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Experimental Investigation on Utilization of Sugarcane Bagasse Ash as a Cementitious Material in Mortar

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Abstract: This study deals with assessing the possibility of using sugarcane bagasse ash (SBA) as a partial substitution of Portland cement to produce mortars.

The SBA with greater pozzolanicity was characterized using chemical analysis and SEM technique. The study investigated the physical properties of materials used. To know the effect of bagasse ash on properties of cement mortar, masonry mortar grade MM5 mix is considered.

The replacement of OPC with bagasse ash was made at 10%, 15% and 20% and fresh properties of mortar were obtained using flow table test, which results the flow spread would decrease with increase of SBA replacement. The test on normal mortar and the mortar with SBA was carried out.

The mechanical properties such as compressive strength, flexural strength and split tensile strength were analysed experimentally for 7 and 28 days of curing. Here Mortar mix of MM5 grade with compressive strength between 4 and 7.5 MPa were achieved. The effect of sample size on the compressive strength is studied along with the replacement of cement by bagasse ash.

Keywords: Mortar, Flow Value, Compressive Strength, Split Tensile Strength, Flexural Strength.

I. INTRODUCTION

The Usage of Portland cement is increasing day by day because of the fast growth of construction in worldwide. Cement production consumes lot of raw materials from insufficient natural resources.

This results in releasing the enormous amount of waste materials and emit the corbondioxide into the atmosphere, which creates a serious environmental problems to overcome these issues the replacement of cement with supplementary cementitious material is considered often obtained from industrial or agricultural wastes.

Sugarcane bagasse ash leads to be good choice for the partial replacement of cement, which have pozzolanic activity due to the high content of silica (SiO_2) present in it.

Pozzolanic activity depends mainly on the combustion temperature, which should be between 400 °C and 800 °C, to stop the formation of crystalline phases of silica [2].

Sugarcane bagasse ash generated in large quantities (67,000 tonnes/day) in India. India ranks in the second position in the production of sugarcane after Brazil.

The major sugarcane producing states in India are Uttar Pradesh, Karnataka, Maharashtra, Tamil Nadu, Gujarat, and Andhra Pradesh. These states contribute more than 85% of the total sugarcane production in India [3].

Sugar cane bagasse ash (SBA) is generated as a combustion by-product of sugar cane bagasse. A huge quantity of bagasse ash generation poses the disposal problems is reduced by recycling process means this industrial waste is used as a cement replacement material in the work

. The mortar proportion of 1:4 (cement sand) ratio and the flow percentage of 80% is used throughout the work. The main objective of the work is to evaluate SBA as cement replacement material in mortar with variable percentage and it is compared with normal mortar by determining their compressive strength, split tensile strength and flexural strength.

II. MATERIALS

A. Cement

In the present work, Deccan Grade 53 Ordinary Portland Cement is used. The obtained physical properties of the cement are given in Table 1.

TABLE 1: Physical Properties of Cement

Sl.No	Tests	Results	Procedure	Requirement as per IS: 12269-1987
1	Specific gravity	3.15	IS 4031	3 - 4
2	Fineness	5%	IS 4031(Part1)-1996	Not more than 10%
3	Standard consistency	32%	IS 4031(Part4)-1988	No standard value
4	Initial setting time	35 mins	IS 4031(Part5)-1988	Not less than 30 min
5	Final setting time	145 mins	IS 4031(Part5)-1988	Not more than 600 min

B. Fine Aggregates

The Manufacture sand (M-Sand) was used as fine aggregate in the present investigation. The sand is free from clayey matter, salt and organic impurities. The properties of the fine aggregate are given in the Table 2.

TABLE 2: Physical Properties of Fine Aggregate

Sl.No	Tests	Results	Procedure	Requirements As per IS: 383- 1970
1	Specific gravity	2.75	IS: 2386(Part3)-1963	2.3 to 3
2	Fineness modulus	2.816	IS: 2386(Part3):1963	2.3 to 3.5
3	Water absorption	1%	IS: 2386(Part3):1963	<3%
4	Bulk density	1630 kg/m^3	IS: 2386(Part3):1963	---------------
5	Sieve analysis	ZONE-II	IS 2386(Part1)-2007	ZONE-I to ZONE-II

C. Water

The water that is used for casting mortar is clean and free from harmful impurities such as oil, alkali, acid etc. In general, the water that is fit for drinking is used for casting and curing of mortar.

