

EFFECTS ON PROPERTIES OF EFUHPC MADE BY SUGARCANE BAGASSE ASH

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Abstract

In this work we examine about sugarcane bagasse ash which is satisfactory for producing Eco-friendly Ultra-High Performance Concrete (EFUHPC) and improving mechanical properties of EFUHPC. In UHPC more amount cement and other materials used which produce huge amount of CO₂, there are major problem for environment. Very less study found on use of SBA in EFUHPC hence we studied for effect of sugarcane bagasse ash on UHPC and futuristic use for EFUHPC. In this work Sugarcane Bagasse Ash by weight of cement used to 0%, 5%, 10%, 15% and 20% and workability, flexural strength, split tensile strength and water absorption are investigated. The result show that mixture using 10% amount of SBA has optimum mechanical strength and water absorption decreased when SBA increased.

Keywords: EFUHPC; Fly Ash; HPC; SBA; UHPC

Introduction

Concrete is mostly huge amount used artificial construction material on the Earth. Concrete is an ideal material having excellent strength, workability, hardness and other properties, allowing members to be easily molded into any desired shape (Azme & Shafiq, 2018; Marvila *et al.*, 2021; Li *et al.*, 2019; Gao *et al.*, 1997; Leng *et al.*, 2023). To obtain 1 ton of cement, approximately 1 ton of CO₂ is generated which has a very harmful effect on the environment and increases global warming.

To decrease the use of cement in concrete and find its alternative, many researchers are working for a long time and are studying various materials which include SBA, BRHA, CCA, WFA, SF etc (Zhou *et al.*, 1995; Gao *et al.*, 1997; Akhnoukh & Buckhalter, 2021; Graybeal & Tanesi, 2007;

Du *et al.*, 2021). It has been observed that no special work has been done regarding the use of SBA in UHPC, due to which it is not being used and there are problems in utilizing it, due to which it is also affecting the environment (Gao *et al.*, 1997; Abhilash *et al.*, 2021; Graybeal & Tanesi, 2007; Chun *et al.*, 2020).

Sugarcane is an agricultural product whose waste is burnt at 300 to 1800 °C to obtain SBA (Wu *et al.*, 2019; Du *et al.*, 2021; Zhou *et al.*, 1995). About 12 billion tons of SC is produced worldwide which can have good pozzolanic properties if burned at 800 to 1200°C for 20 minutes, but only about 3% of it is processed (Ragalwar *et al.*, 2019; Mazloom *et al.*, 2004). The amount of silica in SBA depends on the method of growing SC, temperature,

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method of burning etc. The strength of concrete can be increased by using pozzolanic materials; the pozzolanic reaction itself is responsible for increasing the strength of concrete (Wu *et al.*, 2001; Mazloom *et al.*, 2004).

Ahmad *et al.* (2021) studied the chemical and microstructural properties of SCBA based on the temperature of calcination and burned SCB for 1 hour at 800°C and at 600°C for 3 and 6 hours and found that the amount of silica obtained after burning at 800°C for 1 hour.

Silica fume is also enhancing the properties and make eco-friendly concrete (Gao *et al.*, 1997). Steel fiber provides excellent properties to concrete (Smarzewski, 2020) and Adopted research methodology shown in Figure 5.

Chan and Chu (2004) presented that SCB is waste material of sugar production. It is pozzolanic material. 40% replacement of cement to sugarcane bagasse ash good for comprehensive performance. For producing high strength concrete 30% bagasse ash in place of cement more acceptable. As a result compressive strength not affect but shrinkage decrease. sugarcane bagasse ash replacement may be good for future research for utilization of agricultural waste material. Sobuz *et al.* (2024) this paper presented that sugarcane bagasse ash replaced with OPC and result found that 10% replacement increase 40 to 50% workability of concrete and made 10 to 30 % light weight concrete. By replacement of cement to SCBA increase compacting factor, slump, and workability. For producing high strength concrete 30% bagasse ash in place of cement more acceptable.

