Evaluation of Sugarcane Bagasse Ash and Hydrated Lime use as Cementitious Adhesive Material for Concrete

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***Abstract*—Cement production is one of the major contributors to global Carbin Dioxide (CO_2) emissions, posing significant environment concerns. In order to promote sustainable and eco-friendly construction practices, this experimental investigating the feasibility of using Sugarcane Bagasse Ash and Hydrated Lime as partially replacing of Ordinary Portland Cement in concrete. SCBA is an Industrial product rich amorphous silica, exhibits properties, while hydrated lime enhances the pozzolanic reactivity of SCBA. M30 grade concrete mixes were prepared by partially replacing cement varying proportions of SCBA and HL. Concrete cubes compressive strength was tested for 07 and 28 days after curing. Workability of casted cube is tested on situ. Among the tested mixes the replacement level of 10% SCBA and 7% HL demonstrated the higher compressive strength at 28 days. The finding confirms that SCBA and HL be effectively utilized as supplementary cementitious materials. Leading to reduced cement consumption, lower CO_2 emissions and improved sustainability without compromising structural performance. Hence the SCBA-HL blended concrete presents a viable, economical and environmentally friendly alternative for future construction application.**

I. INTRODUCTION

Cement is one of the important materials in the construction industries used as binding material of concrete production. Billions of tons cement production is done annually and it resulting the high energy consumption with Carbon dioxide, Methane and Nitrous gases from heating [4]. The industry alone accounts for nearly 8% of global CO_2 emission, which has intensified the need for sustainable alternative [1]. Use of supplementary (Adhesive) material are increasing now a day. The high Silica content, SCBA exhibits pozzolanic characteristics, enabling with react Calcium Hydroxide to perform additional components. Hydrated Lime [1]. Hydrated Lime ($Ca(OH)_2$) take crucial performance in enhancing the pozzolanic reaction of SCBA by providing additional calcium ions. The combine use of SCBA and HL promoting strength and durability of concrete. In India there is largest production of sugarcane and industries shown in Fig. 1, generates enormous quantities of bagasse ash annually. Disposal of this waste poses in environmental challenges. Therefore, incorporating SCBA and HL as adhesive material in concrete reduce the same amount of environmental pollution and also supports development and cross-effective construction practices.

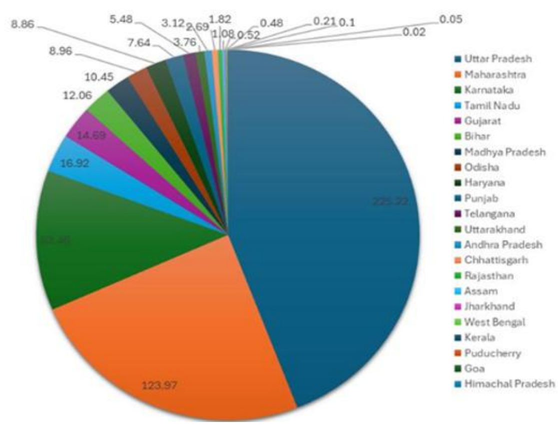


Fig 1. Production of SCBA on 2025 (Million tons)

II. MATERIALS AND METHODS

2.1.1 Cement

Local branded OPC Cement (Ordinary Portland Cement) conforming to Indian Standards was procured from the local market. The cement stratified all physical and chemical requirements prescribed by IS code for concrete applications. Properties of OPC are shown in Table 1 with SCBA.

2.1.2 Sugarcane Bagasse (SCBA)
In road and highways, it is essential to stabilize the subgrade durability, establishes a firm base of the road surface in case of unstable soils. The conventional stabilizing agents like cement and lime are costly and as time have detrimental environmental consequences. To have explored the potential of SCBA for subgrade improvement, and the finding has been quite positive. It is observed that the incorporation of SCBA in subgrade soil augments its strength and minimizes its compressibility [8]. Studies have investigated the effectiveness of SCBA in subgrade stabilization, and the results have been promising However, there is still a need for further research to optimize the use of SCBA. SCBA was collected from local sugar processing industry and burnt at controlled temperatures ranging between 600ºC and 800ºC. The ash was sieved to obtain finer particles. SCBA is dark greenish in color as Ordinary Portland Cement and possesses high porosity and fineness. Due to its porous nature, SCBA exhibits water absorption in the range of 8-15%, depending on particle fineness. The high absorption capacity enhances internal curing but increases water demands. Table 1 shows the composition of SCBA after the treatment is show in [11].

