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Performance Evaluation of High Strength Concrete with Sugarcane Bagasse Ash as Partial Replacement for Cement

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ABSTRACT
Cement production is responsible for atmospheric carbon dioxide emissions (CO_2). The study found that making 1000kg of cement releases over half a tonne of carbon dioxide into the atmosphere. As a result, substitute cement must be made in place of conventional Portland cement (OPC). Waste materials like sugarcane bagasse pose harm to the environment and are difficult to discard. The use of sugarcane wastes in concrete is investigated in this study. Nowadays, there is a great deal of interest in finding construction materials that may be effectively used without compromising environmental sustainability. The concrete ratios used were 5, 7.5, and 10%. Split tension and compression tests were performed on the samples. In order to show that SCBA replacement may be done in part to get improved results, the workability, compression strength, flexural strength, and split tensile strength of concrete were tested for the three mixes and compared to the control mix. It was discovered that the mixes that offer adequate support for the replacement had durability traits such water absorption, carbonation resistance, and corrosion resistance. The partial replacement of SCBA supports environmental conservation as well.

Keywords: *Sugarcane bagasse ash, ordinary portland cement, compressive strength, splitting tensile strength*

INTRODUCTION

Modern concretes put a lot of emphasis on strength in order to reduce the size of structural members and, consequently, the amount of materials used, early strength to facilitate speedy construction, durability to reduce maintenance costs, and the incorporation of industrial and agricultural wastes to lessen environmental degradation.

Using industrial and agricultural wastes as cement replacements can result in less cement being used and less CO_2 being released during the production of concrete. A byproduct of the extraction of sugar cane juice is sugarcane bagasse. An estimated 1.7 million tonnes of bagasse are produced annually around the world.

A substantial portion of the bagasse is used as boiler fuel and to produce electricity, and the rest ash is dumped in earth fills, seriously harming the ecosystem and necessitating immediate action. The existing literature shows that high silica-content pozzolanic ash may be created under controlled burning conditions and has a variety of uses for building concrete. The mechanical properties of high-strength concrete that contains silica fume in binary combination with processed sugarcane bagasse ash in amounts ranging from 10 to 40% by weight of cement are examined in this study. The workability of fresh concrete as well as the compressive, flexural, and tensile strengths of hardened concrete are also examined. The ability of hardened concrete to absorb water is being investigated as a potential indicator of durability. The results show that the combination with 10% SCBA has the highest mechanical strength and that increasing the amount of SCBA reduces water absorption. However, fresh concrete loses a lot of its workability as the ash concentration increases.

LITERATURE REVIEW

High-strength concrete is referred to be concrete that offers higher compression resistance than the nominal strength range stipulated in various design rules. Pozzolans, including fly ash and silica fume, are the most often used mineral admixtures in high-strength concrete. In addition to cement, pozzolanic material may help in the hydration process to generate higher strength in concrete, according to Bahurudeen *et al.* [6,7]. Any material that reacts with water to generate additional C-S-H gel may be used as a binder.

The construction material that is utilised most often daily across the world is concrete. The basic elements used to make cement, a binding agent used in concrete that also emits a considerable amount of carbon dioxide into the atmosphere, are argillaceous and siliceous. The research community is looking for an alternative binding material that may be generated from industrial wastes as fly ash, sugar cane bagasse ash, coal bottom ash, rubber waste, etc. and used in place of cement in various ratios, as proposed by Payá *et al*.

By reducing construction expenses and waste deposition, using such leftover materials helps the environment. A replacement material must possess a number of characteristics in addition to being easily available and affordable, according to Kumar *et al.*

According to Kiran *et al.*, testing was done on sugarcane bagasse ash created by burning waste from sugar production plants. Being the world's biggest producer of sugar, handling bagasse waste poses serious risks to the industries and is quite expensive. Sugarcane bagasse ash, a byproduct of the sugar industry with certain pozzolanic properties as well, may be used as a binder material since it contains silica and traces of calcium oxides, according to Torres Agredo *et al*.

SCBA comprises a 50% cellulose percentage, 25% hemicellulose content, and a 25% lignin content, according to Jagadesh *et al*. Each tonne of sugarcane contains 26% bagasse. According to studies by Ajay *et al.* [1-3] based on the chemical composition of sugarcane bagasse ash, bagasse ash has certain pozzolanic properties. Because of this, sugarcane bagasse ash may be used in certain applications in place of cement.

