"Review on Enhancing Durability of Concrete Using SCBA and Hydrated Lime as Cementitious Additives"

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I.ABSTRACT:

This study investigates the potential of using Sugarcane Bagasse Ash (SCBA) and hydrated lime as supplementary cementitious materials (SCMs) to enhance the mechanical and durability properties of concrete. SCBA, a by-product of the sugar industry, is rich in silica and exhibits pozzolanic characteristics, while hydrated lime improves workability and resistance to chemical attacks. The research explores how SCBA and lime, when combined, can partially replace Ordinary Portland Cement (OPC) in concrete, leading to a reduction in environmental impact and enhancing concrete performance, especially in harsh conditions such as sulfate-rich environments. The findings indicate that SCBA, particularly when processed optimally, can improve concrete's strength, durability, and resistance to chemical assaults. This study contributes to the development of more sustainable and eco-friendly concrete solutions, promoting greener construction practices.

Keywords: Sugarcane Bagasse Ash (SCBA), Hydrated Lime, Supplementary Cementitious Materials (SCMs), Concrete Durability, Sustainable Construction

II.INTRODUCTION:

Concrete is the most frequently utilized building material in the world, because to its flexibility, durability, and low cost. However, its manufacture has a substantial environmental effect, primarily because to the large usage of ordinary Portland cement (OPC), a major source of CO_2 emissions. In recent years, researchers have concentrated on finding long-term alternatives by integrating supplemental cementitious materials (SCMs) such industrial by products and agricultural wastes to partly replace OPC. Sugarcane Bagasse Ash (SCBA), an agro-industrial waste produced during sugar manufacturing, and Hydrated Lime have received a lot of attention for their pozzolanic qualities and potential to enhance concrete performance.

SCBA has a high concentration of silica, which combines with the calcium hydroxide in cement to generate more calcium silicate hydrate (C-S-H), increasing the strength and durability of concrete. On the other hand, hydrated lime, which is recognized for improving workability and resistance to chemical assaults, may help concrete last longer. SCBA and hydrated lime may work together to enhance concrete performance in harsh settings like sulphate-rich soils and groundwater.

The purpose of this research is to assess the potential of SCBA and hydrated lime as SCMs, as well as their effect on concrete's strength. This study aims to explore the viability of using SCBA and lime as sustainable substitutes for traditional cement by defining their physical and chemical characteristics and investigating their impact on the compressive strength and durability of concrete. This research will help to create eco-friendly concrete solutions, encouraging sustainable building practices while lowering environmental effect.

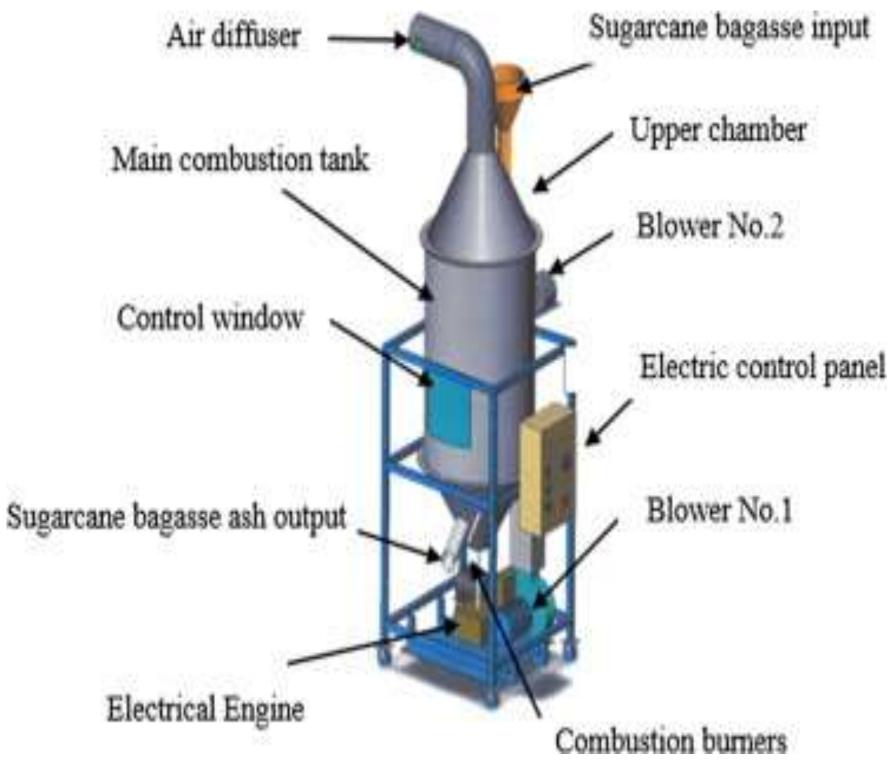

Fig 1.1 Sugarcane Bagasse Ash (SCBA)

