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A Feasibility Study for the Use of Bagasse Ash and Silica Fume in Making Concrete

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ABSTRACT

Background: Research on bagasse and its ash have been done more than a decade. Though several researches have been done on the utilization of the bagasse ash in various fields such as fertilizer, adsorbent, construction material, etc., still sugar industry could not find a complete solution to dispose tons and tons of bagasse ash generated every day. Moreover, many sugar industries in developing countries still use open dumping as the final disposal method for sugar cane bagasse ash. Further other industrial wastes like fly ash, blast furnace slag, etc., find commercial usage and profit by selling it out to the construction industry. But researches indicate that bagasse ash utilization is feasible in building materials only if it is burnt around 600^{o}C and at controlled conditions with further processing such as grinding etc.**Objective:** Hence, this paper investigates the feasibility of using unprocessed bagasse ash obtained calcined by burning bagasse around 1500^{o}C together with silica fume as admixture for various proportions and the strength properties were evaluated. **Result:**Then with same proportion hollow concrete blocks were casted and tested.**Conclusion:**The result shows that the addition of 10% of silica fume along with unprocessed bagasse ash replacement gives improved strength properties at all proportions and hence it could provide a commercial feasibility for the bagasse ash disposal.

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INTRODUCTION

Bagasse is the fiberous residue of sugarcane after crushing and extraction of juice. This ash is used for agricultural purposes though its effect on the fertility of soil is too little compared to the disposal problems .The disposal of these ashes produced is associated with several environmental problems and health hazards. Moreover, the safe disposal of these ashes is quite a big challenge to the sugar industry in the recent years.

On the other hand concrete is the world's most consumed construction material because it combines good mechanical and durability properties. Cement which is one of the components of concrete plays a great role but is the most expensive and environmentally unfriendly material. To alleviate the rising cost of materials especially cement for the production of concrete, hollow blocks, maximized waste utilization, is required through utilizing baggase ash. Each ton of the cement produces approximately one ton of CO_2 and the cement industry is responsible for about 5% of global anthropogenic CO_2 emission (Ernst Worrell *et al*., 2001). These emissions can be substantially reduced if 20% to 30% of bagasse ash is replaced in concrete industry. Thus, this helps to maintain green effect in environmental conditions.

In the present study laboratory tests were conducted for the samples at each percentage of cement replacement with bagasse ash and silica fumes as mineral admixture. The application of bagasse ash with silica fume (BASF) in the production of hollow concrete blocks was also studied. The results will be compared in order to find out the best percentage by weight of cement that has been replaced by baggase ash with and without silica fume as admixture for improved compressive strength and split tensile strength in concrete, as well as to study the effect of BASF on the compressive strength, water absorption and density of hollow concrete blocks.

MATERIALS AND METHODS

OPC 53 grade cement confirming to IS 12269:1987 (IS 12269) specification was used in this study. Bagasse ash was obtained from a sugar mill in Tamil Nadu, India and it properties were studied and reported in Table1.

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Table 1: Properties of Bagasse Ash under Study.

Sl. No.	Test Parameters	Results (%)
1.	Silicon dioxide (SiO_2) + Aluminium Oxide (Al_2O_3) + Iron Oxide (Fe_2O_3)	56.58
2.	Magnesium Oxide (MgO)	0.33
3.	Total Chlorides (Cl)	0.002
4.	Total Sulphur as Sulphur Trioxide (SO_3)	1.01
5.	Loss on ignition	2.43
6.	Calcium Oxide(CaO)	13.47
7.	Manganese Oxides (MnO)	1.14

Fine aggregate of locally available river sand conforming to (IS: 383,1987) with fineness modulus of 2.55 and a specific gravity of 2.62 and Coarse aggregate of blue granite crushed aggregates conforming IS: 383 1987 (IS: 383,1987) with 12.5 mm maximum size with fineness modulus of 6.4 and specific gravity of 2.90 were used in the research. Water conforming to as per IS: 456 (IS 456, 2000) was used for mixing as well as curing of concrete specimen.