Rukzon and Chindaprasirt (2012) present that in high strength concrete, bagasse ash used as pozzolanic material. The pozzolanic material is used 10%, 20% and 30% in place of cement. 10% replacement of cement increase strength of concrete. For producing high strength concrete 30% bagasse ash in place of cement more acceptable. Bahurudeen *et al.* (2014) present that bagasse ash used as additional material in concrete and by-product of sugar industries. Any additional material influenced properties of fresh concrete. In this research sugarcane bagasse ash and super plasticizer both used in concrete mix. Bagasse ash had lesser and processed bagasse ash had high pozzolanic activity and use of bagasse ash increase workability of concrete.

As per above study sugarcane bagasse ash is most significant material which improve the properties of EFUHPc and cement, silica fume, steel fiber, super plasticizer, sand all are the important materials for making UHPC. Cement is used as binding material and providing strength to

concrete but its production is harm-full for environment so replacement of cement is required in construction. As alternative of cement, we used SBA in this work. As per previous researchers study Silica fume, steel fibers are also important materials for making UHPC and enhancing the properties of concrete.

Materials and Methods

Cement

The Cement used was Portland cement 53 grade conforming to IS 12269:1987 manufactured locally shown in Figure 1.



Figure 1. Cement

Sugarcane Bagasse Ash

Sugarcane Bagasse Ash shown in Figures 2 and 3 collected from Sikar local market, India and dried at 110°C for 24 hr to expunge moisture present in this shown in Figures 2 and 3. Raw SBA was again burnt in electric furnace at 400°C for 2 hours and reduced LOI and chemical composition are shown in Table 1.



Figure 2. Shows Raw Sugar Cane Bagasse



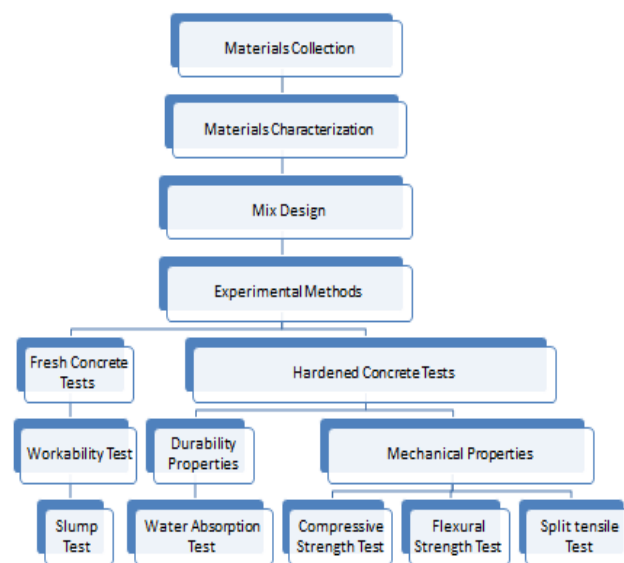
Figure 3. Shows Sugar Cane Bagasse Ash

Table 1. Chemical composition of SBA, Cement and Silica Fume

Oxides	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	SO ₃	K ₂ O	LOI	Remark
SBA	87	2.48	1.8	3.52	3.7	1.2	3.83	6%	In %
OPC	25	4	0.6	63	1.3	2.1	1.3	2.5	In %
Silica Fume	97.88	0.00	0.09	0.66	0.001	0.39	0.12	----	In %

Table 2. Composition of UHPC MIX by fraction of cement

MIX	Cement	SBA	Sand	SF	Steel Fiber	Water	Super Plasticizer
SBA 0	1	-----	1.2	0.24	0.25	0.175	0.003
SBA 5	0.95	0.05	1.2	0.24	0.25	0.175	0.006
SBA 10	0.90	0.10	1.2	0.24	0.25	0.175	0.009
SBA 15	0.85	0.15	1.2	0.24	0.25	0.175	0.006
SBA 20	0.80	0.20	1.2	0.24	0.25	0.175	0.007

**Figure 5. Shows Methodology****Silica Fume**

Silica fume Figure 4 coincided of a grey powder with specific gravity 2.20. In SF SiO₂ was the maximum oxide available, which was 97.9% and the chemical composition are shown in Table 1.

**Figure 4. Shows Silica Fume****Sand**

River Sand collected from local sikar market with maximum particle size 150µm to 600µm.

Super plasticizer

The super plasticizer used polycarboxylate which was produced from locally market with specific gravity 1.08, solid content 34% and yellowish colour. It high quantity water reducing ether base agent which used to gain required workability.