Fig 2. OPC & SCBA

Components	OPC	SCBA
SiO2(%)	18.52	29.62
CaO (%)	63.87	1.67
Al2O3 (%)	6.15	24.29
Fe2O3 (%)	3.05	3.84
MgO (%)	3.23	1.36
Loss on Ignition (LoI (%)	1.85	5.41
Specific Gravity (Kg/m^3)	3711	2049
Color	Gray	Thick Brown

2.1.3 Hydrated Lime (HL)
Hydrated lime (Ca (OH)2) is widely used in industrial application and as binding material in mortars. It is highly reactive and hydroscopic, absorbing approximately 20 – 25% water during mixing. Although HL increase water demand, it significantly enhances pozzolanic reactions and improves workability when used in combination with SCBA. The properties of HL are presented in Table 2 and 3 respectively.

Sr. No.	Chemical Composition of HL	% By weight
1	Calcium Oxide (CaO)	72.0
2	Magnesium Oxide (MgO)	1.0
3	Silicon Dioxide (SiO_2)	1.8
4	Aluminium Oxide (Al_2O_3)	0.5
5	Ferric Oxide (Fe_2O_3)	0.6
6	Carbon Dioxide (CO_2)	2.5
7	Ignition Loss	24

Table 2: Chemical Properties of HL

Sr. No	Physical Properties	Value
1	Specific Gravity	2.3 – 2.5
2	Bulk Density	400 – 600 kg/m^3

Table 3: Physical Properties of HL

2.1.4 Fine Aggregate
Sand is collected from local supplier for conforming ready to use in Zone II with sieved. Fine aggregate is an important construction material small, inert granular particles. Fine aggregate improves concrete density, workability and resistance to environmental

exposure. Physical properties of Fine aggregate are shown in Table 3.

2.1.5 Coarse Aggregate

Coarse aggregate is collected from local supplier and sieved from 20mm to 4.75 mm size ranging was used. Properties of coarse aggregate are shown in Table 3 as relevant to IS code.

Property	Fine Aggregate (Sand)	Coarse Aggregate
Specific Gravity	2.7	2.8
Bulk density (Kg/m^3)	1457	1518
Impact Value (%)	--	9.83
Crushing Value (%)	--	14.47
Water Absorption (%)	2.56	0.15

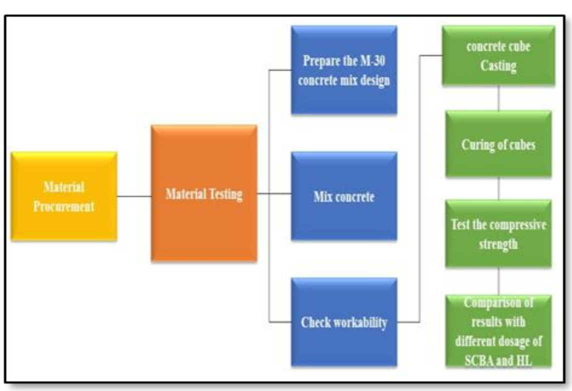
Table 4: Properties of Fine & Coarse Aggregate

2.1.6 Water

It is a crucial for chemical reaction hydration that bind the cement and aggregate, giving it strength. It lubricates particles for making the mix flow and compact easily. The water used was from a municipal supply fit for drinking. Avoided the contained like sewage, oil, acids and other organic matter present in water. If it is doubt the test water for pH (6 – 8), Chloride test sulphate test and organic contents.

2.2 Method

The flow diagram shows the steps involved in method testing the concrete mix for M-30 grade with SCBA and HL to reduce the CO_2 and prepared concrete to make reliable and increasing the life of concrete.



