Utilization of Sugarcane Bagasse Ash to Improve Mechanical Properties and Producing a Sustainable Concrete

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Abstract
The increase in demand and consumption of cement, scientists and researchers are searching to develop alternative binding materials that are not only ecofriendly, but equally contribute to manage the waste. The use of industrial byproduct and agricultural waste obtained through industrial procedures has focused on managing the waste and their reduction. Sugarcane bagasse ash (SCBA) being one of the agricultural waste is a fibrous waste product produced by sugar mills. During the process at Sugar mills, the Fluid from sugarcane is extracted and ash is produced by burning bagasse at high temperatures. In this research study, (SCBA) has been replaced partially in ratios of 0%, 5%, 10%, and 15% by weight of total cement in concrete mixture. Fresh and hardened concrete properties were obtained through tests which include workability test, compressive strength and tensile strength. The test result revealed that the compressive and tensile strengths of concrete increased till 5% SCBA replacement in concrete.

Keywords:
Sustainable concrete, Alternative binders, Compressive strength, Tensile strength, Sugarcane bagasse ash.

1. Introduction

In modern-day, Sugarcane plays a vital role in global economics. Brazil is the largest producer of international supplies that is Sugar and Alcohol. Sugarcane bagasse is a fibrous waste material produced in abundance by sugar mills after extraction of juice from sugarcane. In past, sugarcane bagasse waste used to be dumped and burned in open fields, affecting the environment. Recently, the use of bagasse is aimed to manufacture environment friendly products used instead of traditional plastics and as well papers. With the use of Sugarcane bagasse considerable energy is saved while making these products. With the use of bagasse goods or products, there is an indirect reduction in pollution and consumption of energy. The pyro-processing is a process (in this raw material is heated above heating 1000 ^{0}C for getting physical and chemical properties changed to the parent material) involved in production of cement, releases several amounts of gases and uses resources in significant quantity as fuel [1-3]. During the construction phase of a project, in the modern-day world there are two important requirements of an engineer i.e. to protect the environment as well as accomplishing infrastructure of any country or city which is the basic needs of the residents, and the second requirement is to meet the demands of residents without posing any damage to or creating environmental hazards. [4-6]. Various researchers from developing world have worked on these wastes that include (SCBA), fly ash, rice husk ash, groundnut shell and Metakaolin [7-9]. These materials improve the concrete performance and help in providing friendly and a sustainable environment to the living beings. By incorporating such pozzolanic materials, several concrete properties such as strength, flow-ability, durability, and resistance to cracks in concrete can be significantly enhanced [10-12]. Moreover, when pozzolanic materials are added in cement concrete such as fly ash or sugarcane bagasse ash, they produce a solid concrete due to the dense packing of the fine particles [13-15]. Mohd et al. [16] used (SCBA) and sawdust ash (SDA) in concrete and determined fresh and hardened concrete properties. Cement was Partially replaced with SCBA and SDA in different percentages of 0%, 5%. 10 and 15%. The proportion of SCBA and SDA kept were similar (1:1) in all different percentages in concrete mixture. It was observed that, when the quantity of SCBA and SDA increased in the concrete mixture, workability reduced significantly due to the water

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absorbed by supplementary Cementitious Materials. The concrete strength was decreased after 7 days curing. However, at the curing age of 28 days, the compressive strength was increased by 5.79% when a cement was replaced at 5% with SCBA and SDA. Moreover, Minnu et al. [17] studied the efficiency of Sugarcane Bagasee Ash as a pozzolanic material compared to fly ash and slag considering different concrete properties. The density of concrete, in comparison to Fine Aggregates and slag was decreased due to SCBA being lighter in weight. The rate of reaction of $C(OH)_2$ was significantly impacted with fineness of all Supplementary Cementitious Materials (SCMs). The setting of concrete mixes was retarded, because of incorporation of SCBA by more than 40% compared to Fine Aggregates and Ground Granulated Blast Furnace Slag [18-19]. Moreover, considering the sustainability of the environment, it is required to find other substitutional material such as SCBA and could be a great resource in making an eco-friendly material which can easily be obtained from sugarcane industries [20-21]. Mostly it has been investigated that cement replaced by SCBA provides better results in terms of both tests that is tensile and compressive strength, in the laboratory. Researchers have also replaced little percentage of FA with SCBA [22-23].

Taking into account the suitability of SCBA as a cement replacement material, this study has been carried out to partially replace cement in the ratio of 0%, 5%, 10%, and 15% by weight of total cement in concrete mixture. Various tests have been conducted the results of which are given in the preceding sections.

2. Research Methodology

2.1 Materials Used

Commonly, plain cement concrete (PCC) is a well-known as a traditional cement concrete consists of aggregates (both coarse and fine), and water. It could easily be molded to bring to the required shape and size before it loses plasticity and hardens. PCC is strong in compression but it lacks very much in tension.

Sand is one of the most important ingredients of concrete which is produced after crushing hard stones. Generally, artificial sand is accepted as a by-product while crushing stones to coarse aggregate (CA). The particles are referred as CA if having size greater than 4.75 mm, however, it generally ranges between 9.5 mm to 37.5 mm in diameter.

Sugarcane bagasse ash being the by-product of sugar industries could easily be obtained. The proportion of numerous substances in sugarcane bagasse include about 50% cellulose, 25% lignin and 25% hemicelluloses. SCBA has been found to blend easily with cement and take part in the chemical process and to produce hardened concrete. Figure 1 shows the un-sieved and sieved SCBA.

