Uncontaminating Concrete Mix Using Sugarcane Bagasse Ash: A Review on its Hardened Properties

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Abstract. Concrete is one among the most used material for construction other than water. Cement is the important constituent of concrete. During the production of cement high amount of carbon dioxide is emitted and is responsible for global warming. High amount of cement production is causing environmental problem. Use of agro-waste materials like bagasse ash, increases the strength characteristics of concrete and also causes proper disposal of the waste materials. In this paper, use of sugarcane bagasse ash, an agro-waste product, as a partial replacement of the cement in concrete mix and its effect on the strength parameters of concrete are also identified on the basis of compressive strength, spilt tensile strength and flexural strength. This waste usage is very economical and also have positive impacts on minimizing environmental pollutions.

1. Introduction

We are aware that a lot of damage is done to environment in the manufacture of cement. It emits carbon dioxide associated with other chemicals. The researchers have shown that every one ton of cement manufacture releases its half ton of carbon dioxide, so there is an important need to control the use of cement. On the other hand, material wastes such as sugarcane bagasse is difficult to dispose which causes environmental hazards. The bagasse ash gives high early strength to concrete and also decreases the permeability of concrete [1]. The silica present in bagasse ash reacts with cement components during hydration and improves properties like chloride resistance, corrosion resistance etc. [2]. Hence the use of bagasse ash in concrete not only reduces the environmental pollution, but also improves the properties of concrete thereby reducing the cost. It also improves the durability of the concrete [3].

Because of expeditious developments in agricultural and industrial sectors, large quantities of waste materials are being produced in these sectors. Clearance of these wastes is becoming serious environmental issue these days. Most of the discarded waste results in filling the landfills, which reduces the availability of useful land. These may in turn result in polluting the environment. Most of the industrial byproducts which include, silica fume, fly ash, coal, GGBS etc. could be used for social and economical benefits, by successfully transforming it into cementitious materials which find applications especially in construction fields [4]. Recently, the forestry and agricultural remains are used as biomass fuels. The resulting ashes from the fumes are the final waste products and proper management and utilization of these waste materials are now emerging as a wide area of research. These biomass ashes like palm oil fuel ash, sugarcane bagasse ash, bamboo stem ash, risk husk ash, elephant grass ash etc. are now being utilized as Supplementary Cementitious Materials (SCM) [5]. From the researches and studies done till now, it could be inferred that incorporating the waste ashes in cementitious materials could improve or maintain the mechanical characteristics and properties of concrete [5]. In addition to these the incorporation of these biomass ash in cement production can considerably reduce the greenhouse gas generation involved with the process of cement production and also considerably making these processes economical. This results in reducing the waste disposal pressure and environmental pollutions leading to a sustainable development.
2. Material

2.1. Sugarcane bagasse ash
Sugarcane bagasse ash (SCBA) is the main byproduct from sugar factories which is obtained after the burning of sugarcane bagasse. Sugarcane bagasse is the waste product resulting after extracting the useful or economical sugar from sugarcanes. The dumping of these materials are causing a large environmental problem for the sugar manufacturing factories.

3. Physical properties
The composition and physical properties of SCBA will vary with factors, in particular, the sugar cane variety, combustion duration and combustion temperature, purity of sugarcane bagasse, locations and methods of ash collection, type of cooling, equipments used, ash fineness etc. The colour of SCBA is dark to light black. A better carbon content is specified by a dark black colour of SCBA. Due to the crystallization along with its decomposition at higher temperatures, the bagasse ash seems to be gray over 800 °C and seems to be white over 900 °C [6].

4. Chemical composition
The chemical composition among different SCBA samples is remarkably different. However, most of the samples possesses components of silica, alumina, and other metallic elements [3,9]. As per the specifications of ASTM C618-08a, natural pozzolans having SiO$_2$, Al$_2$O$_3$, Fe$_2$O$_3$ together tallying the whole mass over 50% could be designated as a class C pozzolan and class F pozzolans which have the ratio over 70% [5]. The combined effect of relative stiffness and the pozzolanic activity created by SCBA is due to the presence of silica [7,9].

5. Application
- Sugarcane bagasse, a voluminous by product in the sugar mills following the extraction of juice from the sugarcane, was generally being used as a fuel to the fireside furnaces which was within the corresponding sugar mill. This yield about 8% to 10% ash which contain high amounts of unburnt matter, alumina, silica, iron oxides and calcium oxides [5,6].
- Earlier SCBA was utilized as a fertilizer or it was dumped into landfills. This led to a serious environmental concern. But in the recent years, researches on SCBA focused mainly on its usage as construction materials, because of its pozzolanic features [8].
- Studies indicates that SCBA, is a form of propitious construction material and its usage as a pozzolanic material, include its usage in alkali - activated binders, fillers and aggregates in construction medium [2,8].
- The impression of SCBA in fresh concrete and hardened concrete highlights its properties, which include the physical characteristics, microstructure, mechanical characteristics and sturdiness [5].
- It is now used as a biofuel for warmth, energy and electricity generation and also in the manufacturing of pulp and building materials.
- SCBA is used as a soil stabilization material especially in the case of laterite soil.