D. Sugarcane Bagasse Ash

Sugarcane Bagasse ash, the residual ash was collected from NSL Sugars Limited which is located at, Koppa village, Maddur Taluk, Mandya District, Karnataka. It is burnt at a temperature of 750-800°C. It was transported by packing them in cement bags and then it was dired for 2-3 days to remove moisture content in it. Grounded into fine powder passing through 150 micron sieve used as a cement replacement material throughout the work. The obtained specific gravity of SBA is 1.971 and the fineness modulus of SBA is 2.516%. The chemical properties of SBA are given in Table 3 as per the test report given by the ISO certified laboratory.

TABLE 3: Chemical Properties of Sugarcane Bagasse Ash

Sl.NO	Particulars	Results
1	LOI	13.10%
2	Silicon as SiO_3	76.32 %
3	Aluminium as Al_2O_3	0.2%
4	Iron as Fe_2O_3	4.02%
5	Calcium as CaO	3.68%

As per IS 3812(part1)-2013 specifications the combined chemical composition of SiO_2+Al_2O_3+Fe_2O_3 should be greater than 70% which satisfies the pozzolanic nature of SBA. The more percentages of Silicon oxides in the Table3 shows that Sugarcane Bagasse Ash is a very good pozzolanic material, which satisfies the above-mentioned codal provisions.

III. EXPERIMENTAL WORK

Determination of pozzolanic activity of sugarcane bagasse ash was carried out using the tests like Loss on ignition test (LOI) and conductometric method. The electrical conductivity test is conducted for analysing the pozzolanic material in bagasse ash as per Luxan et.al. The LOI test is performed to know the amount of pozzolanic material in SBA as per IS: 1727-1967. The morphology of the bagasse ash particles was inspected using scanning electron microscopy (SEM). After knowing the pozzolanic activity of bagasse ash, the replacement of OPC with bagasse ash was made at 10%, 15% and 20%. The fresh properties of mortar is determined using flow table test. The flow table test is conducted as per IS 4031(Part7)-1988 to determine the water percentage in accordance flow was kept constant (80%) and also water percentage was determined for varying replacement of cement with bagasse ash. This water percentage is used for casting the specimens. Here cube moulds of size 50x50x50mm, 70.6x70.6x70.6mm, 150xl50xl50mm and cylindrical mould 150x300mm were casted to determine the compressive strength of mortar. Different size cube moulds used in order to determine the scaling effect on the strength properties of mortar. Cylindrical mould size 150x300mm were casted to determine split tensile strength of mortar and the three gang prism mould of size 40x40x160mm were casted to determine the flexural strength of mortar beam. The casted specimens were tested at the age of 7 and 28 days.

Fig. 1 Different size of mortar specimens casted

IV. RESULTS AND DISCUSSION

A. Loss on Ignition Test

The LOI test conducted as per IS: 1727-1967 for the bagasse ash sample passing through 150-micron sieve, obtained LOI value is 8%. LOI less than 10% gives an excellent pozzolanic material as per ASTM code C618. It can be concluded that removal of fibrous particles can significantly reduce loss on ignition of bagasse ash.

B. Conductometric Method

The procedure to conduct this method is followed as per Luxan et.al (1989). Here 5 grams of sample (passing 150-micron sieve) taken and mixed in the 200ml of saturated calcium hydroxide solution. Then measures the changes in conductivity during first 2mins ($\Delta\ \sigma_{2\ min}$, in mS). The conductivity drop takes place in 2mins due to the consumption of Ca^{2+} and OH^- by the pozzolanic reaction. The obtained initial conductivity value is 4.35 mS and final conductivity value is 3.8 mS. Therefore it is concluded that the $\Delta\sigma_{2\ min}$ value is greater than 0.4 hence the bagasse ash exhibits variable pozzolanicity.