Commercially available densified silica fume from Astra Chemicals, India Ltd. Chennai, having the properties shown in Table 2 was used. The main purpose of using Silica fume(SF) was to enhance the bonding between cement paste and bagasse ash(BA) of the dry mix.

Table 2: Properties of Silica Fume under Study.

Sl. No.	Test Parameters	Results in (%)
1.	Silicon dioxide (SiO_2)	99.5
2.	Magnesium Oxide (MgO)	0.01
3.	Aluminium Oxide (Al_2O_3)	0.08
4.	Alkalies	0.29
5.	Loss on ignition	0.28
6.	Calcium Oxide(CaO)	0.01
7.	TiO_2	0.04
8.	Particle Size	800 M

Preparation and Testing of Samples:

This study was carried out in two phases. In Phase I, cubes and cylinders were cast using M25 mix by replacing cement with Bagasse Ash (BA) by 0%, 10%, 20% and 30%. In Phase II, cubes and cylinders were cast using M25 mix by replacing cement with Bagasse Ash by 0%, 10%, 20% and 30% and with 10% addition of silica fume on all replacement level. In this study the water cement ratio was maintained 0.45 by weight of cement for all proportions. For each replacement 3 cubes were cast and its average compressive strength was determined and tabulated for 7, 14 and 28 days. All the materials used were batched by weight proportions. Cube moulds of size 150 mm and cylinder moulds of height 300 mm and 150 mm diameter were used to cast the specimen. Immediately after casting the specimens were covered with plastic sheets for 24hrs to prevent the evaporation of water from the concrete. They were demoulded after 24hrs and cured in water under ambient temperature until they were tested. The compressive strength test was performed according to (IS 516 ,1959) The split tensile test on cylinder of various mixes was done by applying a compressive line load along the opposite generators of a concrete cylinder placed with its axis horizontal between the compressive platens.

RESULTS AND DISCUSSION

Compressive Strength of Unprocessed Ba Blended Concrete :

The compressive strength and split tensile strength of unprocessed bagasse ash based concrete at all replacement level were evaluated and presented in Table 3. The results indicated that replacement of cement by unprocessed bagasse ash burnt at 1500^{o}C gave lesser strength at all replacement level compared to controlled concrete. The results showed the same trend as the other researchers who have studied the effect of bagasse ash as replacement of cement on the compressive strength and revealed that the pozzolanic reactivity was good only when bagasse was burnt around 600^{o}C under controlled burning conditions and in ultrafine nature (Ajay Goyal *et al*.,2007, Guilherme Chagas Cordeiro *et al*.,2009, Martirena, J.F *et al*., 2006, Moises Frias *et al*., 2007,Suvimol S *et al*.,2009)

Table 3: Results of Compressive Strength of Unprocessed BA Blended Concrete after Various Curing Periods.

Sample Designation	% of BA replacement	Compressive Strength after various curing periods (MPa)			Split Tensile strength of Cylinder (MPa)	
		7 Days	14 Days	28 Days	7 Days	28 Days
BA0	0	14.02	22.61	31.00	1.60	2.97
BA10	10	13.68	17.58	25.85	1.40	2.29
BA20	20	9.82	12.58	19.56	0.97	1.65
BA30	30	6.77	8.51	10.04	0.99	1.06

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The compressive strength and split tensile strength of unprocessed BA based concrete at all replacement level is illustrated in Figs. 1 and 2.

