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UTILIZATION OF FAY ASH AND BAGASSE ASH AS THE ECOFRIENDLY BUILDING MATERIALS

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ABSTRACT

The greatest challenge for construction industry in the present times is realization of projects aimed at infrastructure development in harmony with the sustainable development concept. Sustainable development means, judicious use of natural resources for various construction activities. The construction industry, due to its huge size to meet the growing needs of construction activities, is the largest consumer of natural resources such as aggregates, cement (made from lime available naturally) and water etc. To achieve sustainable development in construction sector, it is necessary to replace some of these materials with the alternative materials, which are basically by-products/or waste materials from industries, such as fly ash, granulated slag, silica fume, and their disposal is an environmental threat. These alternative materials not only benefit the environment but also add value to, in the form of enhancement of performance characteristics by judicious selection and proportioning and use. In this study fly ash (FA) and bagasse ash (BA), obtained from fired at controlled conditions, are admixed with Portland cement at different replacement levels. The properties of concrete investigated include compressive strength, splitting tensile strength, modulus of elasticity, modulus of rupture and resistance to chloride ion penetration. Optimum percentage of FA and BA for strength development along with other results are discussed in detail.

INTRODUCTION

The production of Portland cement, an essential constituent of concrete, release large amounts of CO_2 into the atmosphere, i.e., about one tonne of CO_2 for every tonne of Portland cement produced. CO_2 is a major contributor to the green house effect and the global warning of the planet. In this scenario, the use of supplementary cementing materials, such as fly ash, granulated slag and silica fume as a replacement for Portland cement in concrete presents one viable solution with multiple benefits for sustainable development of the construction industry. Fly ash and silica fume are silica-based materials having pozzolanic properties. When these pozzolanic materials are added to cement, the SiO_2 content reacts with free lime released during the hydration of cement and forms additional calcium silicate hydrate as new hydration products (Ghorpade 2006). In addition to these industrial wastes, the agro-wastes such as rice husk, sugarcane bagasse, rice straw and hazel nut shell are also used as pozzolanic materials.

Fly ash is the residue from combustion of pulverized coal collected by the mechanical or electrostatic separators from fuel gases of thermal power plants. Its composition varies with the type of fuel burnt, load on boiler and type of separator etc. The carbon content in fly ash should be as low as possible whereas the silica content should be high. There are about 80 thermal power plants functioning in India generating around 100 million tons of fly ash per annum. Storage and disposal of fly ash is a problem for thermal power stations as it creates severe pollution problems. In view of these serious considerations, lot of investigations have been carried out for utilization of fly ash. It is very disappointing to note that only 5% of the produced fly ash is being utilized in India at present. Thus, there is an urgent need for identifying as many alternate methods as possible for utilization of fly ash. The BIS included fly ash (FA) is one of the approved pozzolonic admixtures that may be blended with cement.

Bagasse is the residue fibre remaining when sugarcane is pressed to extract the sugar. In India, there are about 391 sugar units generating 81.36 million tonnes of bagasse. Bagasse is also used as raw materials for paper making due to its fibrous content and about 0.3 tonnes of paper can be made from one tonne of bagasse. When this waste is burned under controlled conditions, it also gives ash having amorphous silica, which has pozzolanic properties. Singh et al. (2000) carried out experimental study on hydration of bagasse ash (BA) blended Portland cement. Their study concluded that in the presence of 10% BA the compressive strength values were found to be higher than that of control at all ages of hydration. Ganesan et al. (2005) investigated the strength and durability study on concrete of BA and rice husk ash blended cement. Based on their study it was concluded that 25% is optimum for controlled fired BA blended cement concrete.

The aim of this investigation is to study the effect of fly ash and bagasse ash (added separately) as supplementary cementitious materials and the influence of these ashes on the strength and resistance to chloride ion penetration of concrete made with three different cement replacement levels of 10 %, 20% and 30%.

MATERIALS USED AND THEIR PROPERTIES

Ordinary Portland cement (OPC) 53 grade conforming to IS: 12269-1987 (BIS 1987) obtained from a single source was used. Locally available river sand which falls in zone III of IS: 383-1970 (BIS 1970) and crushed blue granite as coarse aggregate were used in the test. The fly ash (FA) from Mettur power plant was used in the present investigation. The bagasse from Shakthi Sugars Ltd., Appakoodal, Erode was used in the test. The bagasse ash (BA) was obtained by burning the bagasse at controlled temperature of 800°C for more than one hour. These ashes were prepared as a fine powder using a pulverizer and kept in polythene bags for further use. The physical and chemical properties of BA and FA are presented in Table 1 and Table 2.