Sales and Lima proposed that a coarser sugarcane bagasse ash alternative to fine aggregate may be used. One of the most important aspects to consider when predicting maintenance costs, according to Kim *et al.*, is the structures' durability, which is directly connected to the materials used, the construction methods used, and environmental conditions.

A material's capacity to absorb, adsorb, and diffuse energy has an effect on how durable it is. According to a research by Km and México, the water absorption test determines the concrete's ability to breach the surface, whereas corrosion resistance may be assessed using potential differences. Therefore, the goal of this study is to explore how high-strength concrete behaves when some cement is replaced by sugarcane bagasse ash. The mechanical properties of concrete are severely impacted, according to prior research on concrete containing sugarcane bagasse ash.[8-10]

Modani and Vyawahare suggested employing sugarcane bagasse ash as a concrete component instead of cement and mortar after analysing a number of research. He went on to suggest that by modifying the burning temperature and method, the quality of bagasse ash may be raised. Comparing the results of several tests, it was found that 20% of the sugarcane should be replaced with bagasse ash since the strength requirements were closer to the control mix.

Ganesan *et al.*, examined the physical and mechanical properties of sugarcane bagasse ash replaced concrete up to 30% in the form of blended cement. He said that the research showed that bagasse ash will fill the micro- and macropores in concrete, giving it more strength. The advantages of adding up to 20% of well-burned sugarcane bagasse ash to cement are also mentioned. These benefits include increasing early strength, lowering water permeability, and showing a decrease in chloride penetration and diffusion. Sugarcane bagasse ash contains pozzolanic properties, according to recent investigations.

Kiran *et al.* looked studied the potential of bagasse ash as a cement replacement with a combination of 1:1.52:2.82 with 0.45 water-cement ratio. Researchers found that 5% replacement produced better results after testing various replacements in increments of 5% up to 25%. Based on their findings, they came to the conclusion that strength will increase later than earlier because the bagasse ash's high concentration of amorphous silica and aluminium oxides causes the pozzolanic reactions it causes to occur more slowly.

Burning generates ash that includes a significant proportion of unburned material, mostly silicon and aluminium oxides, according to study by Payá *et al*. They have shown that bagasse ash has to be synthetically, genuinely, and mineralogical described in order to assess the possibility of their utilization as a concrete replacement material in concrete. A half-cell potentiometer effectively reduces the corrosion of reinforced concrete bars under a variety of environmental conditions.

Broomfeld *et al.* examined the SCBA molecule's nebulousness and shape using an X-ray diffraction (XRD) and scanning electron microscope (SEM). The mixed mortar was constructed in accordance with Japanese specifications, replacing OPC with 10, 15, 20, and 25% SCBA (by weight). Also used a 1:3 mix ratio. In comparison to control mortar, a 15% replacement in the mortar successfully increased 3D shapes. A mixed SCBA sample was subjected to a UPV test to track hydration and quality advancement in line with ASTM Standards.

The effects of utilizing bagasse ash in place of cement on heat of hydration were examined by Dhengare *et al.* The temperature lowers during a typical time period while increasing throughout the duration of normal hydration when concrete is used in place of the bagasse ash in the concrete mixture. He came to the conclusion that the gel formed between the calcium hydroxide in cement and the silicon dioxide in sugarcane bagasse ash is what gives the material its higher compressive strength.

In contrast to concrete made without admixtures, Kumar *et al.* found that adding SCBA, RHA, and stone dust as a partial replacement for cement in plain concrete enhances workability.

According to Anand and Mishra [4, 5], adding fly ash to concrete reduces bleeding, improves cohesiveness, and creates a better surface quality. The study found that replacing cement up to 30% of the time with sugarcane bagasse ash improved performance. Corrosion of the steel embedded in the concrete is a serious issue that threatens the durability of the construction.

Manzur *et al.* advice was as a consequence that steel should be properly encased in concrete and should provide the best degree of defence against moisture and chloride ion penetration.
Using this method, Song and Saraswathy measured the potential difference between the reinforcement and a common reference electrode to ascertain the rate of corrosion that had taken place. Nez-Jaquez *et al.* state that in order to access the durability feature, the corrosion resistance of the optimal value of sugarcane bagasse ash replacement for cement is compared with the control mix.