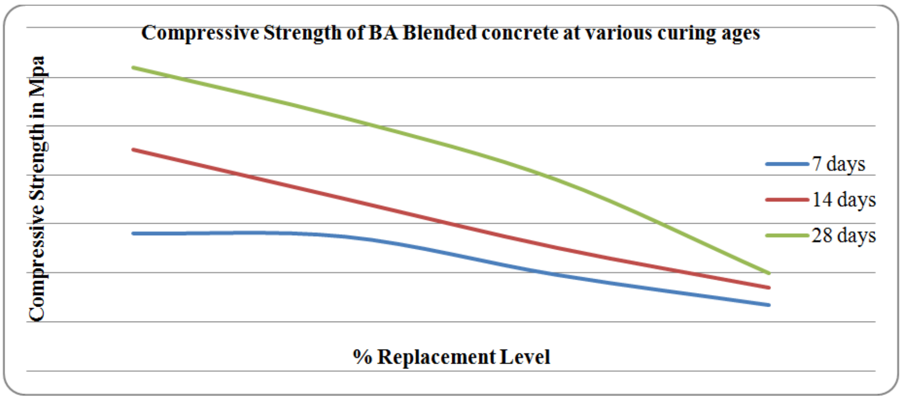

Fig. 1: Compressive Strength of Unprocessed BA Blended Concrete after Various Curing Periods.

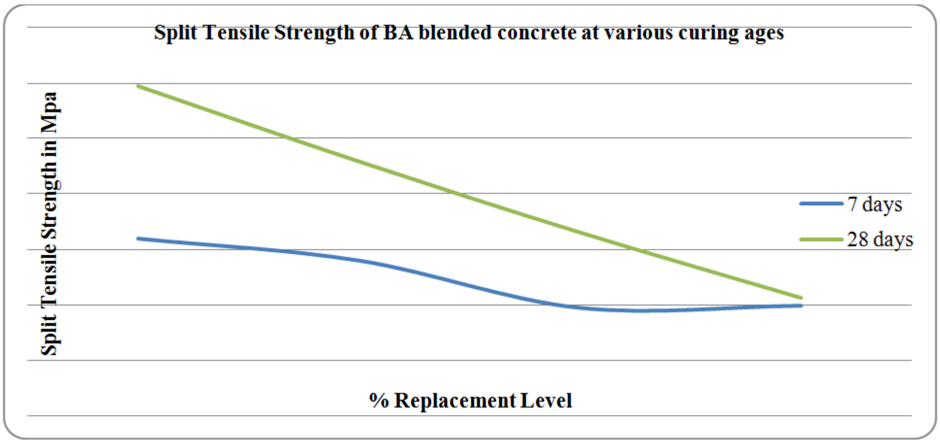

Fig. 2: Split Tensile Strength of Unprocessed BA Blended Concrete after Various Curing Ages.

Compressive Strength of Basf Blended Concrete:

In the second case the compressive strength and split tensile strength of unprocessed BASF based concrete at all replacement level were determined and were shown in Table 4. The results showed that when Silica Fume was added as admixture by 10% the strength of bagasse ash concrete at all replacement level increased considerably at all curing ages.

Moreover the strength of concrete by 10% replacement of cement with BA and 10% addition of silica fume gave optimum strength of 37.9 MPa compared to controlled concrete at 28 days as shown in Fig. 3. (Bashar *et al*., 2012) observed a compressive strength of 20Mpa for crumb rubber concrete at 28days for 1:1:2 mix by replacing cement with 10% crump rubber and 10% SF by volume of cement. He also reported 49Mpa strength for concrete containing 30% flyash and10% SF by volume of cement at 28 days. (Guiherme *et al*.,2009) reported that for high pozzolanic activity grinding is an important parameter for sugarcane bagasse ash. (Moises *et al*., 2011) reported controlled burning of sugarcane bagasse ash at 800^{o}C-1000^{o}C increases pozzolanic activity. In this study the lower in the strength of Bagasse ash concrete compared to flyash may be due to the less pozzolanic activity of bagasse ash obtained which was due to its unprocessed (i.e.,not grinded)nature and resulted from calcination at 1500^{o}C.The split tensile strength of unprocessed BASF based concrete at all replacement level was illustrated in Fig 4.