Mix proportions and casting: A mix M 30 grade was designed as per IS: 10262-1981 (BIS 1981) and the same was used to prepare the test samples. The design mix proportion is given in Table 3. The cement replacement level was varied from 10%, 20% and 30% labelled six series as FA1, FA2 and FA3, and BA1, BA2 and BA3. All the materials were taken by weight as per the mix proportions, and hand mixing was adopted for making concrete.

Details of specimen: The experimental program involves casting and testing of 117 concrete specimens with and without FA and BA. The different specimens considered in this study include 54 numbers of 150 × 150 × 150 cubes for 7, 28 and 56 days cube compressive strength, 42 numbers of 150 mm diameter and 300 mm height cylinder for 28 days split tensile strength and modulus of elasticity value, and 21 numbers of 100 × 100 × 500 mm size prisms for 28 days flexural strength.

Fig. 1: One batch of specimens after 28 after days curing.

All the test specimens were cast in steel molds on a table vibrator and allowed to set for 24 hours. The specimens were then removed from the moulds and kept in the curing pond. The strength characteristics were examined as per IS: 516-1959 (BIS 1959). Three specimens were tested for the required age and the average values was taken. Chloride permeability of the concrete mixes were evaluated as per ASTM C1202 (100 mm dia, 50 mm thick cylindrical sample) at the age of 28 days. Fig. 1 Shows the one batch of specimens after 28 days curing.

RESULTS AND DISCUSSION

Physical and chemical properties: Physical properties of cement, fly ash and bagasse ash are given in Table 1. From the fineness value it is evident that the ashes are very fine particles. The chemical analysis values, given in Table 2 for OPC, FA and BA, showed that the silica content of BA is 64.50%, and FA 59.62 % against the cement value of 21.4%. These confirmed that basically FA and BA are silica rich materials, which can be used as supplementary cementitious materials.

Workability: The mixed fresh concrete was tested for its workability parameters and the results are given in Table 4. From the observed values it is evident that the workability performance of blended cement concrete is better than conventional concrete. The spherical shaped particles of fly ash act as miniature ball bearings within the concrete mix and improve the workability.

Compressive strength: The results of compressive strengths at the age of 28 days are reported in Table 5 and variation with age is shown in Fig. 2. It has been observed that the compressive strength decreases with increase in replacement of cement by fly ash at 7 and 28 days in FA1 and FA3 specimens. The decreased percentage strengths noted in FA1 specimens at 7, 28 and 56 days are 18.12, 12.22 and 10.2 percentage with respect to control specimens. The percentage strength decreased in FA2 specimens at 7 and 28 days by 15.13 and 8 percentage, whereas 10 percentage increase in strength was observed at the age of 56 days with respect to control specimens. The

Table 1: Properties of the constituent materials.

Sl.No	Parameter	OPC used	Fly Ash	Bagasse Ash	Fine Aggregate	Coarse Aggregate
1	Normal Consistency	29 %	30%	30 %	-	-
2	Fineness by Sieving (%)45 micron	80	78.60	91	-	-
3	Initial Setting Time (minutes)	38	84	67	-	-
4	Final Setting Time (minutes)	300	395	350	-	-
5	Specific Gravity	3.15	2.10	1.93	2.55	2.69
6	Bulk density				1747	1590
7	Fineness modulus	-	-	-	2.81	7.16
8	Water Absorption	-	-	-	1.0%	0.52%

Table. 2 Chemical composition of cement and ashes.

Material	SiO_2	Al_2O_3	Fe_2O_2	CaO	MgO	SO_3
OPC	21.4	5.3	3.2	61.6	0.8	2.2
Fly Ash	59.62	26.43	6.61	1.20	0.76	0.58
Bagasse Ash	64.50	6.93	5.69	5.2	1.69	-

Table 3: Mix proportions of the concrete.

Sl.No	Ingredient	kg/m^3	Proportion
1	Portland Cement	450	1 : 1.12 : 2.687
2	Water	191.6	W/C = 0.425
3	Fine Aggregate	504	
4	Coarse Aggregate	1209	

decreased percentage strengths noted in the FA3 specimens at 7, 28 and 56 days were 25.03, 18.00 and 16.13 percentage with respect to control specimens. The reason for the above observation is that pozzolonic reaction in fly ash concrete starts only after release of free lime from hydration of cement which normally takes more than a weak. This is quite in agreement with similar observations reported by earlier researchers on development of compressive strength of fly ash concrete.