Microstructural analysis may be utilised to examine the interior crystalline properties of the concrete material. Using XRD and SEM techniques, pozzolanic activity-related bonding may be found after hydration. The literature study found that there are research gaps on water absorption, carbonation, and corrosion durability tests for high-strength concrete employing SCBA as a cement alternative. This research effort focuses on the behaviour of high-strength concrete with the best substitution of SCBA for cement in order to I estimate the mechanical properties of concrete, (ii) analyse the durability of concrete, and (iii) identify the corrosion resistance property of concrete with SCBA. Using this method, it is possible to determine the best SCBA and associated waste replacement for cement. The findings and conclusions of the present study help the researchers find a useful waste material to replace cement in order to achieve sustainable development and practices.

MATERIAL USED

Sugarcane Bagasse Ash (SCBA)

The leftover sugarcane bagasse was obtained from juice extract manufacturing plants, where it was washed in a tank of water and then dried in the sun. Then, it was allowed to burn completely at 600 °C in the air until it was reduced to ashes; the ashes were then placed in an oven and heated to 200 °C, where they stayed for two hours to completely burn away any lingering organic ingredients (carbon). The ash was ground into smaller pieces using a grinder after being taken out of the oven.

Cement

Concrete Standard Portland cement (OPC) CEM I 42.5N from the Suez Company was used into each batch.

Aggregates

Dolomite aggregates, the coarse material used in this experiment, were available in large quantities throughout the city. The coarse aggregates' nominal maximum size was 12.5 mm, and their specific gravity was 2.58. The experiment's natural siliceous sand has a fineness modulus of 2.48. Testing on coarse and fine aggregate was carried out in accordance with the Egyptian Standard Specification (1109/2002).

Experimental work

The purpose of this research is to ascertain if it is practical to replace pozzolanic material in high-strength concrete with sugarcane bagasse ash. To ascertain the behaviour of high-strength concrete with various substitutes of bagasse ash, mechanical properties, such as compression strength, split tensile strength, and flexural strength, as specified by IS 516:2018, may be employed. The durability of the concrete will be aided by its resistance to corrosion, carbonation, and water absorption.

High-strength concrete employs certain mineral admixtures in addition to cement, fine aggregate, coarse aggregate, and water, claim Rajasekar *et al.* in their study. High-strength concrete that is designed for a typical compressive strength of 60 MPa at 28 days is used in the experiment. To attain this strength, cement (OPC 53 grade), fly ash, and silica fume were used as cementitious elements. The control mix has a water cementitious material ratio of 0.33 and is made up of 1231 kg/m3 of fine aggregate, 375 kg/m3 of cementitious materials, and 1273 kg/m3 of coarse aggregate. To increase the workability of the mix, Supermax 160 is employed as a super plasticizer, adding 1% to the weight of cementitious material.

In accordance with the approach, three ratios of cementitious materials (10%, 20%, and 30%) are replaced for a portion of the sugarcane bagasse ash and compared to the control mix. The control mix is compared with three different proportions of sugarcane bagasse ash for fresh concrete properties like workability and mechanical properties like compression strength, split tensile strength, and flexural strength as well as durability studies like carbonation test, water absorption test, and corrosion resistance offered by the embedded reinforcement in concrete.

CONCLUSION

Using SCBA instead of cement has significantly boosted efficacy. It was discovered that 5% is the ideal replacement percentage for SC in mortar, concrete cubes, and concrete cylinders in order to provide the highest compressive strength and splitting tensile strength. The results of the ideal samples, which included 5% SCBA, showed a 20% improvement in compressive strength and a 33% increase in splitting tensile strength when compared to the control mix. Adding more SCBA results in a reduction in mechanical properties after 5%. The fact that the rate of strength gaining increases over time may be related to the fact that using the ash induces the production of extra C-S-H compound as free CH from the cement's hydration process would react with silica in SCBA, which is characterised by long-term strength gaining. Concrete's workability is increased by increasing the SCBA replacement percentage. In comparison to the control specimen, the fissures that formed when sugarcane bagasse fibres were introduced to concrete had a smaller overall width and length.

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