Strength characteristics of M_{25} concrete blocks using pozzolanic materials

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Abstract

Fly ash and silica fume due to their pozzolanic characteristics are very good admixtures for the development of new concrete blocks, which find application in a variety of construction works such as highways, bridges, housing and industrial infrastructures. Recently, this field is gaining top priority as these admixtures materials are easily obtained as waste from coal thermal power stations and silicon metal and alloys industries. Moreover, the utilization of these in construction industry provides a practical solution to the problem of disposal of waste and has additional environmental benefits worldwide. This prompts researchers to develop blocks using alternate source in the context of sustainable building materials. Concrete blocks were made by partial replacement of cement with fly ash and silica fume for concrete of grade $M_{25.}$ Experimental analysis was done to optimize the percentage of fly ash to be used in the development concrete blocks, then by varying the percentage of silica fume from 5 to 20% the effect of silica fume was investigated. The compressive strength of concrete mix after curing for 7 days, 14 days and 28 days was examined experimentally.

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1. Introduction

Concrete block manufacturing is premier and fastest growing industrial sector through the world as concrete blocks are the backbone of construction structures. Clay bricks have been popularly used in India as well as in many foreign countries from ancient times due to the affordability and durability. Though manufacturing industries of these brickshave harmful eco impact[1,2],as a lot of coal is burnt in kilns. Thus the air and land both get polluted.To circumvent this problemresearchers are lookingfor alternative materials for production of eco-friendly construction material for sustainable housing, industrial infrastructures, bridges and highways.In this situation engineers find concreteblocks as ideal substitutes focussing a lot on production of. These are excellent substitutes for stone or wood in the construction of houses and United States was first to employ the concrete blocks as building materials. The fascinating and earliest known example of a house constructed of onlyconcrete blocks was in 1837 on Staten Island, New York. Popularity of these houses using the concrete blocks grew rapidly in the early 1900s through the 1920s probably due to easy availability of the raw materials required in production of concrete blocks on the sand banks and gravel pits of this country [3,4].These blocks were also used for fencingand many other types of buildings such as garages, silos, and post offices. A large number of these houses were madeparticularly in the Midwestern states[5-7].

Portland cement manufacturers also advertised in many catalogs, these concrete blocks as good material for building houses, moreover these were referred asfireproof, vermin proof, and weatherproof and as an inexpensive replacement for the ever-scarcer supply of wood. Utilization of industrial wastes are in trend in this 21st century, as the manufacturing process is cost effective and has no bad effect on environment because it does not consume of coal as no firing is required. Concrete blocks containing fly ash and silica fume industrial wastes are gaining enormous popularity as formation process requires simple curing process evading firing.Silica fume is a by-product obtained when silicon metal and alloys produced in electric furnaces.The raw materials used in the process are quartz, coal, and woodchips. The smoke coming from furnace operation is called silica fume which is collected and perhaps is the most important material which finds application as a mineral admixture in concrete bricks. Silica fume consists primarily of amorphous silicon dioxide (SiO_2). The individual particles are extremely small, approximately 1/100th the size of an average cement particle. Because of its fine particles, large surface area, and the high SiO_2 content, silica fume is a very reactive pozzolan when used in concrete bricks. The quality of silica fume is specified by ASTM C 1240 and AASHTO M 307.[8,9]

These materials are very durable and have very high strength. Fly ash is one of the industrial by-products, generated during the combustion of coal for energy production and it is recognized as an environmental pollutant[10,11]. Because of environmental problem of fly ash, a good deal of work and applications on the utilization of fly ash has been undertaken world-over. Fly ash properties results primarily from the type of coal burned, the type of combustion equipment used and the fly ash collection mechanism employed. In this research work, the desired concrete blocks were prepared utilizing industrial waste materials (fly ash and silica fume) as a replacement of the cement. First the percentage of fly ash was optimized experimentally by developing concrete blocks with only fly ash, and then the effect of admixture silica fume was examined by taking different percentages. These concrete blocks are found to possess high strength, low cost and improved performance against aggressive environment.

2. Materials and methods

Raw material cement, sand and coarse aggregate were purchased from local market. Fly ash was obtained from Indira Gandhi Super Thermal Plant, Jharli, district Jhajjar, Haryana, India and silica fume was obtained from industrial waste of silicon industry. Ordinary Portland cement of grade 53 (IS456-2000) was used in block making. This cement contains magnesium oxide(MgO) 6%, sulphuric anhydride(SO_3) 4%, Alumina Iron ratio 0.66%, Chloride (Cl^{-1}) 0.10%, Lime Saturation Factor ~1% and Loss on Ignition (LOI) is 4%. Sand pertaining to zone 11 of IS: 383-1970 andcoarse aggregate of maximum size 20 mm size were used.The fly ash/ silica fume contains significant amounts of silicon dioxide (SiO_2) 36 to 55% / 80 to 95%, aluminium oxide (Al_2O_3) 20 to 35% , iron oxide (Fe_2O_3) 0.5 to1.5% calcium oxide (CaO) 5 to 16% / 1% , sulphuric anhydride (SO_3) 0.5 to1.5%, and magnesium oxide (MgO) 1 – 5.5, Loss on Ignition(LOI) is 2% / 1% .