Steel Fiber

The steel fiber used in this study was a straight, brass-coated fiber with a diameter of 0.12 mm and a length of 10 mm, as shown in Figure 5.

Mix Proportion: -

For study total 5 mixes of UHPC were prepared. The control mix SBA 0 has 0% SBA replacement of cement and remaining mixtures were prepared with 5%, 10%, 15% & 20% of SBA replacement of Cement respectively. All mix detail in Table 2.

Methodology

Concrete Mixing: -

A rotating mixer drum was used for mixing the UHPC mix. After mixing cement, SBA, SF, Steel fiber and sand, water was added and make uniform paste. Super plasticizer was added to use in mix at all levels to maintain workable mix.

Compressive Strength Test

For compression test 2000kn capacity UTM was used in which $150 \times 150 \times 150$ mm cubes sample was tested. The samples were first taken out from the curing tank and dried for 1 hour and then placed in the batten of the compression machine. When the upper batten of compression machine is in good contact with the surface of the sample, load is applied at a constant rate until the sample cracks. For compression test, 3 samples of every specimen were used on 7, 28, and 56 days and maximum load attained was recorded, average value of all each was recorded.

Split Tensile Test

For split tensile strength of ASTM C496/C496M-04 was used and three cylinders for each mix were tested and average of result values was recorded.

Flexural Test

For flexural strength testing, ASTM C78 was used and three specimens (size $100 \times 100 \times 500$ mm) for each mix were tested and average of result values was recorded.

Water Absorption

For water absorption test three cylinders tested for each mix and test was carried out at 28days to BS 1881-122 (2011)-02 and average values was recorded.

Workability Test:-

For workability of each mix measured with ASTM C1611 (Slump Flow Test) and each mix was tested for two times.

Results and Discussion

Workability

The effect of SBA on the flow characteristics in EFUHPC was evaluated by flow table test. This test results are indicated to the quality of concrete with respect to, cohesiveness, consistency and the proneness to segregation. The result shows a positive effect in the workability of EFUHPC mixes

due to incorporation of SBA. It can notify that SBA % enhanced in mix workability of mix also enhanced. The results show in the figure no. percentage of SBA in mix used 0%, 5%, 10%, 15 % and 20 % at place of cement were enhanced workability and flow value shows 376mm, 374mm, 381mm, 386mm and 391mm respectively. These results show the use of SBA in EFUHPC, the amount of super plasticizer can be reduced considerably. Workability results shown in Figure 6.

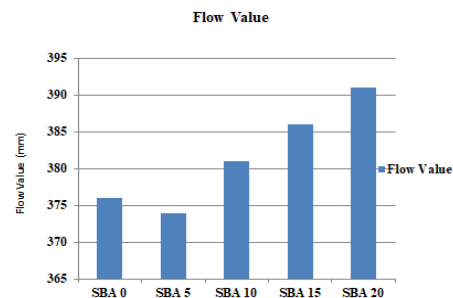


Figure 6. Shows Flow value

Compressive strength

The compressive strength of EFUHPC sample of different mix is showed in fig. The control mix SBA 0 with 100% cement amount was used to comparing the mix with SBA. The compressive strength of specimen was measured at 7, 28 and 56 days at 0%, 5%, 10%, 15 % and 20 %. The compressive strength of EFUHPC was 109, 112, 115.5, 114 and 113 n/mm^2 at 7 days and 179, 183, 187, 185 and 184 at 28 days and 192, 195, 203, 197 and 195.6 at 56 days respectively. As result 10% amount SBA in mix provided optimum results at 7, 28 and 56 days and best for producing EFUHPC. These result details are also shown in Figure 7.