1.1 Material Use

1.Cement:

Portland Pozzolana cement (PPC), a 53-grade cement from Ambuja.
PPC was used to cast all of the specimens. Cement pastes need varying amounts of water to achieve a consistent consistency. Concrete strength development rates vary depending on the kind of cement used. Choosing the right brand and kind of cement is crucial for producing high-quality concrete. The kind of cement used has a significant impact on early strength due to its hydration rate. Additionally, chemical and mineral admixtures must be compatible with cement.

2.Sugar Cane Bagasse Ash (SCBA):

Sugarcane Bagasse Ash (SCBA) is an agricultural waste produced by the burning of bagasse, the fibrous residue left after extracting juice from sugarcane. It is high in silica, which gives it pozzolanic characteristics and allows it to combine with calcium hydroxide in the presence of moisture to generate new cementitious compounds. This pozzolanic process improves the mechanical qualities of concrete, including compressive strength and durability. Incorporating SCBA in concrete may partly replace cement, lowering the carbon footprint of cement manufacturing and promoting sustainable building practices. Furthermore, the inclusion of SCBA in concrete increases its resistance against chemical assaults, such as those generated by sulphates, making it acceptable for usage in harsh environmental circumstances.

3.Hydrated lime:

Hydrated lime, commonly known as calcium hydroxide, is a fine white powder created by hydration of quicklime (calcium oxide). Hydrated lime improves workability and durability in concrete mixes. It combines with other cementitious elements to generate calcium silicate hydrates, which help to strengthen the strength and resilience of the concrete. Its capacity to minimize shrinkage and enhance resistance to chemical assaults, especially sulphate attacks, makes it an excellent additive to concrete mixes subjected to extreme weather conditions. The inclusion of hydrated lime also helps to reduce porosity, increasing the overall density and impermeability of the concrete.

4. Ordinary Portland Cement (OPC):

Ordinary Portland Cement (OPC) is the most widely used cement in the building industry, consisting mostly of calcium silicates, aluminates, and ferrites. It acts as the major binder of concrete, giving strength and structural integrity. OPC is essential in the hydration process, since it combines with water to generate a hard, solid matrix that holds the aggregates together. In this research, OPC is utilized as a control material to assess the performance of SCBA and hydrated lime-modified concrete. Its usage enables the production of baseline mechanical qualities and durability indicators, which are critical for evaluating the performance of supplemental materials.

5.Fine Aggregate:

Fine aggregate, often known as natural or synthetic sand, is made up of particles that pass through a 4.75 mm filter. Fine aggregates in concrete fill the gaps between larger coarse aggregates, decreasing voids and improving mix workability. They also improve the density and strength of the concrete matrix. The qualities of fine aggregates, such as particle size distribution and cleanliness, have a substantial influence on the overall performance of concrete, impacting workability, strength, and durability. Properly graded fine aggregates produce a consistent mix, which prevents segregation and improves concrete cohesiveness.

6. Coarse Aggregate:

Coarse aggregates are made up of bigger particles, usually gravel or crushed stone, that measure more than 4.75 mm. They offer bulk and compressive strength to concrete and are critical to guaranteeing the mix's structural integrity. The size, shape, and surface roughness of coarse particles impact the mechanical characteristics of concrete, as well as its resistance to deformation under stress. Choosing the right kind and quality of coarse aggregate is crucial for obtaining the optimum strength and performance characteristics of concrete, especially when subjected to changing load circumstances and environmental challenges.