Water is an essential ingredient of concrete as it actually participates in the chemical reaction with cement and helps to from the strength giving cement gel, the. Hence thequantity as well as quality of water required to make blocks is very carefully selected. The author selected M_{25} grade of concrete and the water cement ratio was kept 0.5 (w/cm) in this experiment, partial replacement of ordinary Portland cement of grade 53 was done with fly ash first and optimal percentage of fly ash was determined, which ws found to be 15%. The percentage of fly ash was kept constant i.e. 15% and amount of silica fume was increased gradually. In this way, six test specimens of each (S_0 to S_8) were prepared containing silica fume 0% to 15 % with increase of 2.5 % in each sample. The proportions of various combinations of constituents taken for experimental analysis are tabulated in Table 1.

Table1 Percentages of different specimens of concrete block

Specimen No.	w/cm	Percentage of Mix		
		Cement %	Fly ash %	Silica fume %
S_0	0.5	85.0	15.0	0.0
S_1	0.5	82.5	15.0	2.5
S_2	0.5	80.0	15.0	5.0
S_3	0.5	77.5	15.0	7.5
S_4	0.5	75.0	15.0	10.0
S_5	0.5	72.5	15.0	12.5
S_6	0.5	70.0	15.0	15.0
S_7	0.5	67.5	15.0	17.5
S_8	0.5	65.0	15.0	20.0

In order to make concrete blocks first the coarse aggregates of size 20 mm were loaded in conventional rotary drum concrete mixer and a little water was put for mixing, then all the ingredients such as sand, cement, fly ash, silica fume and the remaining of water was added in the ratios and blended for several minutes. Then concrete was transferred in vibrating machine and moulded to blocks having dimension 160mm×110mm×390mm. All the specimens were then demoulded after 24 hour. Finally all the specimens were cured for 7 days, 14 days and 28 days. Workability and compressive strength tests were applied and evaluated on these concrete blocks developed according to the Indian standard codes. i.e IS 456: 2000.

3. Results and discussion

3.1 Workability of Concrete

The workability of concrete determines the amount of useful internal work which is essential to yield full compaction i.e. it refers to energy required to overcome friction while compacting. Hence the relative ease with which concrete can be mixed, transported, moulded and compacted is calculated by workability. The instrument employed for conducting the slump test consists of slump cone or Abrams cone. Slump test was conducted to know the workability of the concrete having different compositions. The slump for S0 sample was found to be 77 mm. For concrete mixes of different composition (S_0 to S_8) little variation was observed, the values are tabulated in Table 2 and graphically shown in Figure 1.

Table 2 Slump on partial replacement with silica fume

Sr. No.	Sample Designation	Slump (mm)	Sr. No.	Sample Designation	Slump (mm)
1.	S_1	78	5	S_5	80
2.	S_2	78	6	S_6	81
3.	S_3	79	7	S_7	82
4.	S_4	80	8	S_8	82

The figure 1 shows that the slump value increased with the increase in amount of chemical admixtures silica fume. The workability is better for 2.5% increase in silica fume in concrete mix than the standard concrete and with another increase of 2.5% it remained almost the same. Then for 7.5% to 12.5 % the value of slump increased, after that for another 2.5% increase in admixture the value remained same, following a increase in value till 20%, thus showing the increase in workability.

