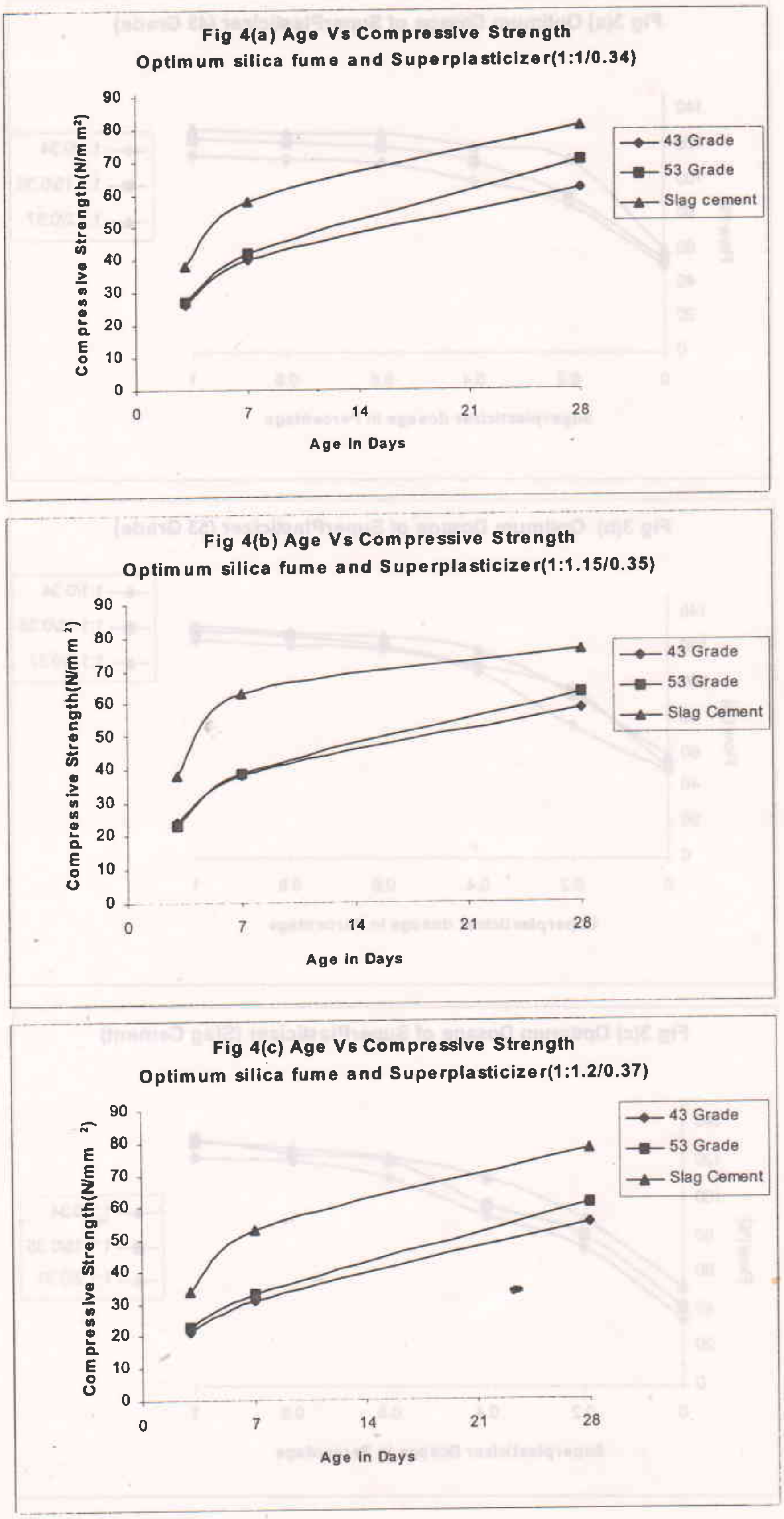


Fig. 4. The compressive strength of mortar cubes for optimum silica fume and superplastizer

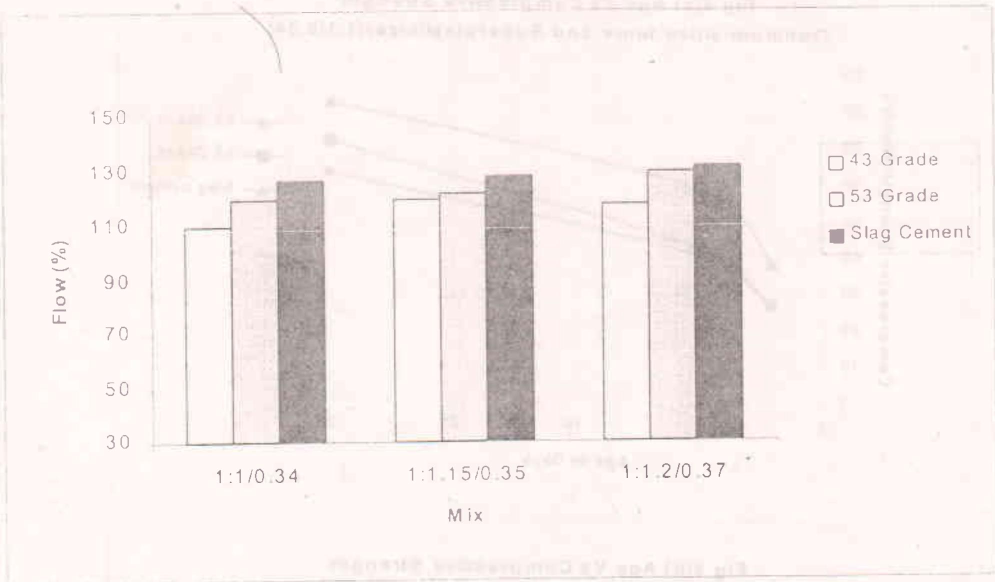


Fig. 5. Variation of Flow with Mix (Optimum Silica Fume and SuperPlasticizer)

CONCLUSIONS

The following conclusions can be drawn from the compressive strength and flow studies on rich mortar mixes using silica fume and superplasticizer.

1) Replacement of cement by silica fume increased the compressive strength of all the mortar mixes.

2) 10% replacement of cement with silica fume gave maximum strength in all the mortar mixes. However even upto 15% replacement of cement with silica fume yield strengths of mortar mixes which are not less than that of the control mortar mixes.

3) The presence of silica fume requires an increased amount of superplasticizer to maintain consistency and flow of mortar mixes as compared to that of control mortar mixes.

4) With an increase in the grade of cement there was a drop in the flow values for all the mixes. Using Sulphonated Naphthalene Formaldehyde(SNF) condensate as superplastizer improved the flow to 100% and above.

5) For a constant cement/silica fume ratio, the flow of mortar is improved by increasing the aggregate /cement ratio, with all the three cement types.

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