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Structural Performance of Building Blocks using Silica Fume

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Abstract—*Popularity of concrete building blocks using additives is increasing at a fast pace mainly due to their structural strength and economic viability compared to other conventional building materials. Industrial wastes such as fly ash and silica fume are excellent supplementary cementitious materials which can be employed to build concrete blocks due to their reactive pozzolanic characteristics. Moreover, the excessive consumption of sand as fine aggregates in construction works poses environmental degradation, which prompts engineers to develop blocks using alternate source in the context of sustainable building materials. Keeping this in mind in this study, concrete blocks were made by partial replacement of fine aggregate with fly ash and silica fume for concrete of grade M25. First, the optimum percentage of fly ash to be used in concrete was calculated by experimental analysis and then keeping the amount of fly ash constant the effect of silica fume was investigated by varying the percentage from 5 to 25%. The examined workability and strength characteristics of concrete mix after curing for 7 days, 14 days and 28 days showed remarkable improvement.*

1. INTRODUCTION

Recently, the concrete blocks containing admixtures have mesmerized the construction industry because of their variety, structural strength and cost effectiveness over other conventional construction materials [1,2]. Concrete is generally graded according to its compressive strength as per IS-156, 2000 and there are fifteen grades from M10 to M80 of concrete in the designation of concrete mix, the letter M refers to the concrete mix and the number refers to the specified characteristic strength of concrete at 28 days expressed in MPa [3]. Aside from grading for structural properties, many materials have grades to determine if they are of finish quality or not, which is certainly true of wood and steel. Industrial wastes such as fly ash and silica fume are excellent supplementary cementitious materials which can be employed to build concrete blocks of better strength [4-7]. This has an advantage as the use of sand is minimized by replacing sand with industrial waste in because the excessive consumption of sand as fine aggregates in construction works poses environmental degradation. This makes the engineers to realize the importance of developing blocks using alternate source in the context of sustainable building materials. Fly ash and Silica fume are industrial by-products, generated mainly in thermal power station and silicon metal industry. These are treated as an environmental pollutant. This paper reports, the formation of concrete blocks made by partial replacement of fine aggregate with fly ash and silica fume for concrete of grade M25. First, the optimum percentage of fly ash to be used in concrete was calculated by experimental analysis and then keeping the amount of fly ash constant the effect of silica fume was investigated by varying the percentage from 5 to 25%. The examined workability and strength characteristics of concrete mix after curing for 7 days, 14 days and 28 days showed remarkable improvement. These concrete blocks find use in construction works and are found to be fireproof, vermin proof and weather proof.

2. 2. MATERIALS AND METHOD

2.1 Materials

In casting building concrete blocks the main ingredients are cement, fine aggregate and coarse aggregate. Ordinary Portland cement of grade 53 (IS456-2000) cement was procured from JK LAKSHMI CEMENT LTD, village Bajitpur, Post Jarli, Jhajjar, Haryana, India and sand was obtained from the bank of Yamuna River flowing in Sonepat, Haryana, India. The sand was washed to remove clay and silt and then sieved through IS sieve no. 4.75 mm possessing 2.4 Fineness Modulus. Coarse aggregate was obtained from construction site near the laboratory, which were sieve through 20 mm sieve. Fly ash was obtained from thermal power station, Jharli, district Jhajjar, Haryana, India and silica fume was obtained from industrial waste of silicon industry [8]. Test were conducted taking M25 grade of concrete keeping water cement ratio 0.5(w/c) and 0.6(w/c). In this project, partial replacement of fine aggregate was carried out first with fly ash and suitable amount providing desired strength and workability was determined experimentally. The percentage of fly ash was kept constant i.e. 15% and percentage of silica fume was varied from 0% to 25% gradually. At least 6-8 blocks of each composition were prepared, in which the percentage of silica fume was put precisely and recorded in table 1.