C. Scanning Electron Microscopy (SEM Analysis)

Microstructural particles in the cementitious material is the reason for knowing the activity of pozzolanic materials. The structure of the bagasse ash (passing 150-micron sieve) particles were qualitatively determined using scanning electron microscopy technique. The SEM was conducted at an acceleration voltage of 5kV. The images obtained as the different shape and size of particles. The obtained particles have a variety of shapes that is Prismatic, spherical, Porous, irregular, and fibrous shaped particles. Irregular shaped Particles were observed using higher magnifications in the microstructure are shown in Fig2. Spherical shaped particles are formed because of melting at high temperature were observed in the microstructure of bagasse ash shown in Fig3. These spherical shaped particles were found to contain oxides of K, P, and Mg. It has been reported that spherical shaped particles are generally alumina silicates and fibrous particles are carbon in Fig2. Prismatic particles were observed, which as a well defined structures and rich in silica shown in Fig3.

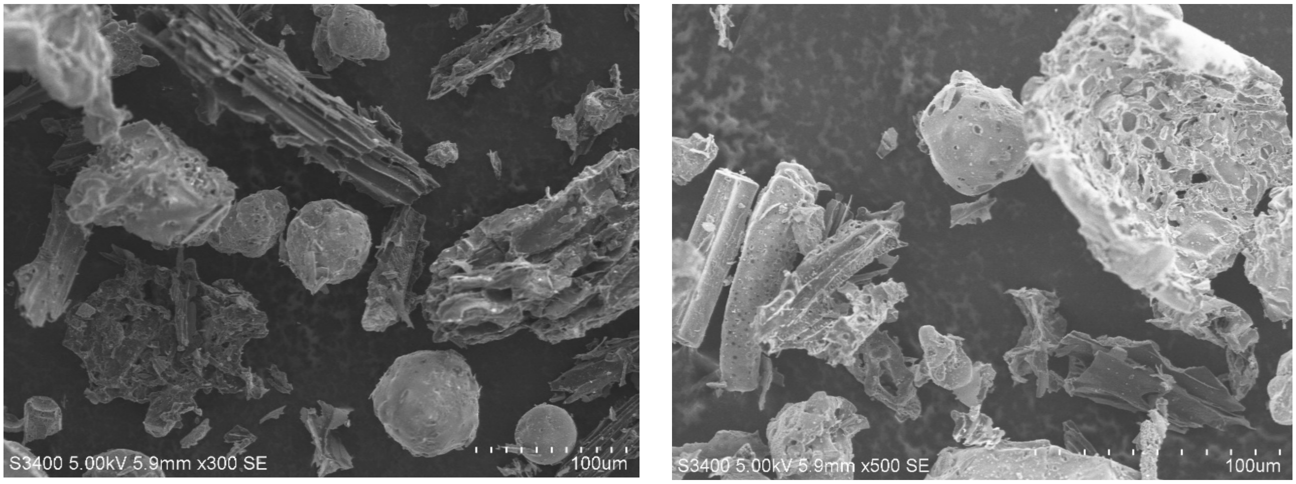

Fig. 2 Irregular, Porous and fibrous shaped particles were observed in the bagasse ash

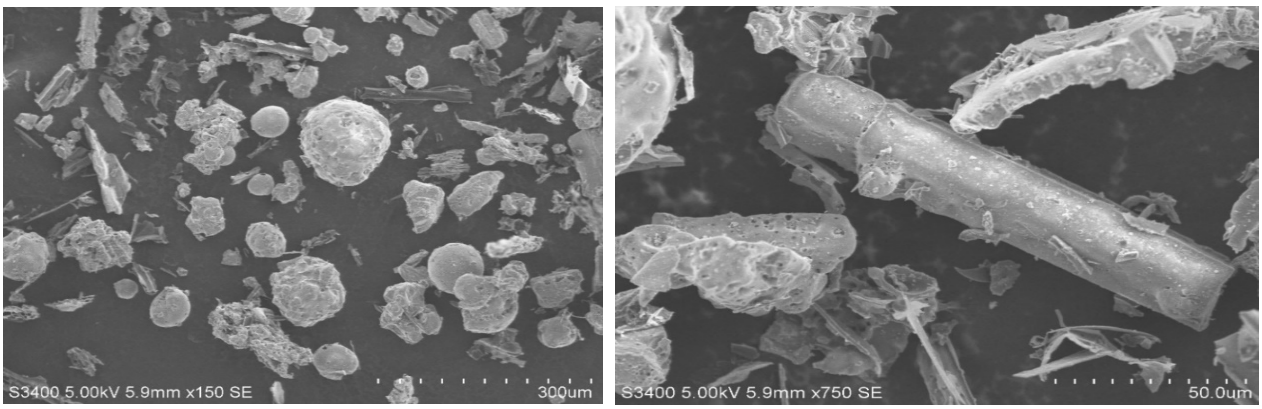

Fig. 3 Prismatic shaped particles and Spherical shaped particles were observed in the bagasse ash

