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Partial Replacement Of Cement With Sugarcane Bagasse Ash Using Superplasticizer

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Abstract: The construction industry is a major contributor to environmental degradation, and cement production is a substantial contributor to the overall CO_2 emissions. Due to this environmental change, there is a greater interest in the partial replacement of cement with other materials, such as agricultural byproducts. This project investigates the use of Bagasse Ash (BA) as a partial cement replacement in concrete. This form of ash, which is a byproduct of sugarcane processing, has pozzolanic properties that provide an opportunity to enhance the mechanical / durability properties of concrete and reduce its environmental impact. The project investigates the effect of different percentage of bagasse ash substitute (5%-30% by mass) on concrete's workability, strength, and durability. In this research project, a series of experimental tests are conducted for both fresh and hardened concrete, including slump, compressive strength, and tensile strength. The results demonstrate that bagasse ash can be successfully substituted for cement in concrete mixes. The project shows that the ideal percent substitution rate for cement is 10% with a good overall balance of workability strength and durability. Furthermore, this substitution is beneficial to the environment and it can assist in the reduction of the overall cost of producing concrete.

The findings of this study not only extend the body of knowledge into sustainable building materials, but also suggest implications for the application of bagasse ash as a cement replacement in a practical sense. This study suggests that bagasse ash is a greener alternative to cement, and that it provides improved concrete durability and performance over time. This further supports bagasse ash in its role for sustainable practice in the building industry. This study supports further exploration into the use of mix design for bagasse ash in concrete and suggest a future use of bagasse ash in a workable mix design for alternative purposes in the building industry, that can ultimately lead to greener and more cost-effective sustainable building materials.

KEYWORDS: Bagasse Ash (BA), Cement Replacement, Sustainable Construction, Pozzolanic Materials, Concrete Strength and Durability, Workability, Green Concrete, Environmental Impact.

1. INTRODUCTION

1.1 Background

Concrete is the most extensively utilized construction material worldwide, credited to high compressive strength, durability, and versatility. However, the manufacturing of cement, a key component of concrete, involves substantial energy utilization accompanied by considerable CO_2 emissions that leads precarious environmental damage and global climate change. Replacing cement, even partially with supplementary cementitious materials (SCMs) can therefore become a global a multi-beneficial solution to mitigate these problems, and improve resiliency, and durability factors in the process, which is the focus for many researchers and practitioners globally working toward sustainable practices.

Sugarcane Bagasse Ash (SCBA) is a by-product of the sugarcane industry after burning the bagasse in sugar mills, and shows some potential as an SCM. This is due primarily to SCBA containing sufficient amounts of amorphous silicates (SiO_2) which can react with and utilize the calcium hydroxide ($Ca(OH)_2$) produced during concrete hydration, which contributes to strength and durability in concrete when used appropriately.

1.2 Need for study

India is among the top global producers of sugarcane and produces millions of tonnes in bagasse annually. The disposal of the above-mentioned ash may introduce environmental concerns, as the ash is lightweight and fine and can contribute to environment issues related to air and soil pollution. Replacing part of the cement content with sugarcane bagasse ash (SCBA) not only diverts waste from the landfill but at the same time decreases cement demand which can lead to cost savings and less CO_2 emissions.

However, the higher specific surface area in SCBA and its porous nature typically reduce the workability of the concrete. Chemical admixtures (e.g. superplasticizers) are used to improve workability. For this study, Conplast SP430 (a superplasticizer based on sulphonated naphthalene formaldehyde) improved the workability and strength of the concrete mixture through reduced water demand and improve particle distribution in the mixture. The objective of this physical-chemical approach is to provide a sustainable concrete mixture that is performance-enhanced through the combination of SCBA and Conplast SP430 combined in a novel manner.

1.3 Literature Review Summary

Multiple studies have explored SCBA as a partial cement replacement. Reports indicate that replacing 5–10% of the cement with SCBA has comparable or superior compressive strength as the control mix, mainly due to the better particle packing and additional C–S–H gel derived from pozzolanic reactions, while replacing 15–20% of the cement typically exhibited decreasing strength due to not enough calcium hydroxide for complete reaction.

The use of superplasticizers such as Conplast SP430 has also been shown to offset workability issues associated with the finer SCBA particle size. A dosage between 0.7 and 1.3 L of superplasticizer for every 100 kg of cementitious material improves flow ability, thereby allowing for a lower water–cement ratio resulting in higher strength. Furthermore, research on long-term performance indicated that SCBA improved durability and decreased permeability and shrinkage.

