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Mix Design of High Performance Concrete Using Silica Fume and Superplasticizer

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Abstract: High Performance Concrete (HPC) now a days used widely in the construction industry world wide. To produce HPC with normal ingredients we use mineral admixtures like Silica fume, fly ash and metakoline and workable agents Superplasticizers are also used. The usage of mineral admixtures in the concrete not only enhances its strength properties but also durability. The compressive strength are investigating finding the optimum use of mineral admixture(Silica fume of levels 0, 5, 10,15, 20 and 25% at 7 days and 28 days of curing). The present investigation aims to give design mix for HPC by using silica fume and superplasticizers.

Keywords: High Performance Concrete, Silica Fume, Superplasticizer and Compressive Strength.

I.INTRODUCTION

High performance concrete (HPC) exceeds the properties and constructability of normal concrete. Normal and special materials are used to make these specially designed concrete that must meet a combination of performance requirements. HPC are made with carefully selected high quality ingredients and optimized mixture designs. HPC will have a low water cement ratio of 0.2 to 0.45. Super Plasticizers are usually used to make these concretes fluid and workable. HPC almost always has a higher strength than normal concrete.

There are many methods of mix design for HPC. The methods proposed by ACI[1], Aitcin[2], Islam Laskar and Talukdar[3] are some methods. In the above methods, the first importance is given to selection of water-binder ratio(w/b) for a given targeted strength, even though the w/b ratio is not a very good predictor of compressive strength of HPC, the use of admixture like silica fume with a superplasticizer as workable agent is now an usual way to obtain high-performance concrete. VinayagamP [4] conducted experiments with silica fume and superplasticizers on high performance concrete with replacement of silica fume 0 to15% and the HPC mixes are tested experimentally for workability, compression, split tension and flexure and concluded that the performance of the design mixe are very good. Hooton [5] conducted experiments on replacement of cement with silica fume and studied physical properties and durability properties like freezing, thawing, sulphate attack and alkali-silica reactivity. He concluded that 28 days compressive strength was maximum at 15% silica fume replacement at a w/b ratio of 0.35 with variable dosage of superplasticizers. Yogendran and Langan [6] investigated on high-strength silica fume concrete at a w/b ratio of 0.34 and percentage of replacement of silica fume 0 to 25, with the varying dosage of superplasticizer and reported that maximum replacement level of 15%. Annadurai and ravichandran [7] conducted experiments for mix design of high strength concrete with admixtures, varying superplasticizer with a range 0.6 to 0.9% with an increment of 0.1% and concluded that addition of silica fume increases

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compressive strength and decreases the slump. Shreekedar and Kumbhar [8] studied the effect of mineral admixtures in mix proportioning of HPC, micro silica is replaced by weight of cement along with suitable super plasticizer, and concluded that better strengths are achieved for 15% replacement .

II. RESEARCH SIGNIFICANCE

The main objective of this present investigation is to develop a mix design procedure, for HPC by varying the percentage of Silica fume (0 to 25%) at constant dosage of superplasticizers and other ingredients, literature available on HPC and ACI code methods. Experiments were carried out on HPC using the above procedure for M60 concrete to obtain good workability and achieve mechanical properties of the mix design and to find the optimum percentage of Silica Fume. Hence the present investigation more emphasis is given to study strength characteristics of HPC using mineral and chemical admixtures like Silica fume and Superplasticizer, for achieving the better composite and also to increase use of Silica fume to maintain ecology and also encourage the use of silicafume.

III. EXPERIMENTAL PROGRAM

A. Materials Used

Ordinary Portland cement of 43 grade, confirming to IS 8112:1989 [9], and locally available river sand as fine aggregate (zone-II) confirming to IS-383-1970 [10] and coarse aggregates (10 mm 31%, and 20mm 69% by weight) were used in the present investigation. The properties of fine aggregate and coarse aggregate are presented in Table 1 and 2 respectively. Properties of cement are shown in Table.3. Superplasticizer (Chemical admixture) suphonated naphthalene formaldehyde CONPLAST SP 430 confirming to BIS 9103-1999 is used as workable agent. Silica fume (Mineral admixture) obtain from ELKEM INDIA(P) LTD, Confirming to ASTM C-1240 in densified form is used.