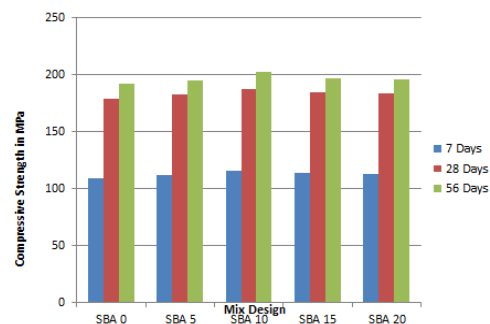


Figure 7. Shows Compressive Strength

Split tensile strength

Figure shows split tensile strength results at 28days similar as compressive strength trends followed. 10% of SBA used in mix enhances the highest tensile strength. After that SBA % in mix enhanced then split tensile strength decrease in results observed. Split tensile strength were observed at 7.1, 7.3, 8.2, 7.9, and 7.4 at amount of 0%, 5%, 10%, 15 % and 20% SBA. As per result 10% replacement of cement with SBA providing optimum results and 10% SBA is suitable for enhancing split tensile strength shown in Figure 8.

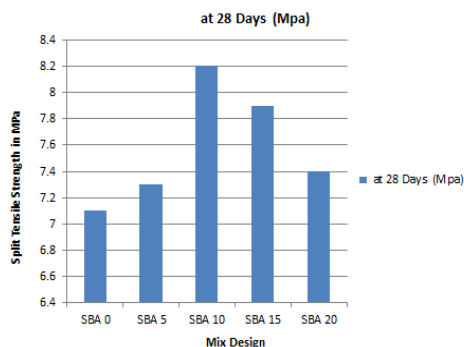


Figure 8. Shows split tensile Strength

Flexural Strength

For flexural strength's results same trend followed similar as compressive strength. 10% amount of SBA used in mix had optimum result which has 8.5% strength more than control mix. After 10% amount of SBA we enhanced SBA in mix flexural strength slightly fall. For flexural strength 0%, 5%, 10%, 15 % and 20% amount of SBA used in mix and after 28 days flexural strength noted 11.2, 11.6, 12.2, 11.9 and 11.8 respectively and 10 % SBA amount provide optimum results which shown in Figure 9.

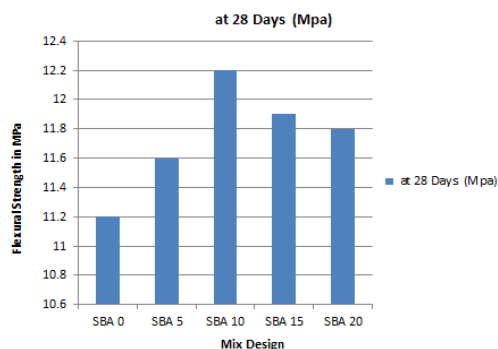


Figure 9. Shows Flexural Strength

Water Absorption

For water absorption test we used formula of % of water of absorption Equation (1) and prepare five concrete mix samples. As result SBA amount in sample enhances then water absorption % decreases. At 0% of SBA water absorption found 1.22% and at 20% amount in concrete mix water absorption found 1.19%.

$$\text{Percentage of absorption} = \frac{W_w - W_d}{W_d} \times 100 \quad (1)$$

where; W_w = Wet weight of sample
 W_d = Dry weight of sample

Conclusions

In this work, investigated the use of SBA as partial replacement of cement and producing EFUHPCC. Cement replacement with SBA on the fresh properties and hardened properties of concrete.

The results showed that slump value increase with an enhances SBA content but at 5% slightly decreases.

A maximum compressive strength 187MPa was found with 10% cement replacement with SBA at 28days cured specimen test and 203MPa at 56 days.

A maximum flexural strength 8.5% more achieved at 28days with 10% cement replacement with SBA as compare to without SBA specimen or control mix.

Split tensile strength were observed at 7.1, 7.3, 8.2, 7.9, and 7.4 at amount of 0%, 5%, 10%, 15 % and 20% SBA.

It is possible to use SBA in the making of Eco-friendly Ultra-high performance concrete with good performance due to pozzolanic action of SBA

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Author Contributions

Devendra Kumar Sharma: Data Collection, Formal Analysis, Investigation, Writing – Original Draft, Visualization, Manuscript Preparation.

Imran Ahmad Khan: Conceptualization, Methodology, Investigation, Validation, Supervision, Writing – Review & Editing.

Ethics Approval and Consent to Participate

Ethics approval and informed consent were not required for this study.

Declaration of Generative AI

The authors declare that no Generative AI tools were used in the preparation of this manuscript.

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Data availability

The datasets generated during and/or analyzed during the current study are not publicly available due to privacy policy of the affiliated research institute, but are available from the corresponding author on reasonable request.

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