Fly ash as a Fine Aggregate Replacement in Concrete Building Blocks

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***Abstract*— Excessive utilization of river sand as fine aggregates in building construction aggravates environmental degradation and urges the need for alternate source in the context of sustainable construction. This paper explores the feasibility of fly ash as fine aggregate replacement in the manufacture of concrete building blocks. An experimental investigation was carried out to evaluate the strength and durability characteristics of concrete building blocks by replacing fine aggregate (river sand) with fly ash. Test results indicate significant improvement in the strength properties of fly ash building blocks compared to conventional concrete building blocks.**

***Index Terms*— Building blocks, Fly ash, Load bearing, Sustainable construction.**

I. INTRODUCTION

Concrete building blocks are most popular these days due to its easy availability and economic viability compared with other conventional alternatives. But usually the strength and durability of these blocks are found far below building standards. Competition among the local manufacturers and scarcity of natural aggregates can be the main reasons for this. Excessive utilization of river sand as fine aggregates in building construction aggravates environmental degradation and urges the need for alternate source in the context of sustainable construction. Several researchers studied the effect of fly ash as fine aggregate replacement in concrete and reported an improvement in strength characteristics along with a reduction in workability
(Siddique R, 2003, Maslehuddin et al, 1989, Mangaraj et.al,1994, ,Dhir et al 2000).An improvement in tensile strength of concrete with fly ash as fine aggregate replacement (sand) was reported by Bakoshi et al.
This paper investigates the feasibility of using fly ash as an alternative source for the partial replacement of fine aggregate in concrete building blocks.

II. EXPERIMENTAL DETAILS

2.1. Materials

2.1.1. Cement.

The cement used was Portland Pozzolana cement satisfying the requirements of IS 4031-1988 under the commercial name Malabar cement.

2.1.2. Fine aggregates.

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River sand (passing through 4.75mm IS sieve and retained at 150 micron sieve) and class fly ash were used as fine aggregates for this study.

2.1.3. Coarse aggregate.

The coarse aggregate used was of 6mm nominal size satisfying the requirements of IS 2386-1970.

The physical properties of above said constituent materials are shown in Table 1.

2.2. Mix design and testing

Trial Mixes 1:2:4 and 1:4:8 were prepared for w/c ratios varying from 0.50 to 0.80% as per IS standards. 150mm x 150mm x150mm size cube specimens were casted and compressive strength was found for 28 and 90 days. Mix design was done for mixes with various replacement levels of fine aggregate with fly ash. 1:2:4 and 1:4:8 mixes with w/c ratios 0.50 to 0.80 were selected as control mixes. Specimen samples from the trial mixes after curing were subjected to compressive strength test, density determination and water absorption test. Results are shown in table 2 and 3.

2.2.1. Compressive strength test

The test was conducted in universal testing machine as per IS 2185 part-I 1979. Specimens stored in water were tested immediately on removal from the water after the specified curing periods and making the surface dry. The dimensions of the specimens were taken to the nearest 0.2mm and their weights were noted before testing. Age of specimen at the time of testing was28 days and 90 days. The load was applied without shock increasing continuously until the specimen breaks down and no greater load can be sustained. The results are shown in Fig.1.

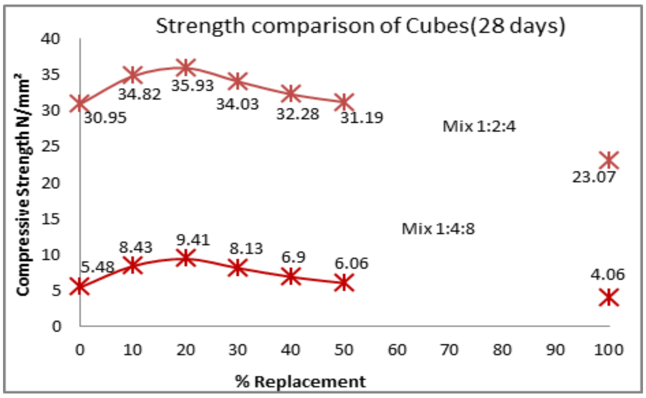

Fig. 1 Compressive strength v/s percentage replacement of fine aggregate.