2.2.1 Material Procurement

Method of acquiring the material for process of selecting, researching, ordering and paying for the raw material required while construction. Purchasing the material from local dealer with all requirement for the test.

2.2.2 Material Testing

All the necessary test of Cement, Sand and Aggregate basic test by the Indian standard (IS). The material is testing on Compressive Testing Machine (CTM).

2.2.3 Prepare the M-30 Concrete Mix Design

The concrete mix proposition is conducted with cement, SCBA, Hydrated lime, aggregate (Fine & Coarse) and adding water for basic concrete mix design which mention in Table 4. For that prepared the cube of (150x150x150mm) size for 7 and 28 days for testing of compressive test.

Steps	Item	Calculation	Result	Unit
1	W/c Ratio	--	0.42	--
2	Water content	--	197	--
3	Cement content	197/0.42	469.05	Kg/m^3
4	Volume of Cement	469.05/3.15	0.1489	m^3
5	Volume of water	197/1000	0.197	m^3
6	Total Volume of (Cement Water)	0.1489+0.3459	0.3459	m^3
7	Volume of aggregate	1.00-0.3459	0.6541	m^3
8	Coarse aggregate	From IS 10262=0.64(0.64*0.9)	0.576	--
9	Fine aggregate	1-0.576	0.424	--
10	Mass of coarse aggregate	0.6541x 0.576x 2.8 x1000	1054.93	Kg/m^3

Table 5: Concrete Mix design

Mix No.	Replacement		Slump in mm	Expected Slump (mm)	Workability Level
	SCBA %	HL %			
Mix 1	4%	2%	85	90-100 mm	Medium Workable
Mix 2	5%	5%	75	75-85 mm	Slightly reduce
Mix 3	10%	7%	65	60-70 mm	Low Workable
Mix 4	15%	13%	55	40-55 mm	Very Low Workable

Table 5: Workability Test

2.2.4 Mix concrete

Prepared concrete mixture for casting the cube of concrete with well compacted for testing material strength for the 7 and 28 days in cube size (150x150x150mm).

2.2.5 Checking workability concrete

The workability of concrete mixes with evaluated using the slum contest and the result clearly shows that the gradual reduction in vocabulary with an increase in replacement percentage of Sugarcane Bagasse Aash and Hydrated Lime.

At the lower replacement level particularly in the mix one that is (4% SCBA + 2% HL) the concrete exhibited the good workability with the help of slum cone values of around 85-100mm. these indicators that tie mix one was easy to handle place and compact without much difficulty. However, has the replacement level increase in mixed to that is (5% SCBA+ 5% HL) the slum value reduced to about 75 to 85 mm that is showing the slight decrease in workability.

A more reduction was observed in mix 3 (10% SCBA + 7% HL) where the slum value dropped to approximately 60 to 70mm. the reduction in workability can be attributed to the high-level high-water observation of SCBA and the hydroscopic nature of hydrated line. SCBA particles are highly 4 and fine which increase the internal surface and area and demand more water for pro[er lubrication of mix. Similarly, the hydrated lime absorb a significant amount of water available in mix.

In mixed 4- 15% SCBA + 13% HL the slum value decreases around 42 to 55 mm indicating very low workability. At this point the concrete becomes steve and difficult to compact which male lead issue such as honeycombing and poor surface finish if not properly manage.

2.2.6. Casting of Concrete Cube

After all mixing calculation and workability of concrete we had prepared the cube of M-30 grade of concrete with different mix of SCBA and HL as mentioned in Table 6. These chemical composition of SCBA and HL are referred from various references for testing the compressive strength of concrete as shown in Table 5.

2.2.7. Curing of cubes

After casting the concrete cube, the time is taken for curing the tested cube is taken for 7 days and 28 days with three different mixes as mentioned in table 6 in curing tank which is constructed on site.