Table.1 Properties of Fine Aggregate

Sieve Size	Weight retained in Sieve (grams)	% retained	Cumulative % retained	% passing
10 mm	-	-	-	100
4.75 mm	55	5.5	5.5	94.50
2.36 mm	90	9.0	14.5	85.50
1.18 mm	143	14.3	28.8	71.2
600 microns	204	20.4	49.2	50.80
300 microns	312	31.2	80.4	19.60
150 microns	178	17.8	98.2	1.80
Pan	18	1.8	100	0

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Table.2 Properties of Coarse Aggregate

Coarse aggregate	Specific gravity	Bulk density (kg/m ³)	Water absorption (%)
CA	2.66	1535	0.52

Table.3 Properties of Cement

Property	Result
Normal Consistency	32%
Setting Time	
Initial	105 min
Final	375 min
Specific Gravity	3.14
Fineness of Cement (By 90 micron sieve)	2% retained
Compressive Strength	
7 days	36 N/mm ²
28 days	58 N/mm ²

B. Mix Proportions of HPC:

For HPC there is no specific method of design mix. In the present investigation ACI method and as also the available literatures on HPC are used. In order to achieve high strength lower w/b ratio is adopted and to achieve good workability superplasticizer is used. The trial mix proportions of the concrete are shown in Table 4. In the present investigation w/b ratio used is 0.29 and dosage of Superplasticizer is 5.11 Kgs/Cum and 28 days target mean strength for all mixes was 69 Mpa.

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Table 4 Mix proportions of concrete (kg/m³)

Nomenclature	w/b	Cement (Kg)	Fine Aggregate (Kg)	Coarse Aggregate (Kg)	water (Kg)	Super plasticizers (Kg)	Silica fume (Kg)
HPC1	0.29	511	773	1044	143	5.11	0
HPC2	0.29	486	773	1044	143	5.11	25.55
HPC3	0.29	461	773	1044	143	5.11	51.10
HPC4	0.29	436	773	1044	143	5.11	76.65
HPC5	0.29	411	773	1044	143	5.11	102.20
HPC6	0.29	386	773	1044	143	5.11	127.75

C. Preparation of Test Specimens

Six concrete mixes were cast with replacement of 0, 5, 10, 15, 20 and 25% silica fume with cement, at a 0.29% w/b ratio. For all the mixes the ratio of cementitious matrix (Cement + Silica fume) to coarse aggregate and fine aggregate was maintained the ratio of 1:1.40:1.89. The slumps are measured and the slump values are decreased when the silica fume increases and the results are showed in Table.5. The cubes and cylinders are casted and cured in curing pond. At 7 days and 28 days (cubes of size 150 mm x 150 mm x 150 mm and cylinders of size 150 mm x 300 mm) were tested for compressive strength of cubes and compressive strength of cylinders and the results are shown in Table.6 and Table.7. The compressive strength of cubes are shown in Fig.1

Table.5 Slump with replacement levels of Silica fume

S.No	Replacement Level	Slump
1	0	95
2	5	82
3	10	77
4	15	71
5	20	64
6	25	58

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Table. 6 Average value of Cube Strength and cylindrical strength of concrete (MPa)

Nomenclature	Cube compressive strength (f_{cu}) 7 days	Cylinder compressive strength (f^l_c) 7 days
HPC1	53.6	42.54
HPC2	56.40	44.58
HPC3	58.88	45.86
HPC4	60.00	49.93
HPC5	58.88	46.87
HPC6	56.80	43.82

Table. 7 Average value of Cube Strength and cylindrical strength of concrete (MPa)

Nomenclature	Cube compressive strength (f_{cu}) 28 days	Cylinder compressive strength (f^l_c) 28 days
HPC1	59.55	47.37
HPC2	62.67	49.49
HPC3	65.33	50.90
HPC4	71.11	55.85
HPC5	67.33	52.32
HPC6	63.11	48.78