D. Fresh Properties of Mortar

The fresh property of mortar is determined using the flow table test. Here water demand increases with the addition of pozzolan in mortar because SBA as a hydrophilic nature, which attracts water more towards it when compared to cement. Based on this, itis noticed that to achieve proper workability, bagasse ash replacement with cement requires more water. Therefore, for better understanding, here flow was kept constant (80%) accordance to water percentage and also water percentage was determined for varying replacement of cement with bagasse ash is represented in Fig4. Results of Workability in terms of flow of mortar after replacing bagasse ash with cement shown in below Table 4.

TABLE 4: Results of Flow Table Test

Sl.NO	% Bagasse ash replacement	Obtained water percentage
1	0%	102%
2	10%	120%
3	15%	125%
4	20%	130%

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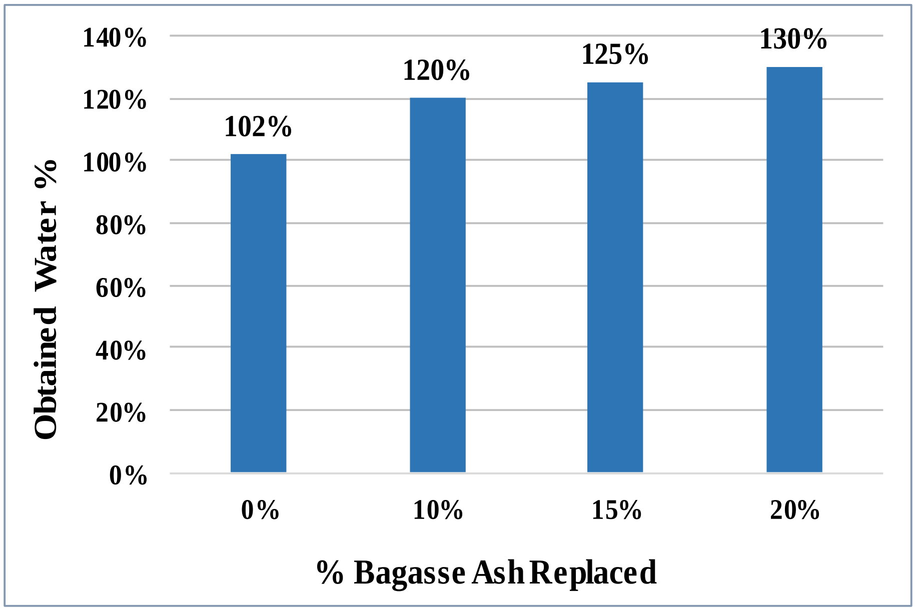

Fig. 4 Variation in water percentage at various replacement levels for mortar

E. Hardened Properties of Mortar

In this work, we discuss the strength behaviour of controlled mortar and replaced bagasse ash mortar for different percentage that is 0%, 10%, 15%, 20%.

1) *Compressive Strength of Mortar*: Outcome of compressive strength test results is shown in the Table 5, Table 6, and Table 7.

TABLE 5: Compressive Strength Values of Mortar Cubes at 7 days

Cube size	Bagasse ash replacement			
	0%	10%	15%	20%
50x50x50mm	7.2	6.933	6.4	5.867
70.6x70.6x70.6mm	7.153	6.82	6.286	5.753
150x150x150mm	7.08	6.767	6.203	5.696