Table 1. Properties of constituent materials

Sl. no	Properties	Materials			
		Cement	River sand	Fly ash(Class F)	6mm Aggregate
1	Specific gravity	3.14	2.54	2.503	2.79
2	Bulk density(kg/m3)		1452	798.2(kg/m3)	1433(kg/m3)
3	Porosity		0.428	0.681	0.487
4	Void ratio		0.748	2.132	0.949
5	Fineness modulus	Residue 5%	2.686		5.73

Table 2. Mix design (1:2:4)

Sl. no	Mix designation	w/c ratio	Fine aggregate Replacement With Fly ash	Average compressive strength (N/mm2)		Average density (Kg/m3)		Water Absorption (%)
			% Fly ash	28days	90days	28days	90days	
1	FC0	0.50	0	30.95	33.99	2339	2364	5.269
2	FC1	0.55	10	34.82	38.12	2365	2384	6.070
3	FC2	0.55	20	35.93	39.17	2383	2401	6.711
4	FC3	0.60	30	34.03	37.97	2338	2350	7.417
5	FC4	0.60	40	32.28	36.25	2304	2325	8.410
6	FC5	0.65	50	31.19	35.13	2268	2312	9.087
7	FC10	0.80	100	23.07	27.27	1969	2057	11.667

Table 3. Mix design (1:4:8)

Sl. no	Mix designation	w/c ratio	Fine aggregate Replacement With Fly ash	Average compressive strength (N/mm2)		Average density (Kg/m3)		Water Absorption (%)
			% Fly ash	28days	90days	28days	90days	
1	FC0	0.50	0	5.48	8.47	2089	2167	7.584
2	FC1	0.55	10	8.43	12.03	2118	2205	8.185
3	FC2	0.55	20	9.41	12.87	2139	2220	8.764
4	FC3	0.60	30	8.13	11.33	2111	2191	9.484
5	FC4	0.60	40	6.90	10.15	2078	2158	10.026
6	FC5	0.65	50	6.06	8.73	1972	2050	10.938
7	FC10	0.80	100	4.06	6.90	1843	1865	12.774

2.2.2 Determination of water absorption

The test was conducted as per IS 2185 part I-1979. The test specimens shall be completely immersed in water at room temperature for 24 hrs. The specimen shall then be weighed. Then the specimen shall be dried in a ventilated oven at 100 to115°C for not less than 24 hrs. Average for the three cubes shall be taken. The results are shown in Fig 2.

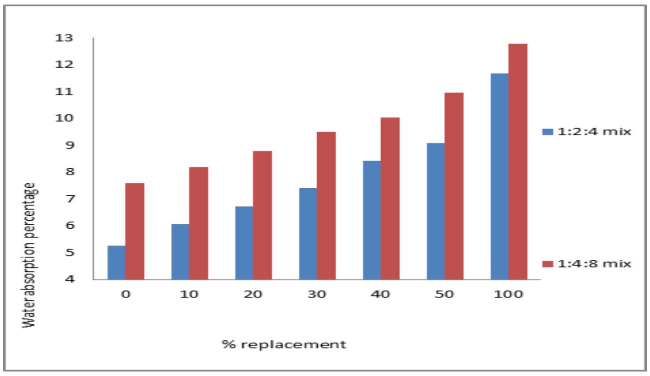

Fig. 2 Water absorption v/s percentage replacement of fine aggregates

2.2.3. Determination of Density

The test was conducted as per IS 2185 part I-1979. Three cubes taken at random from the samples and dried to constant mass in an oven heated to approximately 100°C. After cooling the cubes to room temperature, the dimensions of each cube shall be measured. The cubes are weighed in kilograms and density of each cube is calculated. Average density is found out from the values obtained. The results are shown in Fig 3.