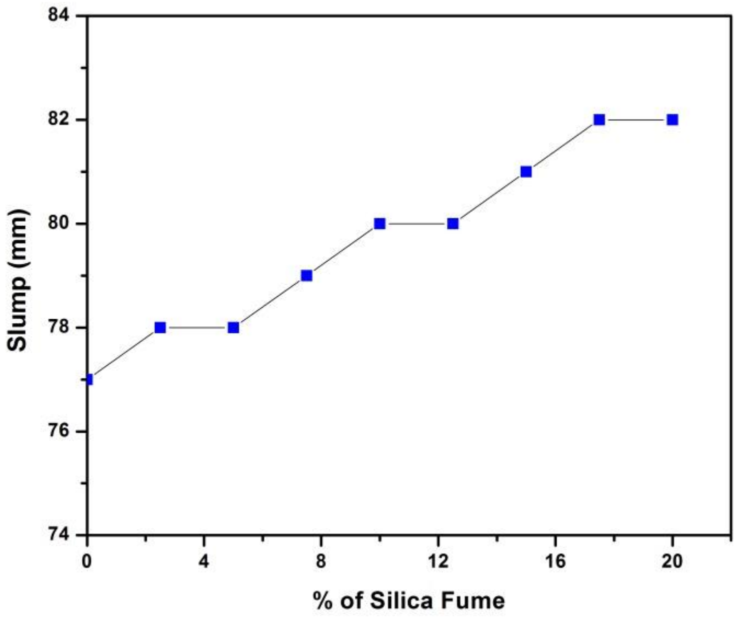

Figure1 Slump on partial replacement with silica fume

3.2 Compressive strength

The compression test was done for all six test specimens (S_0 to S_8) with the help of compression testing machine after curing for 7 days, 14 days and 28 daysin order to check the sustainability of the blocks for construction work. For which the bearing surface of compressor was cleaned and blocks were placed on it,after this load was applied and increased continuously till the specimen gets crushed. The readings were recorded from the meter of the testing machine. The average of three readings was taken to calculate the compressive strength of concrete block in N/mm^2. Then, compressive strength was calculated using formula as given below.

Compressive Strength (N/mm^2) = $\frac{\text{Maximum load at failure in N}}{\text{Cross sectional area in mm2}}$

The cross sectional area of blocks having dimension 160mm×110mm×390mm was calculated by casting five specimens of each concrete block and then the average was taken. The maximum load failure was also determined by keeping the concrete mould in testing machine one by one in the laboratory. Then compressive strength concrete mixture S_0 to S_8 was determined by using the above mentioned formula and tabulated in Table 3.

Table 3 Average Compressive Strength of specimens

Sr. No.	Specimen Designation	Average Compressive Strength (N mm^{-2})		
		7 Days	14 Days	28 Days
1.	S_0	17.39	24.37	27.2
2.	S_1	18.36	25.26	29.46
3.	S_2	19.21	26.65	30.34
4.	S_3	20.63	27.34	31.16
5.	S_4	21.47	28.25	32.42
6.	S_5	22.83	29.44	33.7
7.	S_6	23.9	30.2	34.45
8.	S_7	23.26	28.9	33.22
9.	S_8	22.2	27.89	31.25

The comparative plot of average compressive strength of concrete blocks with respect to percentage of silica fume (0 to 20%) is demonstrated in Figure 2, which clearly illustrates that with each addition of silica fume to standard M_{25} block in the specimens the average compressive strength increases till S_6 specimen. In S_7 (33.22 N/mm^2) and S_8 (31.25 N/mm^2) the compressive strength decreases showing a decrease in strength of concrete blocks. Hence it can be concluded that addition of silica fume greater than 15% decreases the strength may be due to low density and porosity. It is suggested that 15% each of fly ash and silica fume should be added to concrete mix of M_{25} to acquire enough strength. The addition of pozollanic additive i.e. enhances the strength of material. These pozollanic characteristics of both the admixtures in standard concrete mix accounted for increase in compressive strength of the block. Another reason for enhanced compressive strength is the improved bonding between silica fume and cement.

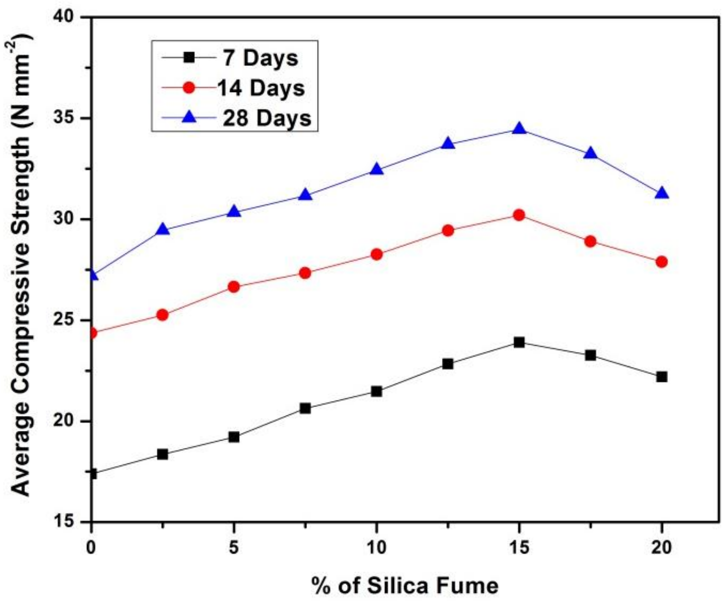

Figure 2 Average Compressive Strength on partial replacement with silica fume

4. Conclusion

In summary, robust concrete and economical blocks of grade M_{25} were fabricated utilizing non hazardous industrial wastes (fly ash + silica fume). The compressive strength of concrete blocks containing fly ash and silica fume was found to be more than that of conventional concrete mix. Experimental investigations revealed that compressive strength decreased beyond 15% content of silica fume. The optimal percentage of cement, fly ash and silica fume determined was 70, 15 and 15 respectively. The slump value for this percentage was 81mm which shows good workability of all prepared specimens. The S_6 concrete block had excellent performance. These blocks find applications in various construction works and are cost effective as well as environmental friendly.

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