The variation of cube compressive strength for the partial replacement of cement by BA at different curing periods is given in Fig. 3. It can be seen that the compressive strength increases with increase in replacement of cement by BA at 7 and 28 days in BA1 and BA2 specimens. The increased percentage strength noted in BA1 specimens at 7 and 28 days are 7.33 and 14.38 percentage, whereas those noted in BA2 specimens are 12.68 and 16.32 percentage with respect to control specimens. The decreased percentage strength observed in the FA3 specimens at 7 and 28 days are 10.38 and 4.54 percentage with respect to control specimens. It can concluded that the BA containing amorphous silica increases the compressive strength.

Table 4: Workability of the concrete.

Slump	CRL	FA1	FA2	FA3	BA1	BA2	BA3
	2.0	3.2	3.2	3.7	2.0	2.5	2.7

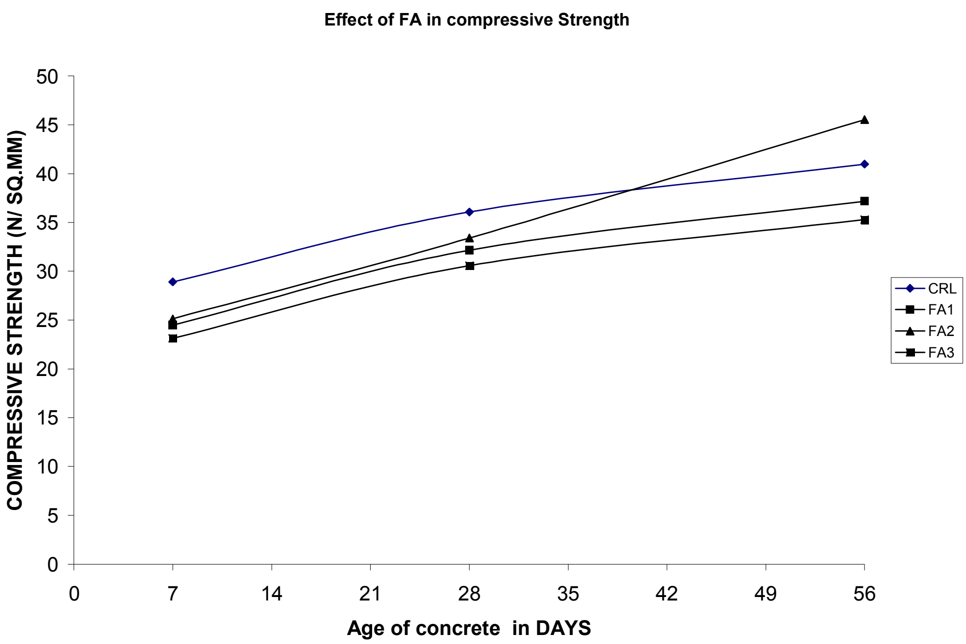

Fig. 2: Comparison of compressive strength for FA series specimens.

Table 5: Strength and durability properties of concrete.

Parameters	CRL	FA 1	FA 2	FA 3	BA 1	BA 2	BA 3
Specimens cured for 28 days							
Cube compressive strength, MPa	36.08	32.15	33.41	30.58	42.14	43.12	34.51
Split tensile strength, MPa	4.8	4.22	4.50	4.11	4.57	5.18	4.657
Flexural strength, MPa	5.98	5.28	5.65	5.19	6.37	6.59	5.77
Cylinder Compressive Strength, MPa	31.69	28.19	27.30	26.81	36.95	36.52	30.26
Secant Modulus of Elasticity, GPa	30.05	29.25	28.67	27.30	30.10	30.50	29.24
Max Strain (10^{-3})	2.14	1.95	1.92	1.89	2.23	2.16	2.09
Chloride Permeability, Coulombs	1646	876	850	830	978	953	940