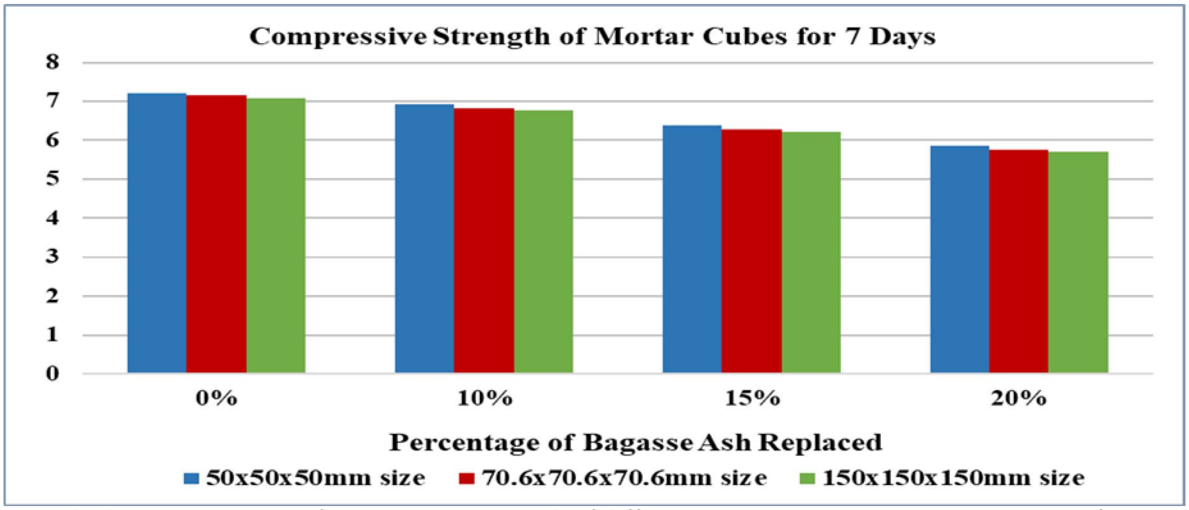

Fig. 5 Graph Showing Variation of Compressive Strength of different mortar size at Varying Percentages of SBA at 7days

TABLE 6: Compressive Strength Values of Mortar Cubes at 28 days

Cube size	Bagasse ash replacement			
	0%	10%	15%	20%
50x50x50mm	8.267	7.867	7.333	6.933
70.6x70.6x70.6mm	8.153	7.686	7.153	6.753
150x150x150mm	7.967	7.553	6.993	6.496

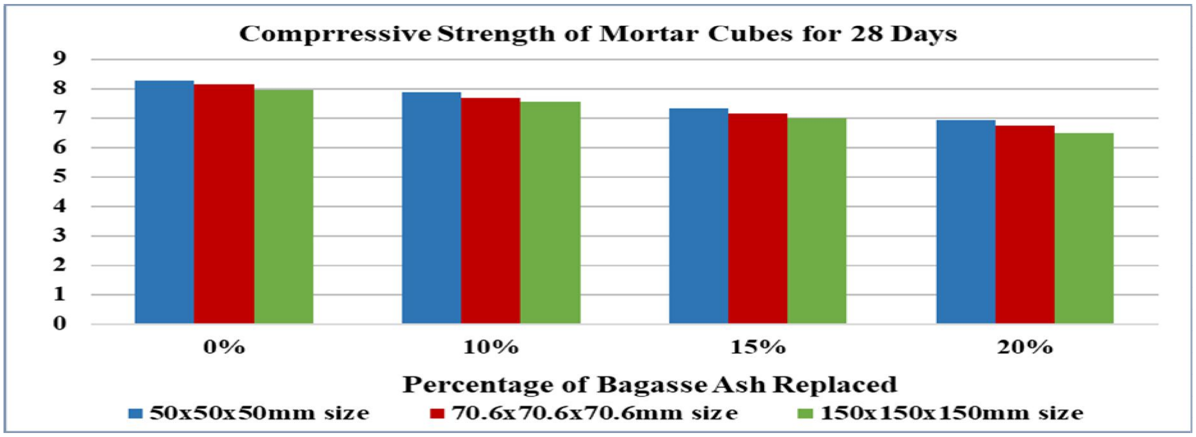

Fig. 6 Graph Showing Variation of Compressive Strength of different mortar size at Varying Percentages of SBA at 28 days

From Fig5 and Fig6, the compressive strength of mortar cube 50mm size having greater compressive strength value of 8.267N/mm^2 at the end of 28 days compare to other mortar cube size with % replacement of bagasse ash.