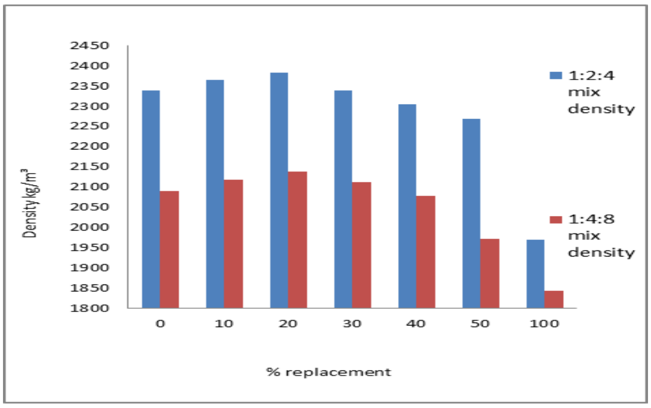

Fig.3 Density v/s percentage replacement of fine aggregate by fly ash cubes

The compressive strength of the cubes were found increasing with a replacement of fine aggregate by fly ash up to 20% and then decreasing for both the mixes. Corresponding variation in density was also observed (Fig 3). Whereas water absorption was found increasing on higher percentage of fly ash replacement owing to the higher surface area of fly ash particles compared with sand (Fig. 2). Results of mix design for different replacement levels of fine aggregate showed an improvement in compressive strength over the control mix up to a replacement level of 50%. Hence blocks were casted for all the replacement level of fine aggregate up to 50% considering the sustainability aspects. Blocks were also casted with 100% replacement of river sand to check the strength characteristics.

2.3. Casting of fly ash blocks

Solid concrete blocks(40x20x15cm) were casted using hydraulic block making machine (H800 from nova engineering company- Fig.4). This machine at a time can cast 5 blocks. These blocks were kept as such for 24 hours in the production yard and cured for 28days and 90 days by immersing fully in water tank. Blocks were taken out of the tank after curing, wiped off and subjected to different tests.

Fig. 4 Block making machine

2.4. Tests on blocks

Building blocks after curing were subjected to compressive strength test, density determination and water absorption test as per IS standards. Results are shown in Table-4 and Table -5

Table 4 Compressive strength, Density and Water absorption (1:2:4 mix)

Sl. no	Mix designation	w/c ratio	Fine aggregate Replacement With Fly ash	Average compressive strength (N/mm2)		Average density (Kg/m3)		Water Absorption (%)
			% Fly ash	28days	90days	28days	90days	
1	FB0	0.50	0	17.19	18.02	2406	2456	5.74
2	FB1	0.55	10	18.56	19.59	2423	2470	6.10
3	FB2	0.55	20	19.54	20.46	2448	2491	8.06
4	FB3	0.60	30	18.32	19.48	2432	2449	9.09
5	FB4	0.60	40	17.59	18.52	2364	2395	9.80
6	FB5	0.65	50	16.96	17.66	2314	2344	10.54
7	FB10	0.90	100	12.63	13.24	1998	2018	14.35

Table 5 Compressive strength, Density and Water absorption (1:4:8 mix)

Sl. no	Mix designation	w/c ratio	Fine aggregate Replacement With Fly ash	Average compressive strength (N/mm2)		Average density (Kg/m3)		Water Absorption (%)
			% Fly ash	28days	90days	28days	90days	
1	FB00	0.60	0	5.18	6.19	2168	2178	7.81
2	FB01	0.70	10	5.80	7.24	2193	2200	7.92
3	FB02	0.75	20	6.62	7.74	2210	2218	8.58
4	FB03	0.80	30	5.52	6.79	2157	2191	10.05
5	FB04	0.80	40	4.96	6.12	2113	2140	10.64
6	FB05	0.85	50	4.40	5.58	2058	2090	11.26
7	FB010	0.90	100	4.01	4.78	1907	1959	15.09

III. RESULTS AND DISCUSSIONS

3.1. Compressive strength

Fig 5 and fig 6 shows the results of tests carried out for the determination of compressive strength on 28 and 90 days of curing for both mixes 1:2:4 and 1:4:8 respectively.