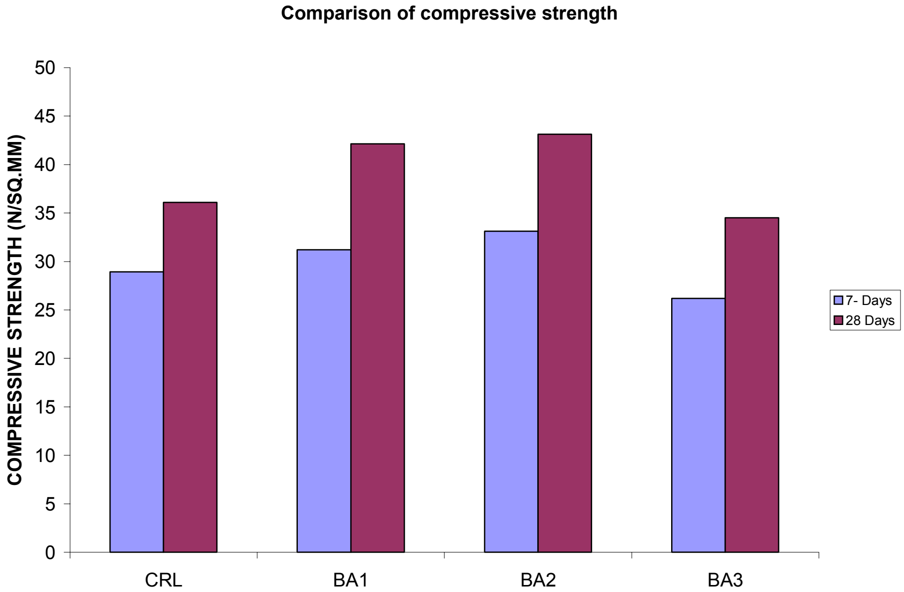

Fig. 3: Comparison of compressive strength for BA series specimens.

Flexural strength: Flexural strength test were conducted for various mixes on beam specimens under two point loading at the age of 28 days and the results are given in Table 5. It is clear that flexural strength decreases with increase in replacement of cement by fly ash at 28 days. The decreased percentage strength noted in FA series specimens one, two and three are 13.127, 5.84 and 15.14 percentage respectively with respect to control specimens. The increased percentage strength noted in BA1 and BA2 are 6.12 and 9.256 percentage, whereas 3.63 percentage decrease in flexural strength was observed in BA3 specimen with respect to control specimens. Fig. 4 shows the experimental test set up. The failure mode of the specimens is given in Fig. 5.

Fig. 4: Experimental test set-up.

Split tensile strength: Split tensile strength tests were carried out at 28 days on cylindrical specimens for various mixes and the results are shown in Table 5. It is clear that tensile strength decreases with

Fig. 6: Strain measurement using DEMEC.

increase in replacement of cement by fly ash at 28 days. The decreased percentage strengths noted in FA series specimens one, two and three are 13.74, 6.67 and 24.19 percentage respectively with respect to control specimens. The increased percentage strength noted in BA1 and BA2 are 5.078 and 7.335 percentage whereas 3.07 percentage decrease in flexural strength was observed in BA3 specimen with respect to control specimens.

Cylinder compressive strength: The cylinder compressive strength for the partial replacement of cement by FA series specimens and BA series specimens are given Table 5. It can be seen that the cylinder strength decreases with increase in replacement of cement by FA series specimens. The decreased percentage strength noted in FA series specimens one, two and three are 12.415, 16.08 and 18.20 percentage respectively with respect to control specimens. The increased percentage strengths noted in BA1 and BA2 are 14.23 and 13.22 percentage whereas 4.7 percentage decreased strength was observed in BA3 specimen with respect to control specimens.

Fig. 5: Failure mode of

Modulus of elasticity: The secant modulus of elasticity was determined from the load deformations observation of the cylinder specimen and are presented in Table 5. In all the cases it was found that the value decreases with increase in fly ash as replacement of cement by weight. The decreased

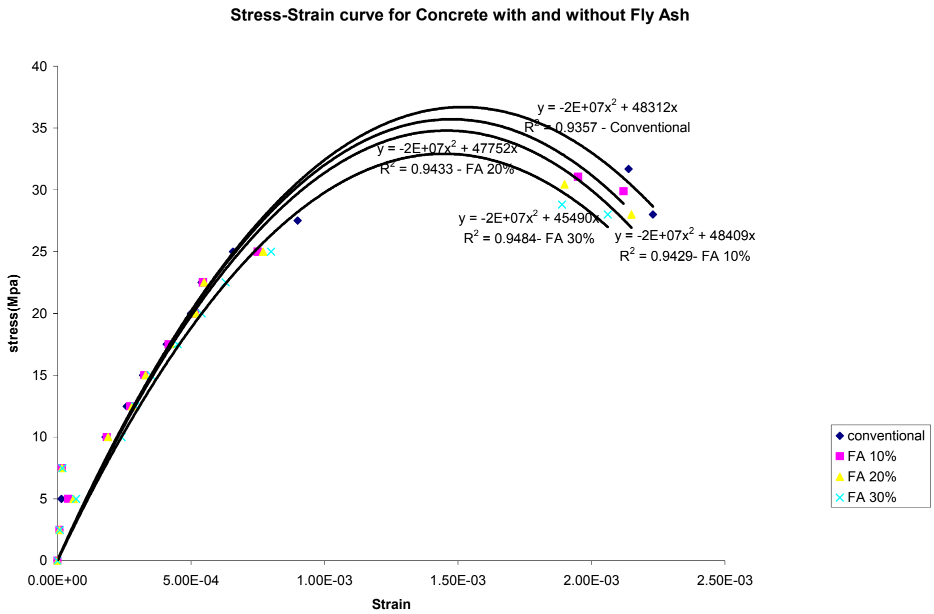

Fig. 7: Stress-strain of FA series specimens.