Table 1 Composition of concrete blocks

Specimen No.	w/cm		Percentage of Mix		
			Cement %	Fly ash %	Silica fume %
S_0	0.5	0.6	85	15	0
S_1	0.5	0.6	80	15	5
S_2	0.5	0.6	75	15	10
S_3	0.5	0.6	70	15	15
S_4	0.5	0.6	65	15	20
S_5	0.5	0.6	60	15	25

2.2 Methodology

Conventional rotary drum concrete mixer was used for blending the concrete mix. To prepare the mix the coarse aggregates of size 20 mm were loaded in drum and poured a small amount of water first, then all the constituents required for casting moulds were loaded one by one (sand, cement, fly ash, silica fume and calculated water) and rotated for 3-4 minutes. The concrete was shifted immediately to vibrating machine and finally casted blocks having dimension 100 ×200 ×400 mm. The samples after 24 hours were taken out of the mould and cured for 7 days, 14 days and 28 days. The average area of all the blocks was calculated. Workability and compressive strength were evaluated on these concrete blocks according to the Indian standard codes i.e. IS 456: 2000.

3. RESULTS AND DISCUSSION

3.1 Workability

The slump test signifies the workability of concrete, which indicates water-cement ratio, but there are various other factors like properties of materials, mixing methods, dosage, admixtures, which affect the concrete slump value. The instrument to determine slump provides immediate results (recorded in mm) to know the workability of specimens. This test is extensively used to test workability since 1922 because it is very simple and entails low cost. The slump is determined as per procedures mentioned IS: 1199 – 1959 in India. The values of slump are given in Table 2 and graphically represented in Figure1. The figure clearly shows 22.38% decrease in the specimens from A_1 to A_5 while 30.93% decrease in specimens from B_1 to B_5 upto15% increase in silica fume. Moreover, the graph further shows a decrease till 25% increase in silica fume. Therefore, the optimal percentage of additive is found for A3 and B3 specimens of concrete blocks.

Table 2 Slump values of samples

Sr. No.	Sample Designation	Slump (mm) 0.5(w/c)	Sample Designation	Slump (mm) 0.6(w/c)
1.	A_0	67	B_0	59
2.	A_1	62	B_1	54
3.	A_2	58	B_2	47
4.	A_3	52	B_3	41
5.	A_4	45	B_4	35
6.	A_5	34	B_5	26

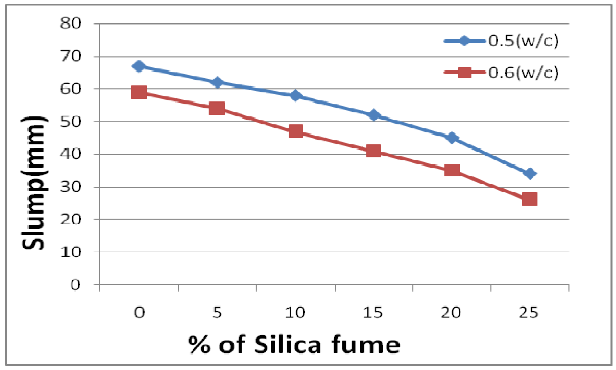

Figure 1 Slump on partial replacement with silica fume

3.2 Compressive strength

The concrete characteristics are qualitatively dependent on its compressive strength, hence the standard compressive strength of designed specimens of concrete blocks after being cured for 7 days, 14 days and 28 days were tested by loading them till failure using a compression testing machine [9]. Then the load value was recorded at maximum failure, which was used to determine the compressive strength. The area of at least six similar compositions of blocks was calculated. At least five load readings of each block of A and B series were recorded and calculated the average compressive strength in N/mm^2 using formula: Compressive Strength = P/A, where P is the maximum load (Newton) and A is the area in mm^2. From the recorded value at maximum load, the compressive strength was determined for $A_{1\text{-}5}$ and $B_{1\text{-}5}$ series of specimens (water-cement ratios 0.5 and 0.6) having the increasing percentage of silica fume as shown in Table 3 and 4.

