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Effect Of Sugarcane Bagasse Ash On Compressive Strength And Workability Of Concrete

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ABSTRACT

Ordinary Portland cement (OPC) is one of the main ingredients used in concrete production and remains largely irreplaceable in the civil construction industry, despite being a versatile but relatively high-cost material. Large scale cement production causes significant environmental problems, including CO_2 emissions, while also contributing to the depletion of natural resources. This has led researchers to investigate the use of agricultural and agro-industrial by-products as supplementary cementitious materials in concrete. The main parameter investigated in this study is normal concrete (1:2:4 at 0.5 w/c) with partial replacement of cement by sugarcane bagasse ash (SBA) at 0%, 5%, and 10% by weight. This paper presents a detailed experimental study on compressive strength at 7 and 28 days, along with workability. Test results indicate that the use of SBA in concrete improved performance in strength up to an optimum replacement level, with the highest 28-day compressive strength of 25.9 MPa recorded at 5% SBA replacement, compared to 22.5 MPa for the control mix.

Keywords: Sugarcane Bagasse Ash, Workability, Compressive Strength

INTRODUCTION

Concrete is a widely used construction material for various types of structures due to its structural stability and strength. OPC remains one of the main ingredients used in concrete production and has no true alternative in the civil construction industry. Unfortunately, cement production involves the emission of large amounts of carbon dioxide into the atmosphere, with each tonne of cement produced associated with roughly a comparable tonne of CO_2 release, and the cement industry recognized as a significant contributor to global anthropogenic emissions [7]. It has therefore become necessary to identify supplementary materials that can partially replace cement, supporting sustainable construction while reducing the environmental burden of cement production.

Sugarcane is a major food and cash crop across tropical and subtropical regions and forms the principal raw material for sugar production. Sugarcane bagasse, the fibrous residue left after juice extraction, is generated in enormous quantities and, when

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disposed of directly on open land, contributes to environmental nuisance and waste accumulation [1]. It has been estimated that approximately 280 kg of bagasse waste is produced per tonne of sugarcane processed [2]. Sugar production is economically significant in Pakistan, one of the world's major sugarcane-producing countries, with national output reported in the tens of millions of tonnes annually [3]. The resulting bagasse waste presents both a disposal challenge and an opportunity for beneficial reuse. Controlled combustion of bagasse for power and steam generation in sugar mills produces sugarcane bagasse ash (SBA), which has increasingly been recognized as a pozzolanic material, although research on its influence on concrete behavior remains comparatively limited [4].

Beneficial reuse of this waste stream as a cement replacement material offers economic and environmental advantages, including reduced landfill burden, conservation of cement resources, and lower associated CO_2 emissions [5]. Previous studies have reported favorable results for SBA as a partial cement replacement. Malyadri [9] investigated 5% cement replacement with SBA and reported an increase in concrete strength, though without identifying an optimum replacement percentage. Kawade [10] examined replacement levels of 10–30% across multiple concrete grades and found that up to 15% replacement could be used favorably, identifying 15% as the optimum dosage in that study. Building on this body of work, the present study investigates sugarcane bagasse ash as a partial cement replacement at 0%, 5%, and 10% levels in a 1:2:4 normal concrete mix at a water-cement ratio of 0.5, evaluating its effect on compressive strength at 7 and 28 days and on workability, in order to identify the optimum replacement percentage for this mix design.

METHODOLOGY

Materials and Methods

The materials utilized in this study were:
Ordinary Portland Cement (OPC)
Fine Aggregate (Bholari, Pakistan)
Coarse Aggregate
Sugarcane Bagasse Ash (SBA)
Water

Cement

Cement is a fine powder that, upon addition of water, binds aggregate together as a hard mass following hydration over a period of days. Lucky OPC was used in this research, conforming to the specification of BS-12.

Table 1: Properties of Cement

S.No	Name of Test	Test Finding
01	Setting Time (ASTM C-191) Initial	145 minutes
	Final	310 minutes
02	Soundness (Le-Chatelier's Expansion, BS-12)	1 mm
03	Compressive Strength (ASTM C-109) 3 Days	2250 psi (15.5 MPa)
	7 Days	3150 psi (21.7 MPa)

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	28 Days	4910 psi (33.8 MPa)

Fine Aggregate

Bholari hill sand was used as fine aggregate, conforming to Zone II of BS 882.