1.4 Scope of work

This study is intended to investigate the properties of M20-grade concrete and its workability by partially replacing cement with Sugarcane Bagasse Ash in several different proportions and adding Conplast SP430 for super plasticizing effects. The project shows that:

- Cement was replaced by SCBA in proportions of 0%, 5%, 10%, 15%, and 20% by weight.
- Superplasticizer could be added to the mix at 0.7 L and 1.3 L for each 100kg of binder.
- When we assessed the properties of fresh concrete as measured by slump and compaction factor, using the appropriate SCBA proportion and superplasticizer dosage resulted in acceptable fresh properties of concrete.
- When we measured hardened properties, compressive strength was assessed at 7 days,14 days and 28 days.
- A suitable SCBA equation proportion and superplasticizer dosage could be identified to maximize both compressive strength and workability.

This study promotes sustainable construction practices utilizing industrial by-products and decreasing cement use for green, eco-friendly infrastructure development.

2. OBJECTIVE

1. To utilize Sugarcane Bagasse Ash (SCBA) as a partial replacement for cement in M20 grade concrete and evaluate its effect on the fresh and hardened properties of concrete.
2. To determine the optimum percentage of SCBA that can replace cement without adversely affecting the strength and workability of concrete.
3. To investigate the influence of Conplast SP430 superplasticizer on the workability, water reduction, and strength performance of SCBA-blended concrete mixes.
4. To study the combined effect of SCBA and Conplast SP430 on the mechanical properties of concrete, including compressive strength, density, and compaction factor.
5. To evaluate the pozzolanic behavior of SCBA through its contribution to the long-term strength development (7, 28, and 90 days of curing).
6. To promote sustainable construction practices by converting agricultural waste (SCBA) into a useful cementitious material, thereby reducing environmental pollution and cement consumption.

3. MATERIALS AND METHOD

3.1. MATERIALS

Concrete comprises of cement, fine aggregate, coarse aggregate, water, and a superplasticizer. In this study, Ordinary Portland Cement (OPC) of 53 grade was used as the primary binder. Cement was replaced, partially, with Sugarcane Bagasse Ash (SCBA) at a value of 10% by weight.

3.1.1. Cement: OPC of 53 grades, conforming to IS: 1229-1987 is used with specific gravity of 3.15.
3.1.2. Fine aggregate: Fine aggregate used is locally available river sand. Tests on fine aggregate are conducted as per IS: 383-1970.It is found that specific gravity is 2.65. Fine aggregate belongs to zone III grade having fineness modulus of 2.04.
3.1.3. Coarse aggregate: Gravel of 20mm nominal size is used. The specific gravity is 2.72
3.1.4. Water: Portable water conforming to IS 456:2000
3.1.5. Sugarcane Bagasse ash: It is sieved through 150 μ and used. The specific gravity of SCBA is 1.83.

3.2. Treatment of Sugarcane Bagasse Ash (SCBA)

Sugarcane bagasse (SCB) was obtained from a local sugarcane juice outlet in the area. The bagasse was still in a wet condition after juice extraction. The following steps were completed to generate the SCBA with the best pozzolanic properties.