2.2.8 Testing compressive strength of Cube

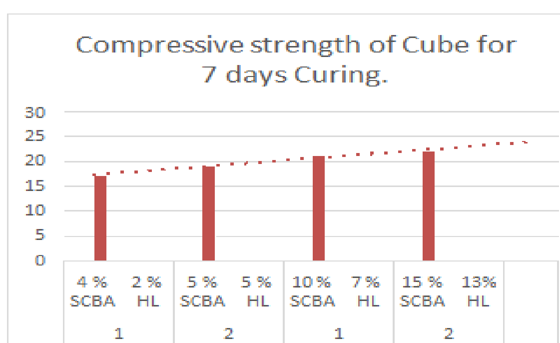
The compressive strength of cubes are tested on CTM for respected 7 days and 28 days curing time.

2.2.9 Comparison of results with different dosage of SCBA and HL

All the test results with different dosage are referred from research paper and mentioned table 7 and 8.

Authors	Replacement Levels (%)	Compressive Strength Findings (MPa)	Optimum Replacement
Ramesh and Kishore [16]	0, 5, 10, 15, 20	27.9, 28.3, 24.4, 22.0, 19.7	5%
Kiran and Kishore [17]	0, 5, 10, 15, 20, 25	39.4, 45.5, 42.9, 39.7, 30.0, 18.7	5%
Modani and Vyawahare [18]	0, 10, 20, 30, 40	22.3, 23.8, 21.9, 19.2, 14.7	10%
Khan, et al. [19]	0, 5, 10, 15, 20	50.2, 50.1, 53.8, 48.0, 43.4	10%
Srinivasan and Sathiya [20]	0, 5, 10, 15, 20, 25	21.5, 29.5, 24.7, 19.3, 18.9, 17.7	5%
Ramakrishnan, et al. [21]	0, 5, 10, 15, 20	42.3, 45.5, 39.3, 51.6*, 46.3	5%
Rerkpiboon, et al. [22]	0, 10, 20, 30, 40, 50	41.1, 46.5, 46.0, 41.2, 39.4, 37.6	10%

Table 5: Influence of SCBA on compressive strength at 28 days from various references.



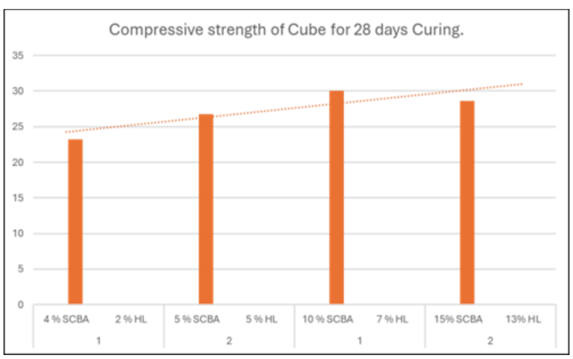
Graph 1- 7 Days compressive strength

Mix No.	Mix Description	Cement (Kg/m3)	Hydrated Lime (HL) (Kg/m3)	Sugarcane Bagasse Ash (Kg/m3)	Water (Kg/m3)	Fine Aggregate (Kg/m3)	Coarse Aggregate (Kg/m3)
Mix 1	4% SCBA + 2% HL	438.20	9.40	17.50	197	748.81	1054.93
Mix 2	5% SCBA + 5% HL	422.14	23.45	22.5	197	748.81	1054.93
Mix 3	10% SCBA + 7% HL	380.00	32.90	45.00	197	748.81	1054.93

Table 6: Different mix proportion of SCBA and HL in concrete mix.

Sr. No.	Grade of Concrete	Date of Casting	Testing Date	C/S Area (cm2)	Crushing Load (KN)	Compressive Strength (N/mm2)	Average Compressive Strength (N/mm2)
				225	403.3	17.92	
1	M-30 4% SCBA + 2% HL	25-11-2025	05-12-2025	225	361.7	16.07	17.11
				225	390.7	17.36	
				225	414.7	18.43	
2	M-30 5% SCBA + 5% HL	25-11-2025	05-12-2025	225	391.4	17.39	18.84
				225	466.3	20.72	
				225	478.7	21.27	
3	M-30 10% SCBA + 7% HL	25-11-2025	05-12-2025	225	470.4	20.90	21.15
				225	479.4	21.30	
				225	480	21.33	
4	M-30 15% SCBA + 13% HL	25-11-2025	05-12-2025	225	495	22.00	21.92
				225	505	22.44	