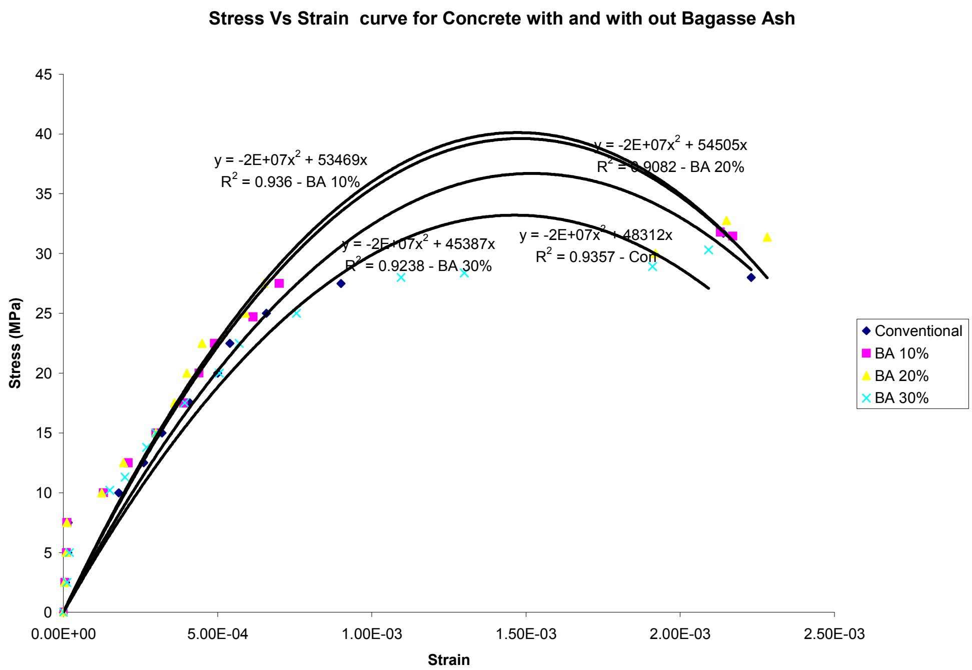

Fig. 8: Stress-strain of BA series specimens.

percentage value noted in FA series specimens one, two and three are 2.735, 4.59 and 9.15 percentage respectively with respect to control specimens. This may be due to replacement of cement particles by fly ash particles of lower modulus of elasticity and also because of their smaller size and spongy nature. The increased percentage values noted in BA1 and BA2 are 0.16 and 1.49 percentage whereas 2.77 percentage decreased in elasticity value was observed in BA3 specimen with respect to control.

Stress-strain variation: Strains were measured using demountable mechanical gauge at regular intervals of loading (Fig. 6). The stress-strain curves were drawn for each percentage replacement of cement by fly ash as given in Fig. 7. The initial portion of the stress versus strain curve of the fly ash concrete almost follow the curve of normal concrete. The maximum strain observed in all the specimens is given in Table 5. The stress-strain curves drawn for each percentage replacement of cement by BA are given in Fig. 8. Examination of stress-strain curves clearly shows that at the same stress level the axial strains for the BR1 and BR2 specimens are always higher than controlled specimens.

Fig.9: Chloride permeability test.

Rapid chloride permeability test: Rapid chloride permeability test was conducted as per ASTM C 1202 standards (Fig. 9). The values of chloride permeability in terms of total charge passed through the specimen for various mixes are given in Table 5. It was observed that addition of mineral admixtures has excellent resistance to chloride ion penetration and the charge passed in coulombs was below 1000, which is well below of normal concrete.

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CONCLUSIONS

1. Fineness of FA and BA indicates that these ashes are smaller size particles as compared to OPC.
2. Workability performance of blended cement concrete is better than conventional concrete. This is due to lubricating effect of ash particles while mixing.
3. The mechanical properties of FA series specimens decrease in early days strength, whereas increased percentage was observed in BA series specimens as compared to controlled concrete.
4. Durability (measured here as the resistance to chloride permeability) was improved noticeably in all the mixtures.

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