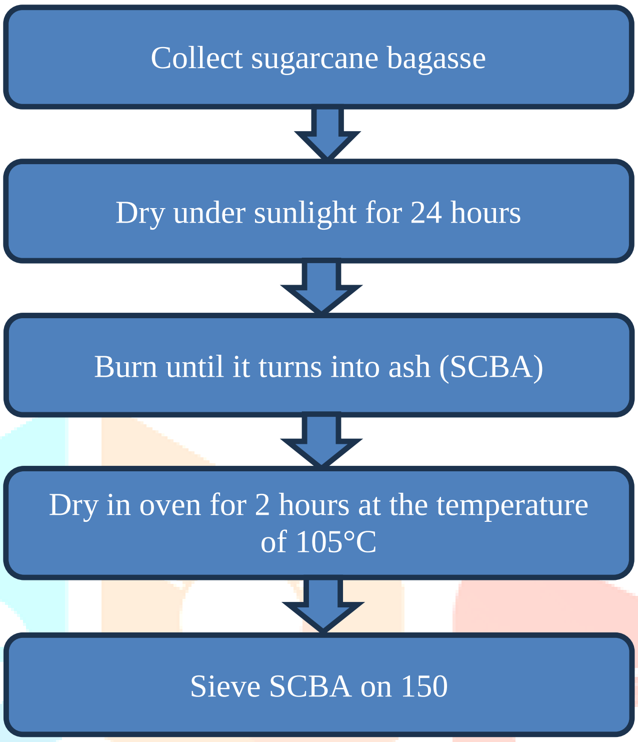

Fig 1 . Preparation of SCBA

1. Drying: The bagasse collected was sun-dried for 24 hours to remove all surface moisture.
2. Burning: The sun-dried bagasse was then burned in an open environment until all the SCB was turned into greyish ash.
3. Oven Drying: The ash was then dried in an oven at 105°C for 2 hours to remove any remaining moisture.
4. Sieving: The dried ash was sieved through a 150 µm sieve to obtain fine SCBA that has a smooth texture and uniform size distribution.

The SCBA obtained was stored in airtight containers until it was required to ensure no moisture was absorbed in the SCBA before it was to be used with the cement.

Fig 2. Sugarcane Bagasse Ash

3.3 Experimental Procedure

For compressive strength testing, three concrete cubes (150 mm × 150 mm × 150 mm) of each mix types were cast. The mix containing 10% SCBA replacement and 0.8% Conplast SP430 was tested against the control mix (0% SCBA). After 24 hours of curing, the cubes were and then cured in water for 7 and 14 days. The compressive strength was completed using Compression Testing Machine (CTM) in accordance with IS 516: 2018.

4. RESULTS AND DISCUSSION

Testing of Concrete

In order to evaluate the performance of concrete with partial replacement of cement by nano-silica and coarse aggregate by coconut shell, the following tests were conducted.

4.1. Workability Test (Slump Cone Test):

The purpose of the workability test is to evaluate the ease of mixing, placing, and compacting fresh concrete without segregation. In the slump cone test, a standard conical mold (the slump cone) is filled with fresh concrete in three layers, with each layer being tamped down with a rod. After the cone has been removed, the area which has settled vertically is measured in millimeters and is referred to as the slump. A larger slump indicates a greater workability of the material, while a lower slump indicates a stiffer mix.

Mix Name	% of Replacement	Trial no	Slump Cone Value (mm)	Average Slump Cone Test (mm)
M20	0	1	65	68
		2	70	
		3	68	
M20	10%SCBA+0.8%SP	1	85	88
		2	90	
		3	88	

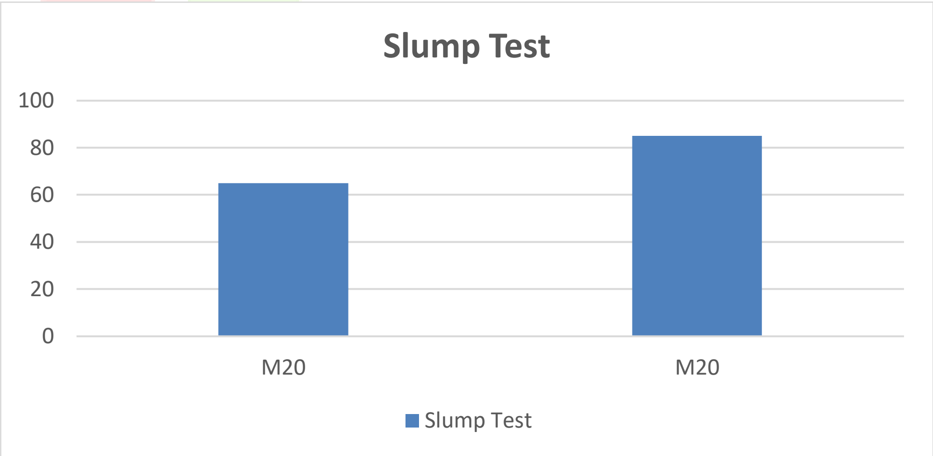

Fig 3. Tensile Strength test

4.2. Compressive Strength Test:

The compressive strength test is a measure of the ability of hardened concrete to resist an axial load prior to crushing. Concrete is poured in cubic sizes (usually 150 mm by 150 mm by 150 mm), cured for various duration periods (7, 14 or 28 days), and subsequently tested in a Compression Testing Machine (CTM). One of the applications of the test is the computation of the compressive strength as maximum load over the cross-sectional area of the specimen. The test is applied in testing to confirm the suitability of concrete in structural purposes.