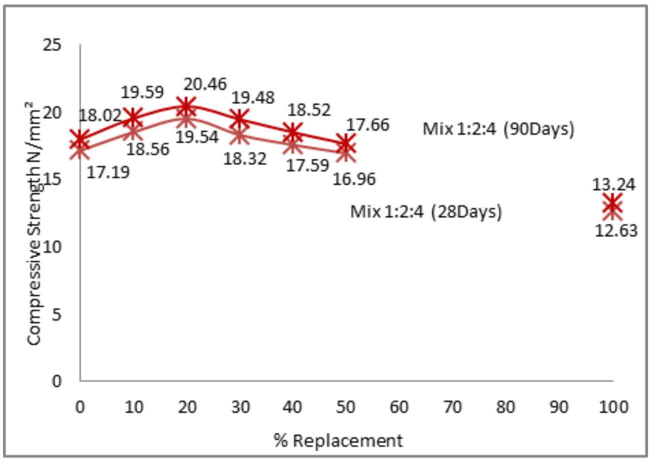

Fig 5. Compressive strength v/s percentage replacement of fine aggregate by fly ash

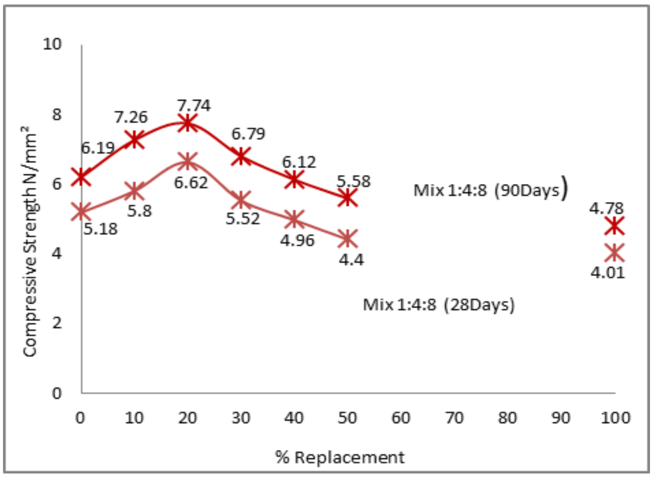

Fig 6. Compressive strength v/s percentage replacement of fine aggregate by fly ash

In concurrence with the results of mix design, similar variation was observed in the tests results of concrete building blocks for both mixes 1:2:4 and 1:4:8. Compressive strength was found increasing as the percentage of fly ash up to 20% replacement and decreasing thereafter. An improvement in strength was reported for all replacement levels of fine aggregate with fly ash with respect to control mix up to 40%(1:2:4) and 30%(1:4:8).

The superior performance of these mixes compared with control mix can be due to the pozzolanic action and packing effect of fly ash particles. Fly ash acting as a source of reactive silica and alumina reacts with calcium hydroxide liberated during the hydration of cement and contributes to higher strength. Finer fly ash particles gets packed up between the interface of fine aggregates and course aggregates particles and thus reducing the entrapped air in the mix. This results in the densification of the mix and imparts an improvement in strength.

The reduction in compressive strength above 20% replacement can be due to the weak bonding between cement paste and fly ash particles. This is mainly due to the physical properties of fly ash which repels water during mixing process and entrapping air on its surface. This results in the non homogeneity of the mix at higher water binder ratios above 40% and results in boulder formation. Since fly ash particles are finer than (higher specific surface area) river sand, the requirement of water increases at higher replacement levels which results in the lowering of adhesion of concrete matrix and thus causes strength reduction.

3.2. Water absorption

The water absorption of fly ash concrete blocks increases as the percentage of fly ash replacement increases as seen in Fig 7. This can be due to the higher values of void ratio and porosity of fly ash particles compared with sand. The presence of entrapped air on the surface of fly ash particles creates voids in the concrete matrix resulting in higher water absorption. Even though the water absorption increases, the results were within the limits as specified by IS codes.