TABLE 7: Compressive Strength Values of Cylindrical Mortar

Sl.NO	% Bagasse ash replaced	Compressive strength(MPa)	
		7 days	28 days
1	0%	7	7.77
2	10%	6.69	7.356
3	15%	6.156	6.77
4	20%	5.463	5.993

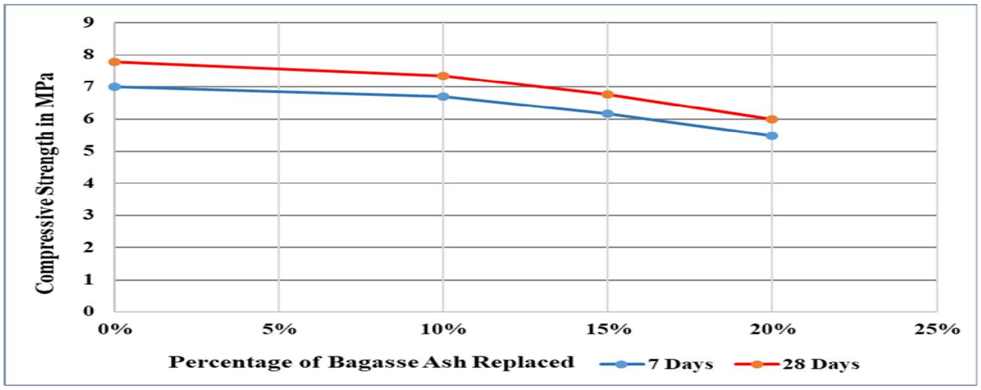

Fig. 7 Compressive strength of cylindrical mortar for 7 and 28 days v/s percentage replacement of SBA

From the Fig7, the cylindrical mortar with 10% of SBA after 28 days of curing had higher strength when compared to the mortar with other replacement percentages. Hence, 10% is considered as the optimum percentage for replacement.

2) *Split Tensile Strength of Mortar:* The result of tensile strength of cylindrical mortar are shown in Table 8 and graphical Variation shown in Fig 8.

TABLE 8: Tensile Strength Values of Cylindrical Mortar

Sl.NO	**% Bagasse ash replaced**	**Split tensile strength (MPa)**	
		7 days	**28 days**
1	0%	1.16	2.018
2	10%	1.056	1.890
3	15%	0.971	1.575
4	20%	0.839	1.107

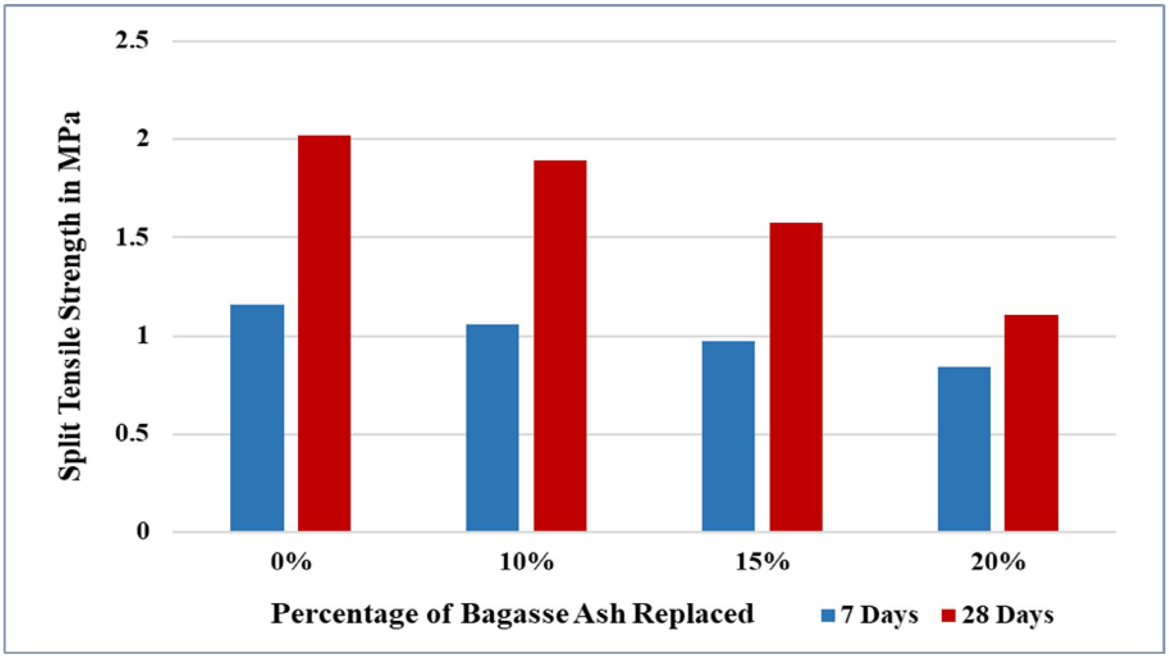

Fig. 8 Split Tensile strength of mortar for 7 and 28 days v/s percentage replacement of SBA