Table 2: Properties of Fine Aggregate

S.No	Property	Result
01	Specific Gravity	2.63
02	Water Absorption	2.55%
03	Grading Zone	II

Coarse Aggregate

Crushed aggregate of 20 mm and 12.5 mm size, with specific gravity of 2.67 and water absorption of 0.52%, was used, procured from the local market in Karachi, Pakistan.

Sugarcane Bagasse Ash

Sugarcane bagasse was brought from Dadu Sugar Mill, Piaro Goth, Pakistan, and burnt in a closed drum under uncontrolled burning conditions. SBA was obtained after passing through a 300 μm standard sieve, and the sieved fraction was used for the experimental study. Regarding the density and microstructure of SBA, Aigbodion [12] reported that sugarcane bagasse ash is a very lightweight material with a density of approximately 1.95 g/cm³. This value falls within the density range typically associated with carbon and silica constituents, reported as 1.8 g/cm³ and 2.2 g/cm³ respectively [13, 14].

Table 3: Chemical Analysis of Sugarcane Bagasse Ash

Constituent	Chemical Analysis (%)
SiO_2	65.0
Al_2O_3	3.95
Fe_2O_3	9.17
CaO	12.6
MgO	0.6
SO_3	0.2
LOI	8.88

Water

According to ACI guidelines, water used for preparing concrete should be of potable quality. In this investigation, ordinary tap water fit for drinking was used in preparing all concrete mixes and for curing.

Table 4: Mix Composition

Mix ID	Cement %	SBA %	Aggregate %	W/C Ratio
M1	100	0	100	0.5
M2	95	5	100	0.5
M3	90	10	100	0.5

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Workability

Workability is defined as the property of freshly mixed concrete or mortar that determines the ease and homogeneity with which it can be mixed, placed, consolidated, and finished. Workability was measured using the slump cone test.

Experimental Procedure

Standard cube specimens (150 mm × 150 mm × 150 mm) were used to determine compressive strength. Three specimens were tested at each of 7 and 28 days for every sugarcane bagasse ash (SBA) replacement level, resulting in a total of 18 cubes cast for strength testing. Constituent materials were weighed and mixed by hand. The water-binder ratio (W/B, where binder = cement + SBA replacement) was maintained at 0.5 by weight of binder. Concrete was placed in layers, with each layer compacted before the next was added. Specimens were demolded after 24 hours, cured in water for periods of 7 and 28 days, and subsequently tested for compressive strength.

RESULTS AND DISCUSSION

Workability

Workability refers to the ease with which a concrete mix can be handled and placed, and is commonly assessed using the slump test. Figure 1 illustrates the workability of concrete mixes with varying proportions of SBA as a partial replacement for cement. Slump values increased progressively with increasing SBA content, from 40 mm at M1 (control, 0%) to 47 mm and 52 mm at M2 (5%) and M3 (10%) replacement, respectively, corresponding to increases of 17.5% and 30% over the control mix. This improvement in workability can be attributed to the fine texture and particle morphology of SBA, which reduces internal friction between particles and improves the flow of the mix.