Fig.1: Un-sieved and sieved SCBA

Moreover, water is essential material for the cement hydration, however, whole water is not used for this purpose. Some part of the water used is to offer good workability during mixing and placing. However, sometimes accelerators and retarders also used as admixtures for workability and setting of cement concrete. For the purpose of mixing concrete, potable water is preferred which is usually free from impurities. Non-potable water and water resulting from concrete production operations can be employed as mixing water in concrete keeping in view the minimum requirements or criteria given in ASTM C1602 ASTM C1602-18 "Standard Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete" [24] are met.

3. Experimental activity

3.1 Fineness Modulus

During the experimental program, Fineness modulus (FM) test based on Sieve Analysis was conducted in accordance to ASTM C33/C33M-18, "Standard Specification for Concrete Aggregates" [25]. The Fineness Modulus (FM) of sand was found to be 1.25. A total of 36 samples were fabricated, using a proportion of cement and aggregates equal to 1:2:4 (Refer Figure 2). The water to binder ratio was retained at 0.5 for all the batches. Dimensions of the specimen were 100 mm x100mm for cubes and 200mm x 100mm for cylinders. After making plain specimen, cement was replaced 5, 10, and 15% by SCBA. Fineness modulus results shown in table 1 were calculated using below equation,

$$Fineness\ Modulus\ (FM) = \frac{\Sigma\ Cumulative\ Weight\ Percentage\ Retained\ on\ Sieve}{100}$$

3.2 Slump Cone Test

The most common test to determine the workability of concrete is slump test which is carried out in accordance to ASTM C143, "Standard Test Method for Slump of Hydraulic Cement Concrete" [26]. This test is aimed to determine the change in water content as measured by the differences attained in slump. The slump test was carried out for all concrete mixtures with different proportions.

Fig. 2 Specimen taken out from molds (left: cylinders, right: cubes)

Table 1: Results of Fineness Modulus of Sand

Sieve #	Weight retained (grams)	Cumulative Weight	Sieve #
Sieve Analysis and Fineness Modulus of Sand			
8	15	15	1.5
16	35	50	5
30	80	130	13
50	130	260	26
100	540	800	80
Pan	200		
Fineness Modulus (FM) found to be = 1.25			

4. Mechanical Testing

The maximum capacity of any specimen to bear the load till its crushing is known as the Compressive strength of concrete. This Compressive strength test of concrete was carried in accordance to ASTM Standard C39/C 39M-16, "Test Method for Compressive Strength of Cylindrical Concrete Specimens" [27]. Compressive strength of both cubes (refer to Figure 3) and cylinders (Refer to Figure 4) was determined. The split cylinder test identifies the tensile strength of concrete which was performed on the cylindrical specimens. Being an indirect measure of tensile strength of concrete, it ensures acceptable results [28].

Fig 3: Testing of Cubes (Compressive)

Fig.4: Testing of Cylinders (Split tensile)

5. Results and discussions

Results in Figure 5 demonstrate that partial replacement of SCBA 0, 5, 10, and 15% from cement somehow increases the strength 0f concrete. The results obtained from the plain concrete and SCBA split tensile cylinder tests are shown in Figure 6.

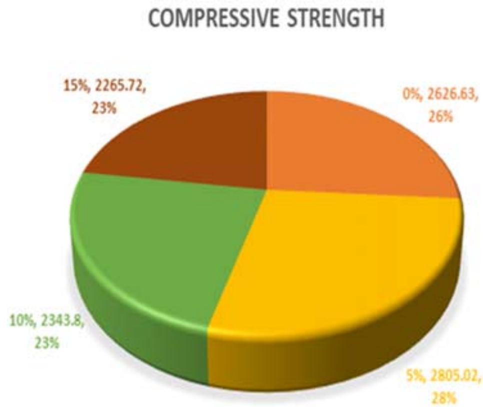

Figure 5: Compressive strength of cubes (1:2:4) after seven days of curing

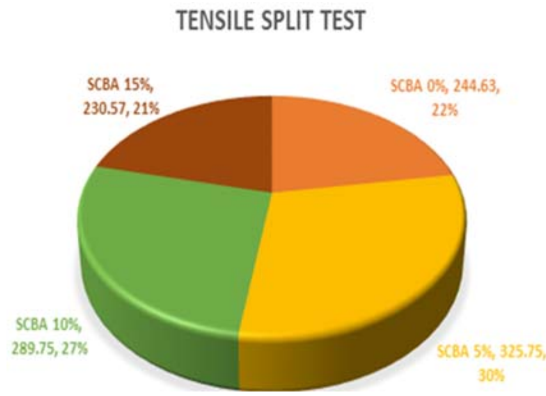

Figure 6: Tensile split cylinder after seven days curing

The above results shown in Figure 6 show that partial replacement of SCBA 0, 5, 10, and 15% from cement has increased the strength of concrete.

6. Conclusions and future work

In this research study mechanical properties of concrete including compressive strength and tensile strength were determined. The cement replaced by SCBA was in 0, 5, 10, 15 percent in concrete. The total specimen fabricated were used for the curing period of 7 days. After conducting the experimental study, it could be revealed that;

- The compressive strength increased till 5% of cement replaced Sugarcane bagasse ash.
- The tensile strength also increases when cement was replaced by 5% with sugarcane bagasse ash in concrete.
- This research work only replaced 0, 5, 10, 15 % cement with sugarcane bagasse ash using a proportion of 1:2:4. However, similar research study could be conduct using the proportions of 1:1:2 and 1:1.5:3 or any suitable proportion.
- In this study cement is only replaced by 0, 5, 10, 15 % with SCBA; however, further analysis can be carried out on 20%, 25% and 30% of cement with SCBA replacement.
- In this study sieve no 200 is used; however, in further research, sieve, no 300 can be taken into account because in the previous research, it has been observed that as the particles are small, they make a stronger bond, which result in the enhanced strength of concrete.

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