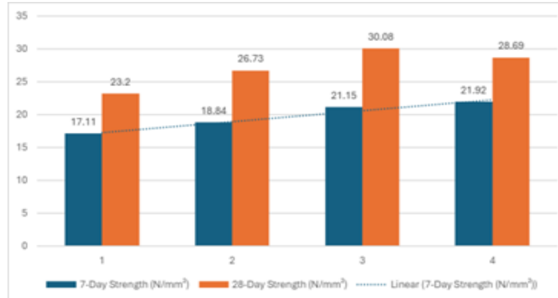
Table 7: Compressive strength of Cube for 7 days Curing.



Graph 2- 28 Days Compressive Strength

Sr. No.	Grade of Concrete	Date of Casting	Testing Date	C/S Area (cm2)	Crushing Load (KN)	Compressive Strength (N/mm2)	Average Compressive Strength (N/mm2)
				225	513.5	22.82	
1	M-30 4% SCBA + 2% HL	25-11-2025	2 6 -12-2025	225	526.5	23.40	23.20
				225	526.5	23.40	
				225	597.0	26.53	
2	M-30 5% SCBA + 5% HL	25-11-2025	2 6 -12-2025	225	586.35	26.06	26.73
				225	621.9	27.62	
				225	646.1	28.71	
3	M-30 10% SCBA + 7% HL	25-11-2025	2 6 -12-2025	225	708.8	31.50	30.08
				225	676.2	30.05	
				225	630	28.00	
4	M-30 15% SCBA + 13% HL	12-02-2026	1 4 -03-2026	225	656	29.16	28.95
				225	668	29.69	

Table 8: Compressive strength of Cube for 28 days Curing.



2.3 Novelty of Study

This study compared with earlier research on Sugarcane Bagasse Ash (SCBA). Most studies are replaced by cement by SCBA usually between 5% and 10% with different result of strength of concrete.

In this study we had used SCBA with Hydrated Lime (HL) Which has improves the pozzolanic reaction and take the concrete to give better performance. We got the result the that Mix with 10% SCBA and 7% HL with better comprehensive strength as compared to many of previous studies at similar level. This because of the Hydrated Lime and extra calcium, which helps in making the concrete denser and stronger. From this study provides a better and more effective method for strength of concrete as sustainable construction.

Unlike earlier studies that mainly focus on single-material replacement, this study provides a more balance and efficient approach by improving strength while also reducing cement consumption and CO2 emission. Therefore, the proposed SCBA-Hl blended system offers a more practical, scientifically supported, and sustainable advancement over conventional SCBA-based concrete reported in previous research. Crushing strength for M30 grade of concrete is 31.50 N/mm2 obtained for the proportion of 10% SCBA+7% HL. Higher SCBA and HL content significantly improves strength due to: Strong pozzolanic reaction, dense microstructure SCBA and HL can be effectively used as partial replacement of cement in M-30 concrete. Strong pozzolanic reaction, dense microstructure SCBA and HL can be effectively used as partial replacement of cement in M-30 concrete. Higher replacement (up to 17% total: 10% SCBA + 7% HL) gives better compressive strength. Thus, this combination can be recommended for eco-friendly and economical concrete production.

III. CONCLUSION

The experimental study confirms that SCBA and HL can be used as partial replacements of cement in M30 grade concrete successfully. Among the tested mixes, 10% SCBA + 7% HL achieved the highest compressive strength. The improved strength is due to enhanced pozzolanic reaction and denser concrete microstructure. The use of SCBA reduces cement consumption and CO_2 emissions, contributing to sustainable construction. Hence, SCBA–HL concrete is economical, eco-friendly, and structurally efficient. The results shows the strength of concrete indicates out of the three proportions of SCBA and HL, the highest

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