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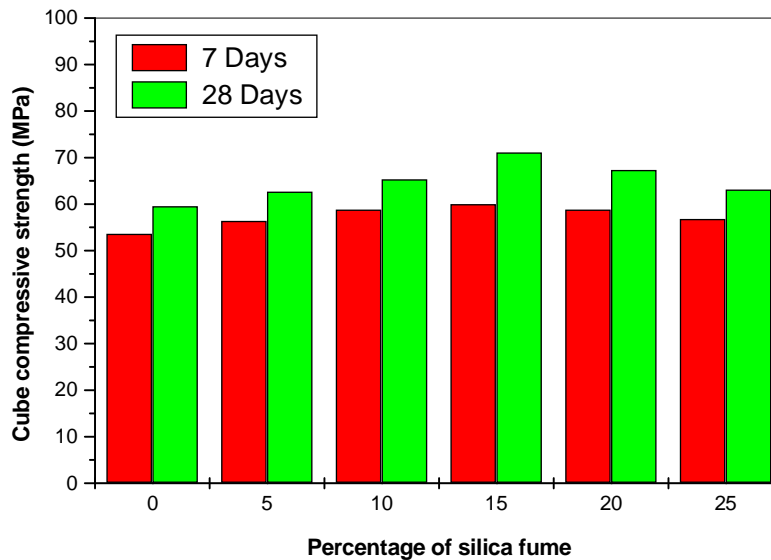


Fig.1 Percentage of silica fume replacement with cement Vs compressive strength

IV. DISCUSSION OF TEST RESULTS

Replacement of cement by silica fume in HPC improved of compressive strength up to 15% replacement and after that the strength were reduced both for 7days and 28 days. This may be due to the fact that the decrease of strength is due to pozzolonic reaction and filler effect of Silica fume.

V. CONCLUSION

The following conclusions can be made on the basis of the current experimental results.

1. A mix design procedure for HPC using silica fume and super plasticizer is formulated by ACI method of mix design and available literature on HPC.
2. As the silica fume content increases the compressive strength increases up to 15% [HPC4] and then decreases. Hence the optimum replacement is 15%.
3. The 7 days and 28 days cube compressive strength ratio of HPC is 0.84 to 0.9
4. The percentage replacement of cement by silica fume increases, the workability decreases.

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APPENDIX

Mix Proportion Of M60 Grade Concrete

STIPULATIONS FOR MIX PROPORTIONING

Characteristic Compressive Strength = 60 N/mm²

Maximum size of aggregate = 20 mm

Degree of workability (slump) 50-100 mm

Degree of quality control Good

Type of exposure Severe

TEST DATA OF THE MATERIAL

Cement OPC – 43 G

Specific Gravity of Cement 3.14

Specific Gravity of C A 2.66

Specific Gravity of F A 2.62

The Target mean strength

$$f_m = f_{min} + ks$$

Where

f_m = Target mean strength at 28 days.

f_{min} = Characteristic Compressive Strength at 28 days

k = A statistical value depending upon the results and no of test.

s = Standard deviation

$$f_m = 60 + 1.65 \times 5 = 68.25 \text{ N/mm}^2$$

From ACI 211.4R Table 4.3.4 Assuming slump as 50 to 75 mm and for C.A size 20 mm the Mixing water is = 174 lit. on experience the water content usage is 148 lit

Cement Content is calculated From ACI 211.4R Table 4.3.5(b)

Take W/b ratio = 0.29

Weight of Cement = 148/0.29 = 510.34 Kg/cum, Say 511 Kg/cum.

From ACI 211.4R Table 4.3.3 Dry rodded volume of coarse aggregate is 0.68% of volume of concrete.

Wt. of CA = 0.68 x 1535 = 1043.80 Kg/cum, Say 1044 Kg/cum.

Material	Wt. kg/cum	Absolute Volume cum
Weight of water	148	148 / 10 ³
Weight of cement	511	511/3.14 =162.73 / 10 ³
Weight of Coarse Aggregate	1044	1044/2.66=392.4 / 10 ³
Entrapped air		2 / 10 ³
	Total =	705.13 / 10 ³

Therefore absolute volume of fine aggregate = [(1000 / 10³) – (705.13 / 10³)]

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$$= 294.87 \times 10^3$$

Absolute volume of fine aggregate = $0.295 \times 2.62 \times 1000$

$$= 772.9 \text{ kg/cum, Say } 773 \text{ Kg/cum.}$$

Super plasticizer: use 1% $(1/100) \times 511 = 5.11$ lit

Correction for water :

Weight of water = $148 - 5.11 = 142.89$ lit, Say 143 lit.

Calculated quantities of materials per cum of concrete are

Cement = 511 Kg

Fine Aggregate = 773 Kg

Coarse Aggregate = 1044 Kg

Water = 143 lit

Super plasticizer = 5.11 lit

Silica fume = 75 Kg/cum

W/C = 0.29