Above Fig8 shows that, the split tensile strength value 2.018N/mm^2 of normal mortar at the age of 28 days is higher compared to other percentage replacement of SBA mortar.

3) *Flexural Strength of Mortar:* The result of flexural strength of mortar beam are shown in Table 9 and graphical Variation shown in Fig 9.

TABLE 9: Flexural Strength Values of Mortar Beam

Sl.NO	% Bagasse ash replaced	Flexure strength (MPa)	
		7 days	28 days
1	0%	2.286	3.813
2	10%	2.006	3.36
3	15%	1.353	2.8
4	20%	1.073	2.33

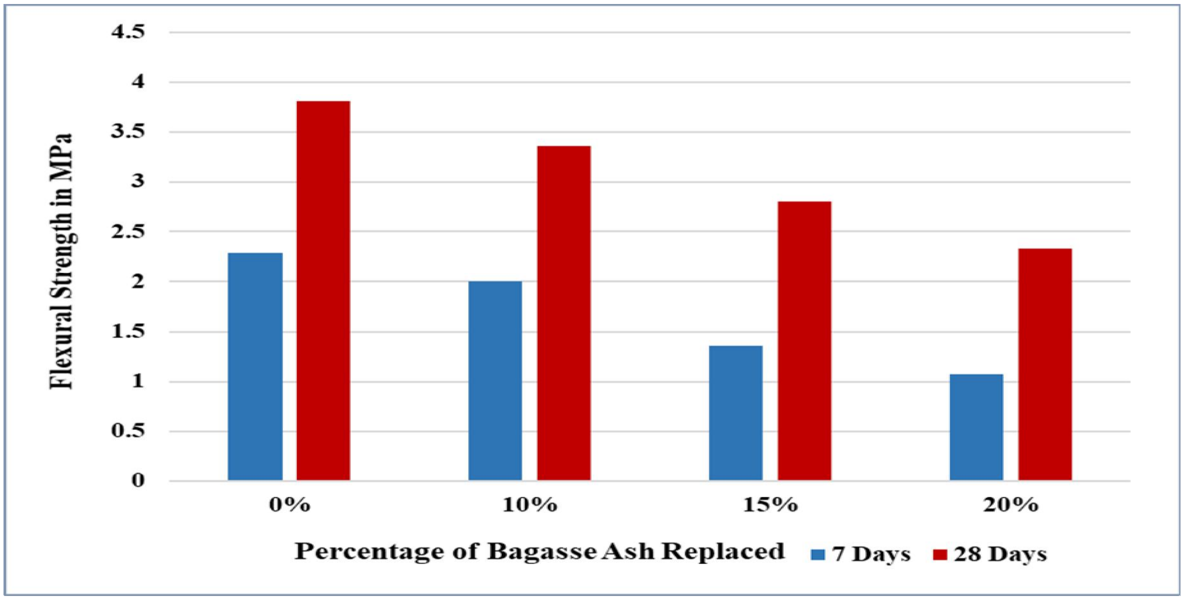

Fig. 9 Flexure strength of mortar for 7 and 28 days v/s percentage replacement of SBA

Above Fig9 shows that, the flexural strength value 3.813N/mm^2 of normal mortar beam at the age of 28 days is higher compared to other percentage replacement of SBA mortar beam.

V. CONCLUSION

Sugarcane bagasse ash is a material that has a great potential to use as a partial replacement in mortars. The research analysed the percentage of amorphous SiO_2 using LOI test. The pozzolanic activity of SBA is analysed using Conductometric test. The SBA was characterized using chemical analysis and SEM technique. Here properties of fresh mortar confirm that SBA increases the workability of mortar. It is concluded that replacement upto 20%, the minimum compressive strength required for the MM5 grade mortar mix is achieved according to IS 2250-1981. From the obtained results, the compressive strength of mortar cube 50mm size having greater compressive strength compare to other mortar cubes. It is concluded that as the specimen size increases the compressive strength decreases. The split tensile strength and flexural strength of mortar specimen after 7 days and 28 days of curing decreases with increasing the percentage of replacement of cement by SBA. There is no specific IS code approved the minimum flexural and tensile strength required for the mortar.