6. Effect of sugarcane bagasse ash on workability
Reddy et al. (2017) revealed from the workability slump cone test results that cement could be very beneficially replaced with SCBA up to a maximum value of 10%. In their work, proportions of concrete mix designs for M20 grade was carried out according to the specifications of IS:10262-2009. Different mixes with 5%, 10%, 15% and 20% SBCA replacements were tested for workability and concluded that, the partial replacement of cement in concrete with SCBA, enhances the workability, whereby the use of superplasticizer is not much essential [11].
Mangi et al. (2017) conducted slump test with and without SCBA, to verify the consistency of normal concrete mix. From the results, after executing the slump test on M15 and M20 concrete grades, a continuous slump rise was observed when replaced with SCBA. Here the values observed fall in between low degree and medium degree of workability. Hence the usage of superplasticizer is not very crucial [1].

Priya et al. (2016) conducted both slump test and compaction factor test for workability with 0% to 25% replacement of SCBA in cement. In both the tests the workability values increased with the increase in percentages of SCBA, depicting that the SCBA content can reduce the water requirement of concrete [8].

The comparison of slump values are shown in Table 1

| Si. No | Authors                  | Mix | Replacement with SCBA (%) | Average slump value (mm) |
|--------|--------------------------|-----|---------------------------|--------------------------|
| 1      | Mangi et al. (2017) [1]  | M15 | 0%                         | 31.94                    |
|        |                          |     | 5%                         | 37.48                    |
|        |                          |     | 10%                        | 44.64                    |
| 2      | Mangi et al. (2017) [1]  | M20 | 0%                         | 27.89                    |
|        |                          |     | 5%                         | 42.50                    |
|        |                          |     | 10%                        | 51.12                    |
| 3      | Priya et al. (2016) [8]  | M25 | 0%                         | 70                       |
|        |                          |     | 5%                         | 85                       |
|        |                          |     | 10%                        | 90                       |
|        |                          |     | 15%                        | 100                      |
|        |                          |     | 20%                        | 125                      |
|        |                          |     | 25%                        | 160                      |

7. Effect of bagasse ash on its hardened properties

7.1. Compressive strength

Priya et al. (2016) replaced cement by 5%, 10%, 15% and 20% respectively and tested for compression strength at 28 days. The loading rate of compression testing machine was 0.5 tonnes per second. It was detected that compressive strength of M0 concrete mix had a higher value than M5 concrete mix and concluded that the amount of amorphous silica present was higher than the CaOH produced during the hydration reaction and this would reduce the strength of specimen. The result
showed that, the concrete mix with 10% of SCBA replacement and with 28 days curing, indicated the maximum strength in comparison with the concrete mixes with other percentage replacements of SCBA [8].

From the studies of Amin (2015) the compressive strength of 3 days, 7 days and 28 days with different SCBA replacement levels has increased and has attained comparable values to those of the control concrete specimens. Concrete grade used was M25. The 3 days compressive strength of 20% SBCA was same as that of 7 days compressive strength of control specimen however the 28 strength being slightly higher. The optimum percentage replacement of SBCA was found to be 20% [10].

The comparison of compressive strength of various specimens in the above mentioned works are shown in Table 2.

**Table 2.** Comparison of average compressive strength of specimens (M25)

| Si. No | SCBA replacement (%) | Priya et al. (2016) [8] | Amin (2011) [10] |
|--------|-----------------------|-------------------------|------------------|
| 1      | 0%                    | 33.281                  | 36               |
| 2      | 5%                    | 37.351                  | 42               |
| 3      | 10%                   | 38.077                  | 43               |
| 4      | 15%                   | 36.769                  | 42               |
| 5      | 20%                   | 35.752                  | 40               |
| 6      | 25%                   | 30.956                  | 35               |