Table 3 Average Compressive Strength of specimens for 0.5(w/c)

Sr. No.	Specimen Designation	Average Compressive Strength (N mm^{-2})		
		7 Days	14 Days	28 Days
1	A_0	17.39	24.53	27.42
2	A_1	18.36	25.82	29.34
3	A_2	19.21	27.65	31.67
4	A_3	21.63	29.54	32.58
5	A_4	21.17	29.22	32.24
6	A_5	20.25	28.46	31.85

Table 4 Average Compressive Strength of specimens for 0.6(w/c)

Sr. No.	Specimen Designation	Average Compressive Strength (N mm^{-2})		
		7 Days	14 Days	28 Days
1	B_0	16.14	24.12	26.86
2	B_1	17.64	24.94	28.63
3	B_2	18.58	26.44	30.54
4	B_3	20.56	28.18	31.96
5	B_4	20.12	27.75	31.32
6	B_5	19.15	27.24	30.66

The results of compressive strength for 28 days demonstrate that the strength increases by 18.81% for A series and by 18.98% for B series with increase in percentage of silica fume from 5% to 15% and thereafter the values start to decline in both water cement ratios as depicted in Figure 3and 4. The figures reveal that the decline in average compressive strength of B series is greater than A series but the average decrease in both the water cement ratios is more or less the same. For 7days and 14 days also an increasing trend is observed for strength till 15% increase, which decline on further use of silica fume. Therefore, the use of silica beyond 15% is not recommended.

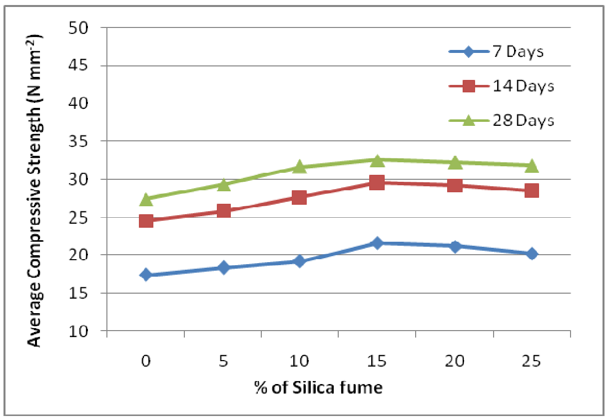

Figure 2 Average Compressive Strength on partial replacement with silica fume for 0.5(w/c)

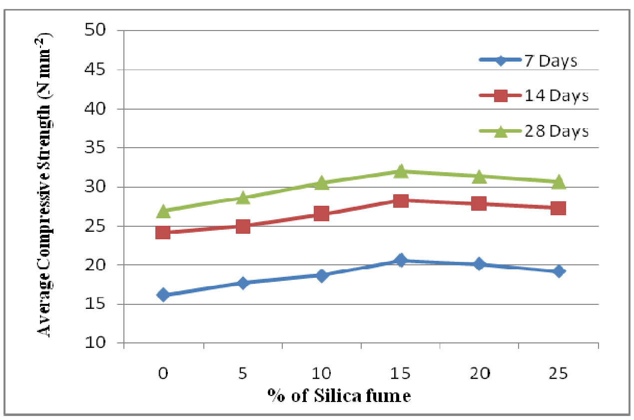

Figure3 Average Compressive Strength on partial replacement with silica fume for 0.6(w/c)

4. CONCLUSION

It is concluded from the results of 28 days of compressive strength for 0.5w/c and 0.6w/c that decrease is approximately 18% in both the series (A and B) of prepared blocks up to 15% replacement of fine aggregate with silica fume for concrete of grade $M_{25.}$ Similar pattern was observed for compressive strength of 7days and 14days but with reduced strength as curing requires minimum 28 days. The workability was found to be in decreasing order and a drop of 22-33% was seen for slump values of A and B series of blocks up to fifteen percent. Hence the percentages of silica fume and fly ash recommended for M_{25} blocks is 15% each beyond this percentage it starts losing its compressive strength and have a large drop in its workability.

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