Compressive Strength(N/mm^2) – Load(P)/Cross Sectional Area(A)

Fig 4: Compressive Test

Result:

For 7 days,

Mix Name	% of replacement	Trial no	Load (KN)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
M20	0	1	409.5	18.2	18.2
		2	418.5	18.6	
		3	402.8	17.9	
M20	10%SCBA+0.8%SP	1	445.5	19.8	19.8
		2	452.3	20.1	
		3	438.8	19.5	

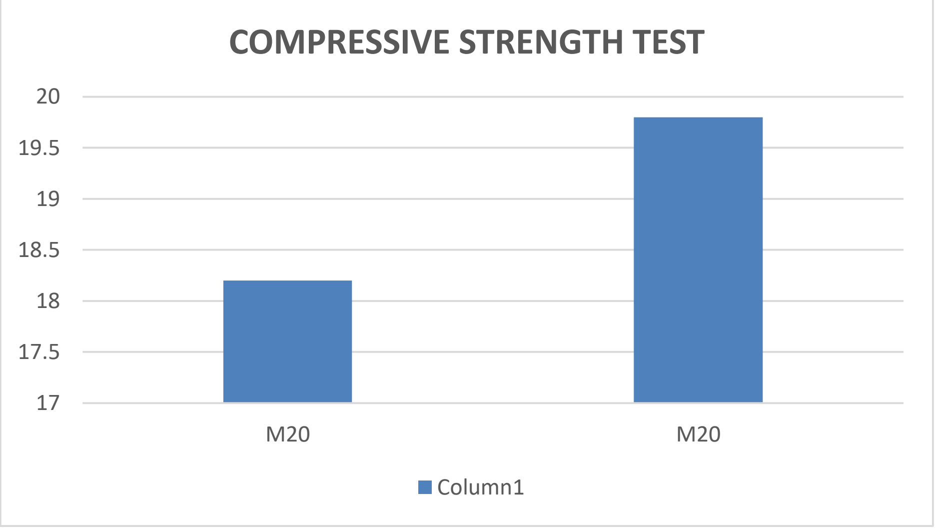

Fig 5. Compressive Strength test for 7 days

For 14 days,

Mix Name	% of replacement	Trial no	Load (KN)	Compressive Strength (N/mm²)	Average Compressive Strength (N/mm²)
M20	0	1	508.5	22.6	22.6
		2	517.5	23	
		3	504	22.4	
M20	10%SCBA+0.8%SP	1	544.5	24.2	24.4
		2	553.5	24.6	
		3	549	24.4	

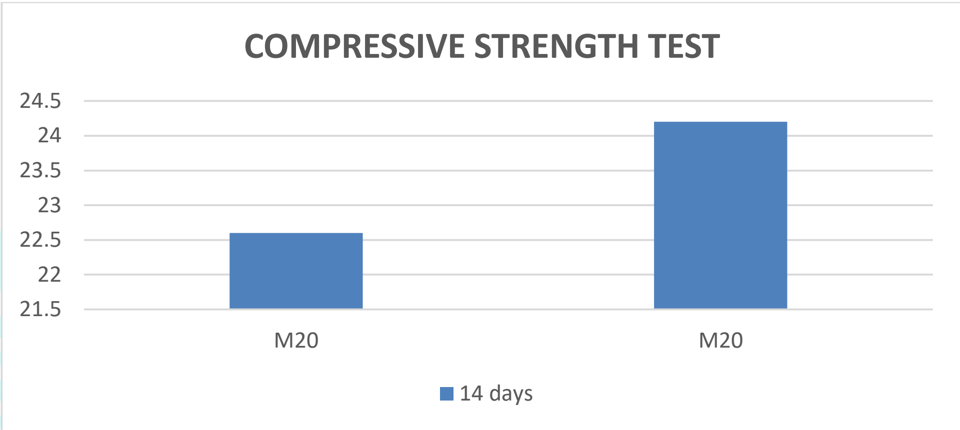

Fig 6. Compressive Strength Test for 14 days

4.3. Tensile Strength Test:

Split tensile strength test is employed to find the tensile strength of concrete, which is generally much less than its compressive strength. Concrete cubes or cylinders are loaded diametrically along their axes with a compressive load that induces tension and subsequent splitting of the test specimen. Split tensile strength testing assists in evaluating the resistance of the concrete to cracking under tensile stress. The measured splitting tensile strength(T) of the specimen was calculated using the following formula

$$T=2P/(\pi DL)$$

Result

For 7 days,

Mix Name	% of replacement	Trial no	Load (KN)	Tensile Strength (N/mm²)	Average Tensile Strength (N/mm²)
M20	0	1	130.8	1.85	1.88
		2	135.7	1.92	
		3	132.9	1.88	
M20	10%SCBA+0.8%SP	1	144.9	2.05	2.08
		2	149.9	2.12	
		3	147.1	2.08	