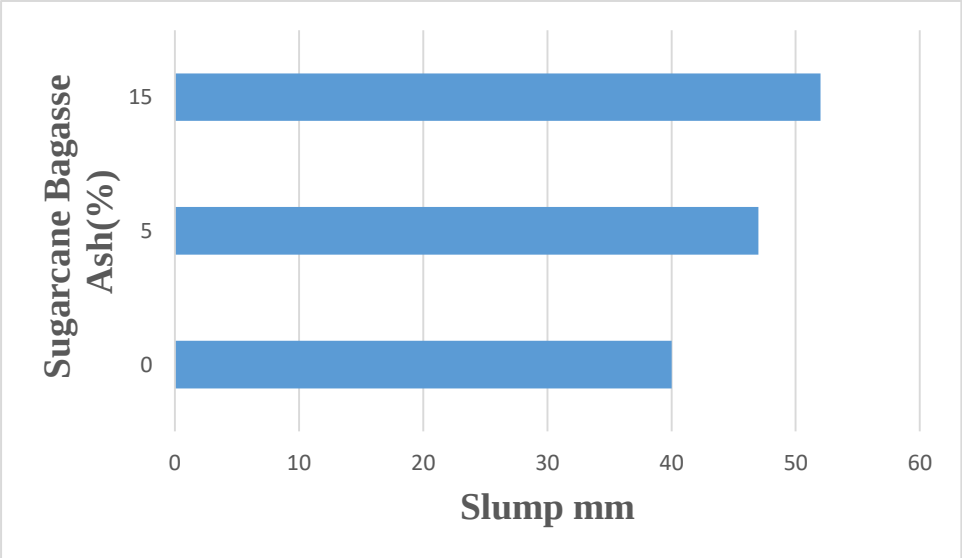

Figure 1: Slump vs. Sugarcane Bagasse Ash (%)

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Compressive Strength

Figure 2 shows the compressive strength results at 7 and 28 days of curing. Strength increased at 5% SBA replacement but decreased at 10%, though it remained higher than the control mix at both ages. At 28 days, strength increased from 22.5 MPa (control) to 25.9 MPa at 5% replacement, an increase of about 15.1%. At 10% replacement, strength dropped to 23.4 MPa, still 4.0% higher than the control. The same pattern was seen at 7 days: strength rose from 15.7 MPa (control) to 18.1 MPa at 5% replacement (+15.3%), then fell to 16.3 MPa at 10% replacement (+3.8%). This shows that 5% is the optimum SBA replacement level, giving the best balance of workability and strength. Beyond 5%, excess ash likely does not fully react, reducing the strength gain. Based on these results, SBA is recommended for use in concrete at up to 5% replacement, as it improves compressive strength while reducing cement use.

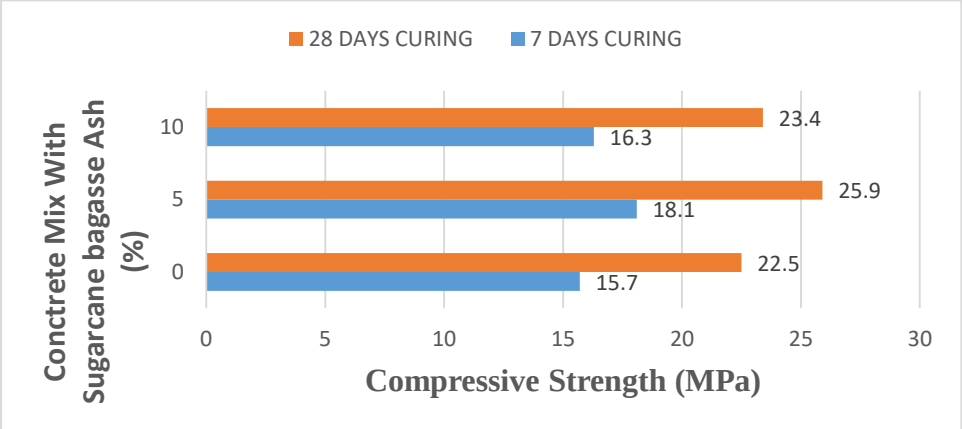

Figure 2: Compressive Strength of Sugarcane Bagasse Ash Concrete Mixes at 7 and 28 Days

CONCLUSION

Sugarcane bagasse ash (SBA), an agro-industrial by-product, can be effectively used in concrete as a partial cement replacement.

The highest 28-day compressive strength (25.9 MPa) was achieved at 5% SBA replacement, an increase of about 15.1% over the control mix (22.5 MPa).

At 10% replacement, strength dropped to 23.4 MPa, still 4.0% higher than the control, showing that 5% is the optimum replacement level for this mix design.

Concrete with 5% SBA can be used in structural applications needing improved compressive strength, while higher replacement levels give lower returns.

Workability improved steadily with SBA content, with slump increasing from 40 mm (control) to 47 mm and 52 mm at 5% and 10% replacement.

This study shows that using sugarcane bagasse ash in concrete can improve strength up to an optimum dosage while reducing cement use, and can help reduce waste disposal and CO_2 emissions from cement production. It also provides a way to reuse an agricultural waste material from Pakistan's sugar industry that would otherwise be discarded.

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