Table 4: BASF Blended Concrete on the Compressive Strength after Various Curing Ages

Sample	% of BA replacement	Silica Fume %	Compressive Strength of cube at various curing ages (MPa)			Split Tensile strength of Cylinder (MPa)	
			7 Days	14 Days	28 Days	7 Days	28 Days
BASF0	0	10	15.82	20.00	34.93	2.98	2.93
BASF10	10	10	19.37	27.38	37.90	2.57	2.9
BASF20	20	10	12.59	20.67	26.25	0.88	2.0
BASF30	30	10	8.58	9.89	14.46	0.40	1.11

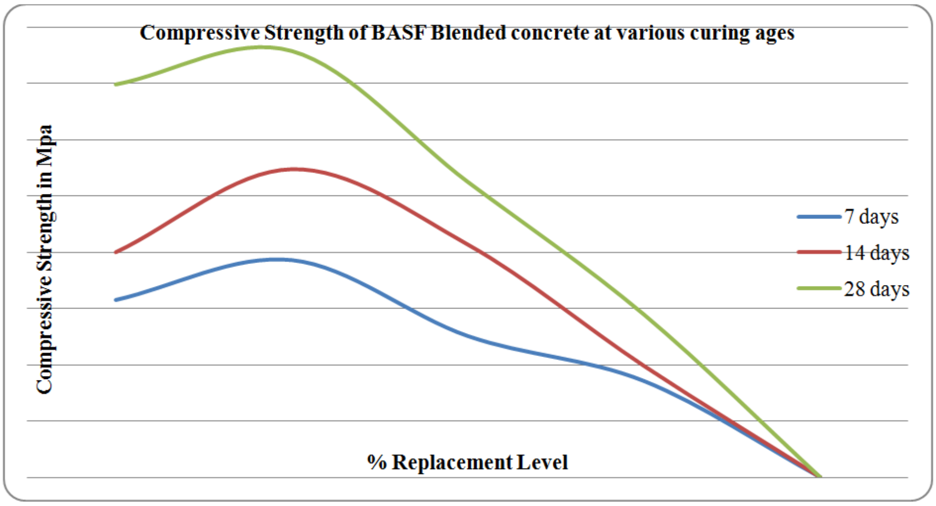

Fig. 3: Compressive Strength of BASF Blended Concrete after Various Curing Ages.

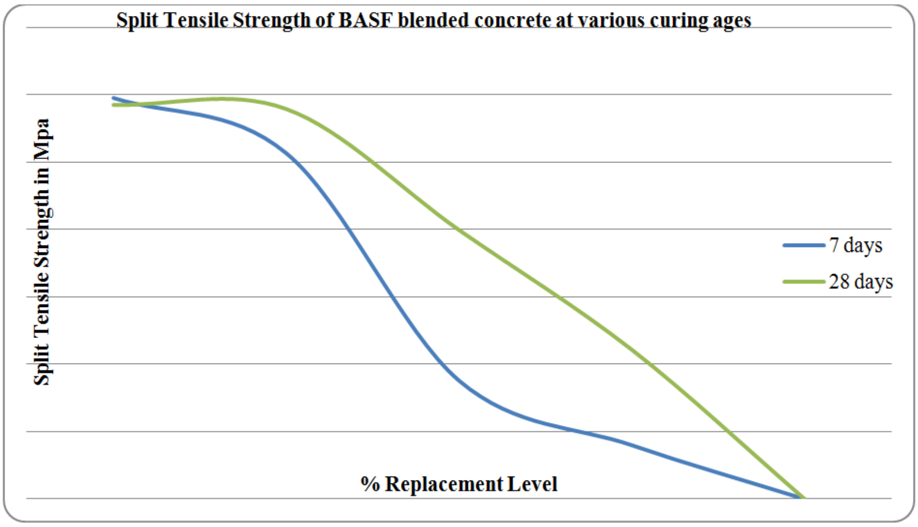

Fig. 4: Split Tensile Strength of BASF Blended Concrete After Various Curing Ages.

Application of Basf in the Manufacture of Hollow Blocks:

After exploring the strength properties of concrete, the same mix proportion was adopted to cast hollow block specimens of size 400 × 150 × 150 mm using BASF concrete as shown in Fig. 5.

