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 (SiO2) 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.

| Sl.No | Tests               | Results | Procedure                                      | Requirement as per IS: |
|-------|---------------------|---------|------------------------------------------------|------------------------|
| 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.

| Sl.No | Tests               | Results | Procedure                                      | Requirements As per IS: |
|-------|---------------------|---------|------------------------------------------------|------------------------|
| 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/m³ | 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 dried 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.

| Sl.NO | Particulars        | Results |
|-------|--------------------|---------|
| 1     | LOI                | 13.10%  |
| 2     | Silicon as SiO₂    | 76.32%  |
| 3     | Aluminium as Al₂O₃| 0.2%    |
| 4     | Iron as Fe₂O₃     | 4.02%   |
| 5     | Calcium as CaO     | 3.68%   |

As per IS 3812(part1)-2013 specifications the combined chemical composition of SiO₂+Al₂O₃+Fe₂O₃ 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 bagasse ash 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, 150x150x150mm 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](image)

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 ($\Delta \sigma_{2\text{ min}}$, 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 $\Delta \sigma_{2\text{ min}}$ 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, it is noticed that to achieve proper workability, bagasse ash replacement with cement requires more water. Therefore, for better understanding, here flow was kept constant (80%) according 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.

| Sl.NO | % Bagasse ash replacement | Obtained water percentage |
|-------|---------------------------|---------------------------|
| 1     | 0%                        | 102%                      |
| 2     | 10%                       | 120%                      |
| 3     | 15%                       | 125%                      |
| 4     | 20%                       | 130%                      |
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/mm² 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

| SI.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.

| 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   |

![Graph showing split tensile strength of mortar for 7 and 28 days vs percentage replacement of SBA](image)

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.

| 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    |

![Graph showing flexural strength of mortar beam](image)
Above Fig 9 shows that, the flexural strength value 3.813N/mm² 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 SiO₂ 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.

REFERENCES

[1] S Praveenkumar, J Shannugasundaram and B Samynathan, “A Study on Effect of Bagasse Ash in Properties of Cement Paste and Mortar”, International Journal of ChemTechResearch, ISSN: 0974-4290, Vol.10 No.8, pp 219-225, 18 September 2017.
[2] C.Bernabe Reyes, W. Martinez Molina, E. M. Alonso Guzman, “A study on Using Bagasse Ash as a Substitute for the Preparation of Cement Mortar”, 2nd International Conference on Green Materials and Environmental Engineering (GMEE 2015).
[3] Bahurudeen, A.V. Marckson, Arun Kishore, Manu Santhanam, “A Study on Development of sugarcane bagasse ash based Portland pozzolana cement and evaluation of compatibility with superplasticizers”, Construction and Building Materials 68 (2014) 465–475 Elsevier Ltd.
[4] Sirirat Janjaturaphan and Supaporn Wansom, “A Study on pozzolanic activity of industrial sugar cane bagasse ash”, National Science and Technology Development Agency (NSTDA), Sci.Technol. Vol. 17 No. 4: 349-357, Oct-Dec 2010.
[5] Romildo Alves Berenguer, Fernando Artur Nogueira Silva, Eliana Cristina Barreto Monteiro “A study on Effect of Sugarcane Bagasse Ash as Partial Replacement of Cement on Mortar Mechanical Properties” Electronic Journal of Geotechnical Engineering, 2016(21.14), pp 4577-4586. Available at ejge.com.
[6] G.C. Cordeiro, R.D. Toledo Filho, L.M. Tavares “A Study on Pozzolanic activity and filler effect of sugar cane bagasse ash in Portland cement and lime mortars”, Cement & Concrete Composites 30 (2008) 410–418, Elsevier Ltd.
[7] Nuntachai Chusilp, Chai Jaturapatkulkul, Kria Wood Kiattikomol “A Study on Effects of LOI of ground bagasse ash on the compressive strength and sulphate resistance of mortars”, Construction and Building Materials 23 (2009) 3523–3531 Elsevier Ltd.
[8] IS: 1727-1967, Indian standard code for Methods of test for pozzolanic materials, Bureau of Indian Standards, New Delhi.
[9] IS: 2250-1981, Code of practice for preparation and use of masonry mortars, Bureau of Indian Standards, New Delhi.
[10] IS: 12269-1987, Indian Standard code for ordinary Portland cement 53 grade specification, Bureau of Indian Standards, New Delhi.
[11] IS: 4031-7 (1988): “Methods of physical tests for hydraulic cement, Part 7: Determination of compressive strength of masonry cement”.

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