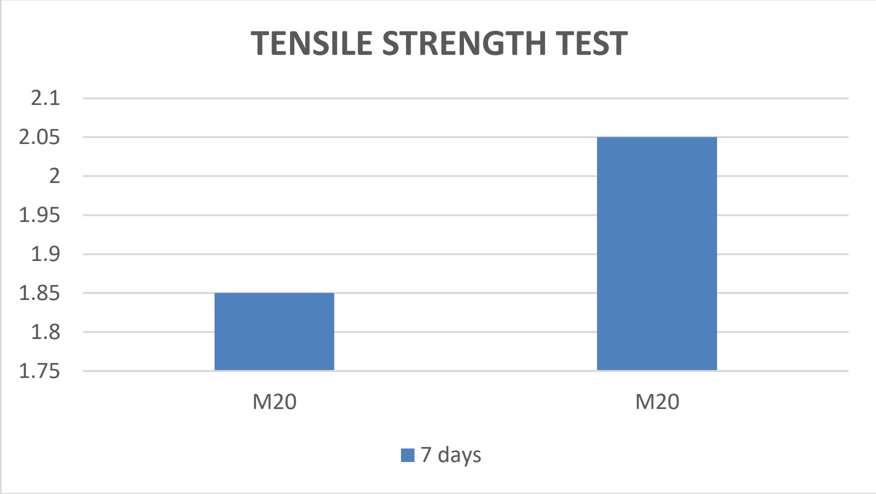

Fig 7. Tensile Strength Test for 7 days

For 14 days,

Mix Name	% of replacement	Trial no	Load (kN)	Tensile Strength (N/mm^2)	Average Tensile Strength (N/mm^2)
M20	0	1	152	2.15	2.15
		2	154.1	2.18	
		3	149.9	2.12	
M20	10%SCBA+0.8%SP	1	166.1	2.35	2.35
		2	168.3	2.38	
		3	164.7	2.33	

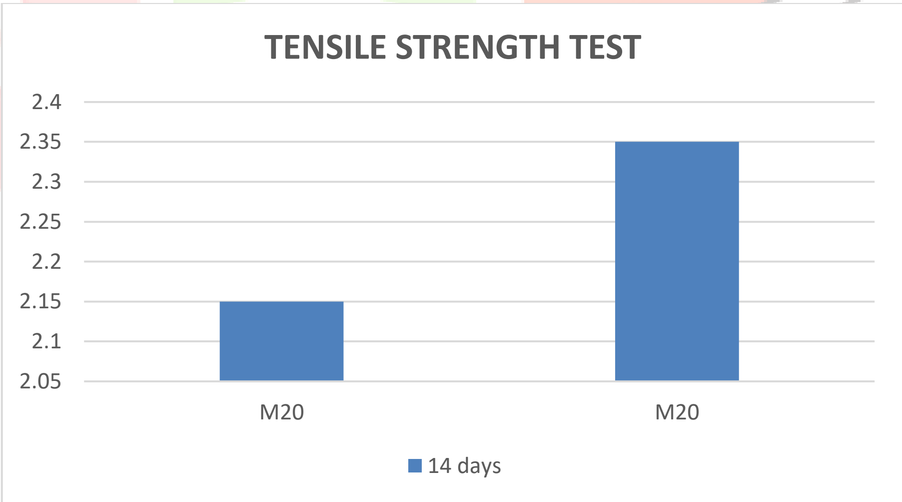

Fig 8. Tensile Strength Test for 14 days

5. CONCLUSION

The current research examined the viability of partial substitution of cement by 10% Sugarcane Bagasse Ash (SCBA) in M20 grade concrete while using a superplasticizer (Conplast SP430) to increase workability. The results of the experiments reveal that SCBA can satisfactorily function as a supplementary cementitious material, enhancing the sustainability of concrete through the use of agro-waste and minimizing the consumption of cement.

The compressive strength and split tensile strength of SCBA-replaced concrete were found to be a little less than the normal concrete at young ages but improved remarkably at 14 days, reflecting good pozzolanic activity. Superplasticizer addition guaranteed suitable workability without adding more water, hence resulting in easier handling and placing of the concrete mix.

In general, the research proves that partial substitution of cement with SCBA and the optimum dosage of superplasticizer yields concrete with acceptable mechanical characteristics and increased sustainability. This method, in addition to minimizing the environmental loads of cement production, provides a financially advantageous approach to environmentally friendly building materials.

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