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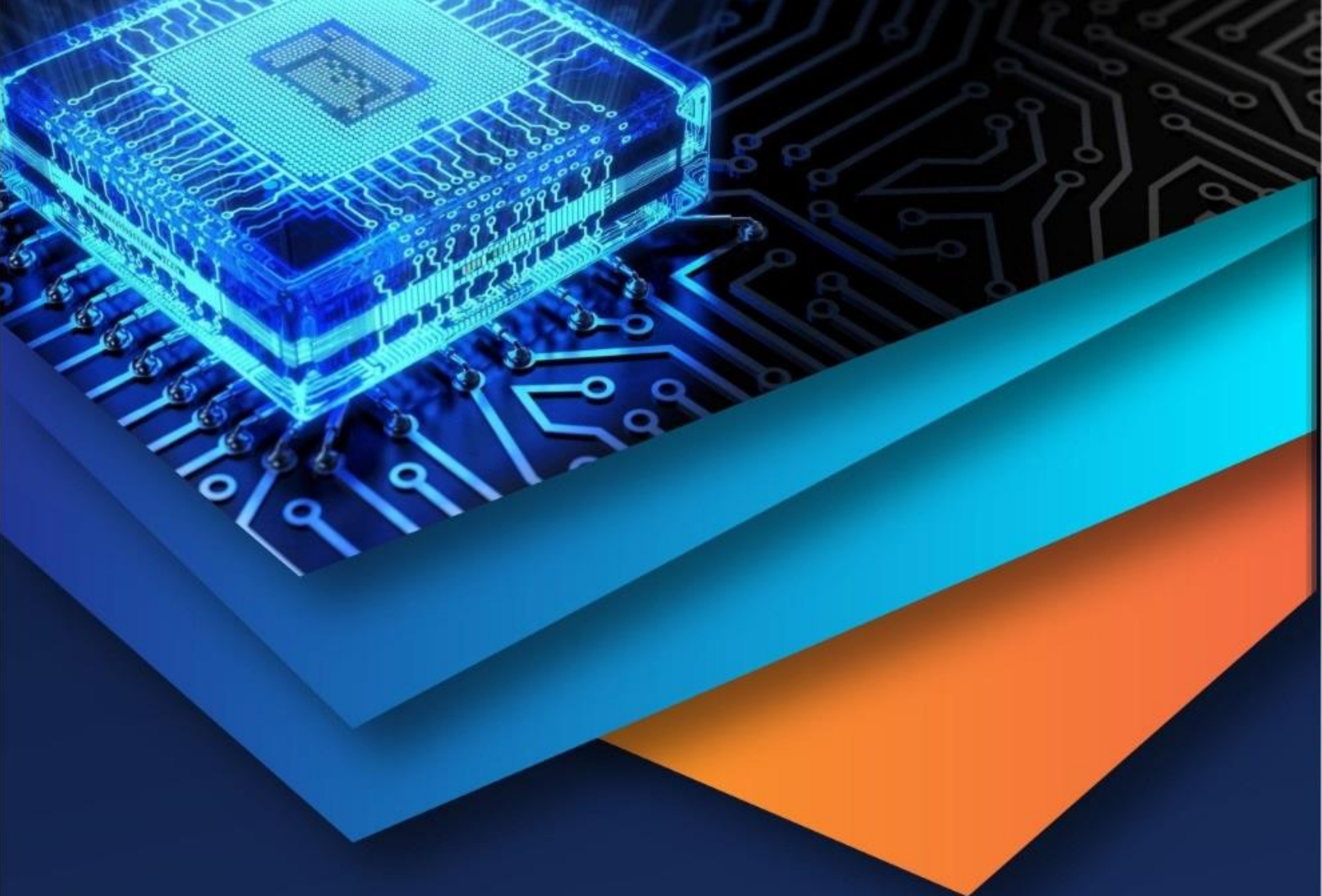

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