Fig. 5: Hollow Concrete Blocks Cast and Tested.

All ingredients were weigh batched at the commercial manufacturing plant automatically as specified above except the sand which was replaced by quarry dust confirming to (IS: 383, 1987) (Bashar et.al.,2012) reported for the hollow concrete block of 1:1:2 mix the water content adopted for all the mixtures was 8% of the total batch weight .Hence in this study the water cement ratio was increased slightly to 0.55 to support hollow blocks production. All mixing, casting, and accelerated curing of all hollow masonry units were performed by the manufacturing plant following their standard commercial production procedure. The specimens were cured in water tank up to the testing age.

The compressive strength test was carried out after various curing ages as per the test procedure detailed in (IS: 2185 ,2005) .The tests were conducted for eight specimens and the average was taken for each mix proportion at all replacement level and the results are shown in Table 5. The specimens were wiped to a surface dry condition upon removal from the curing tank just before the test.

Table 5: Compressive Strength Test of BASF Blended Hollow Concrete Blocks

Sample Designation	% Replacement of baggasse ash	Silica fume added in %	Compressive strength days after various curing ages (MPa)			
			7 days	14 days	21 days	28 days
BASF0	0	10	6.51	7.32	7.74	9.4
BASF10	10		6.18	6.91	7.30	9.98
BASF20	20		4.26	5.76	6.53	7.10
BASF30	30		4.17	5.63	6.01	6.80

Water Absorption Test and Density Test:

After the investigation of compressive strength for hollow concrete block it was further needed to find the water absorption and density of hollow concrete block for conforming to the requirements of specification as per(IS: 2185 ,2005) .Hence water absorption and density properties for hollow concrete blocks were investigated as prescribed in (IS: 12440,1998)at all replacement levels and the average results are reported in Table 6.

Table 6: Water Absorption and Density of BASF Blended Hollow Concrete Blocks.

Sample Designation	Water Absorption %	Density in kg/m^3
BASF 0	2.44	1683.70
BASF 10	2.16	1626.41
BASF20	2.72	1586.27
BASF30	2.24	1598.19

In short, results showed that the compressive strength and water absorption and density of the hollow concrete block made of BASF blended concrete at 10%, 20% and30% falls under IS: 2185 (Part 1) Grade A load bearing units which specifies minimum block density of 1500 kg/m^3 and minimum average compressive strength of 3.5, 4.5, 5.5 and 7 N/mm^2, at 28 days (IS: 2185 ,2005) .(Bashar *et al*.,2012) reported for similar mix proportion of 1:1:2 mix with 15% flyash,0% crump rubber and 10% SF replaced by volume of cement the compressive strength of hollow concrete block was 11.8 N/mm2.In this study it is observed that a maximum compressive strength of 9.98 MPa was attained with 10% BASF replacement at 28 days as illustrated in Fig 6.

Conclusions:

Based on the test results of the experimental investigations the following observation were drawn:

- The unprocessed sugarcane bagasse ash was suitable to be used as a CRM with silica fume as admixture.
- Up to 10% SCBA (sugar cane Bagasse ash) in concrete could be considered as the optimum replacement level for short term strength while 20% - 30% replacement level was useful for long term strength.
- Burning the bagasse at high temperatures would produce ash with crystalline silica. This ash was successfully replaced in the production of hollow concrete blocks with silica fume as admixture.
- The reuse of bagasse ash as a cement replacement in the production of hollow concrete blocks using silica fume as admixture could provide a satisfactory solution to environmental concerns associated with waste management.
- BASF based hollow concrete blocks up to 30% replacement of cement could be used for load bearing units as per (IS: 2185,2005).

Hence BASF finds potential utility in structural concrete as well as in hollow blocks production. However, the bagasse ash property may vary due to burning conditions, temperature, environmental conditions etc. Hence it is further needed to develop such materials in each sugar industry to effectively resolve the disposal problem of the bagasse ash and simultaneously achieve energy conservation.

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