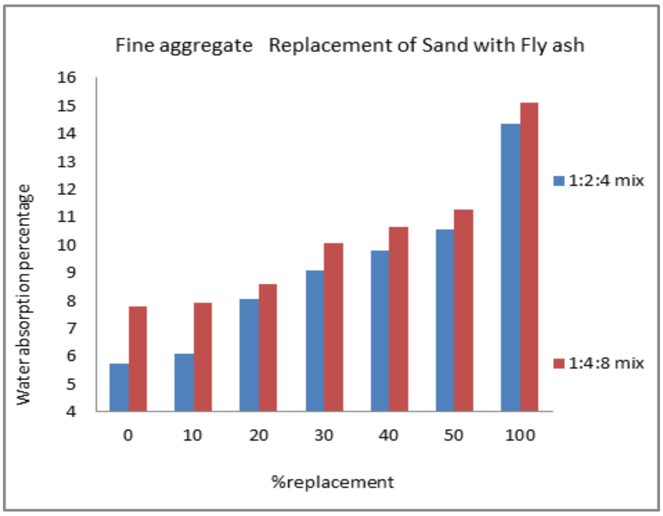

Fig 7. Water absorption v/s percentage replacement of fine aggregate by fly ash block

3.3. Density

Fig 8 shows the results of tests carried out for the determination of density of both mixes 1:2:4 and 1:4:8.

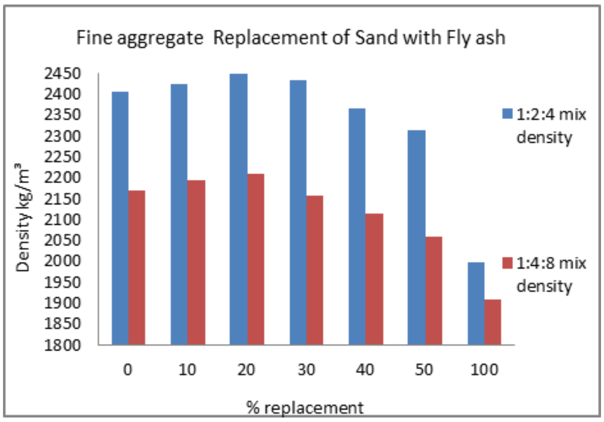

Fig 8. Density v/s Percentage replacement of fine aggregate by fly ash block

The results observed in the density of fly ash blocks shows a similar pattern in the variation as observed in the case of compressive strength of the blocks.

Density of concrete blocks increases up to 20% replacement as similar to compressive strength. This is due to the denser matrix of mixes resulting from the pozzolanic action and filler effect of fly ash particles with in the mix. Above 20%, reduction in the density occurs due to the presence of excess residual fly ash after the pozzolanic reaction.

In addition to this the specific surface area of the concrete matrix increases as the fly ash replacement increases and hence resulting in a lower density. This can also be attributed to the lower specific gravity of fly ash when compared to the specific gravity of sand.

IV. CONCLUSIONS

The results of this study shows that the proposed fly ash concrete block can be successfully suggested for sustainable construction as it has got the following advantages over the conventional blocks.

- *Strength characteristics.*

Even though the maximum compressive strength was observed for 20% replacement level, the blocks with a higher replacement of 30% can be suggested for practical application as it has got a strength and density as par with that of the optimized value. Among the two mixes, the blocks produced with 1:2:4 mix exhibited higher values as specified by ASTM standards for load bearing masonry. Hence it can be recommended for higher strength requirements. Whereas the blocks with 1:4:8 mixes can be recommended for non load bearing application as per ASTM standards. At the same time both the mixes satisfied the requirements of load bearing masonry specified by IS standards.

- *Economic aspects*

Blocks produced with 1:4:8 mix with a fly ash replacement of 20% can be suggested for load bearing application considering economical aspects and satisfying IS requirements

- *Environmental aspects*

Utilization of fly ash, an abundantly available waste material from thermal power plants as a constituent material in concrete building blocks replacing river sand certainly improves the sustainability of construction.

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