Kvjd (2015) had done an experimental research on partially replaced concrete mixes with SCBA in HCL solutions. He casted M35 grade blocks with SCBA mix and tried curing it in normal water and HCL solutions. Finally, it was found that there was a decrease in strength for concrete specimens in HCL solutions as compared to concrete specimen cured in normal water. Compressive strength increased for 7 days, 28 days and 60 days when cured in normal water but it after curing 28 and 60 days in HCL solutions [2]. Table 3 describes the variation in results both in the case of normal water and in HCL.
Table 3. Compressive strength results (in normal water and HCL), Kvjd (2015) [2]

| Sample Designation | Replacement of SCBA in cement | Compressive strength |
|--------------------|-------------------------------|----------------------|
|                    |                               | 7 days   | 28 days | 60 days |
|                    |                               | Normal water | HCL     | Normal water | HCL     |
| C0 0%              |                               | 35       | 32.5    | 45        | 42.5    | 51.38   | 45       |
| C1 5%              |                               | 39       | 37.33   | 48.8      | 43.5    | 49.6    | 46.5     |
| C3 10%             |                               | 39.5     | 39      | 52.3      | 51.33   | 52.5    | 48.16    |
| C4 15%             |                               | 35.5     | 33.16   | 48.5      | 40.5    | 50.66   | 44       |
| C5 20%             |                               | 31.66    | 31.66   | 44.83     | 40      | 45.5    | 39.5     |
| C6 25%             |                               | 32.83    | 20.16   | 43.66     | 30.66   | 40.3    | 26       |

7.2. Split tensile strength

Priya et al. (2015) studied that the split tensile strength of concrete was more than M0 concrete mix upto 20% replacement SCBA in cement. Further, increase in replacement upto 25% led to the reduction in tensile strength due to dilution effect [8].

Bisanal et al (2020) experimented the split tensile strength of cylindrical concrete specimens of grade M30 grade with 5%, 10%, 20% & 30% of bagasse ash substitutions with cement. The 7 days and 28 days split tensile strengths of these specimens increased considerably upto 20% replacements of SCBA [12]

Batool et al (2020) conducted split tensile strength tests with 5%, 10%, 15%, 20%, 25%, and 30% replacement of SCBA in concrete and it was depicted that maximum tensile strength was given by specimen with 10% SCBA replacement. The results implied that there was a significant reduction in tensile strength for samples with higher SCBA substitution [13].

Modani et al. (2013) examined the aspects of SCBA, on the tensile strength of concrete. They casted 45 cubes and 15 cylindrical specimens. SCBA was replaced by 0%, 10%, 20%, 30% & 40% by volume of sand based on the mix volume. The water-cement ratio was 0.40 and the superplasticizer dosage was 0.8%. The 28 days split tensile strength was noted. The test was implemented on cylindrical specimens with 150mm diameter & 300mm height (as per Indian standards). Form the test they detected that the tensile strength development of these mixes decreased with the increase in percentage replacements of SCBA [4].

7.3. Flexural strength

The results obtained from the studies of Priya et al. (2016) specify the difference in flexural strength of specimens with different cement substitutions. The value of flexural strength of M2 mix of 10%
SCBA is higher than that of M5 mix with 25% replacement. Since the flexural strength values of SCBA replaced concrete was more, it could be employed in slabs, beams etc. [8].

Amin et al (2020) investigated the contribution of finely Ground Bagasse Ash (GBA) in the production of Engineered Cementitious Composites (ECCs) along with Polyvinyl Alcohol (PVA). 10%, 20% & 30% replacements were made to cement with bagasse ash. Nine rectangular beam specimens of size 320 mm length, 40 mm height and 12 mm thickness were casted for testing flexural strength using four point loading and tested at end of 14, 28 & 91 days. The results depicted that, the influence of increasing percentage of bagasse ash on the flexural strength reduction was decreasing with aging from 14 days to 28 days and then from 28 days to 91 days [14].

Bisanal et al (2020) experimented the flexural strength of M30 concrete beams with 5%, 10%, 20% & 30% of bagasse ash substitutions. The 28 day flexural strength of these beams increased considerably upto 20% replacements of SCBA [12].

8. Conclusion
From the papers reviewed, it could be inferred that in its unadulterated form, the bagasse ash proved to be a possible ingredient of concrete, since it can be a beneficial replacement for fine aggregate and cement.

- In economic point of view, SCBA when replaces cement saves capital especially in the construction industry. Since sugar bagasse ash is a by-product material, it could be used as a replacement material for cement inorder to reduces the level of carbon dioxide emissions by the cement manufacturing industry.
- Cement with partial replacements of SCBA enhances the workability property of fresh concrete and use of super plasticizers could be considerably reduced.
- In concrete, replacement of cement with upto 20% SCBA performs well compared to ordinary concrete in terms of strength parameters like compressive strength, split tensile strength and flexural strength.
- Permeability of concrete also reduces with the addition of SCBA resulting in increased durability of structures.
- In addition, it resolves the scrapping problems which are associated with the sugar manufacturing industries hence keeping the environment pollution free and sustainable.

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