IIILITERATURE REVIEW:

Michelle S. Rodrigues et al. (2023): This study evaluated the reactivity of sugarcane straw ashes (SCSA) burned at various temperatures (600-900°C) and their incorporation into blended cement and lime pastes. The results showed that SCSA600 and SCSA700 ashes enhanced compressive strength and reduced total pore volume compared to control pastes. The ashes were characterized by various techniques, including X-ray fluorescence and thermogravimetric analysis. The research highlights that sugarcane straw ashes, particularly those calcined at 600-700°C, exhibit strong pozzolanic properties, making them suitable for partial replacement of Portland cement and hydrated lime in concrete and mortar applications.

Shazim Ali Memon et al. (2022): The study investigates the potential of processed sugarcane bagasse ash (SCBA) as a supplementary cementitious material (SCM) in concrete. The research shows that grinding SCBA for 45 minutes improves its pozzolanic reactivity by 2.92 times. The incorporation of SCBA as a cement replacement (up to 40%) increased concrete workability while reducing its density. Compressive strength and durability tests revealed that 30% SCBA replacement results in a compressive strength of 21 MPa after 28 days, which is suitable for structural applications. The study also found enhanced resistance against sulfuric and hydrochloric acid due to microstructure densification.

Andréia Arenari de Siqueira et al. (2022): This research investigates the use of sugarcane bagasse ash (SCBA) and limestone filler (LF) as partial replacements for clinker in Portland cement to improve mechanical and durability performance. The study developed five different blended Portland cements using binary and ternary mixes of SCBA and LF. Mortars produced with these cements showed improved compressive strength, reduced water absorption, and enhanced durability. The specimens were immersed in sulfuric acid for 56 days to assess deterioration, revealing that SCBA significantly improved the sulfuric acid resistance of the mortars, making it a promising sustainable material for construction.

Amol Kamalakar Mali et al. (2021): This study evaluated the pozzolanic reactivity of sugarcane bagasse ash (SCBA) from 30 sugar industries. The reactivity was assessed using several methods including the strength activity index (SAI) and thermogravimetric analysis (TGA). The results revealed that SCBA demonstrates pozzolanic properties due to its high amorphous silica content. However, coarser particles, high loss of ignition (LOI), and the porous nature of SCBA hindered its strength development. The study suggests that SCBA samples with higher amorphous silica (>25%) and lower LOI (<20%) should be prioritized for use in cement-based systems, offering an efficient selection protocol.

Er. Sumit Sharma et al. (2021): Green concrete is a sustainable alternative that reduces environmental impact by replacing traditional cement with waste materials. The study introduces the concept of green concrete, which uses agricultural and industrial by-products as partial substitutes for cement. This reduces energy consumption and CO2 emissions, as well as the environmental harm associated with concrete production. Green concrete is not only cost-effective but also enhances durability. The concept focuses on environmentally responsible production, making it a key innovation for the future of the concrete industry, contributing to more sustainable and low-carbon infrastructure development.

Laura Landa-Ruiz et al. (2021): This research investigates the physical, mechanical, and durability properties of six concrete mixtures, including a conventional concrete (CC) and five ecofriendly ternary concretes (ETC) made with varying proportions of sugarcane bagasse ash (SCBA) and silica fume (SF). The results showed that ETC mixtures had comparable physical properties to conventional concrete, but exhibited superior durability, especially in terms of electrical resistivity, which increased with the percentage of SCBA and SF. The mixture with 40% replacement of Portland cement showed the highest resistivity, indicating improved durability, thus supporting the viability of using these materials for sustainable construction.

José da Silva Andrade Neto et al. (2021): This study investigates the effects of adding sugarcane bagasse ash (SCBA) on the durability of concrete, particularly concerning chloride migration, carbonation, and alkali-silica reactions (ASR). The study found that SCBA significantly improved concrete’s resistance to chloride diffusion, enhancing its durability by up to 97.3%. However, the addition of SCBA increased carbonation, reducing the alkaline reserve in concrete and shortening its lifespan in carbonated environments. Despite this, concrete with up to 10% SCBA maintained a service life of more than 50 years in industrial conditions, making SCBA a promising material for enhancing concrete durability.

Pritish Gupta Quedou et al. (2021): The study evaluated the mechanical and durability properties of concrete containing up to 20% sugarcane bagasse ash (SCBA) as a partial replacement for Ordinary Portland Cement (OPC). Concrete with 10% SCBA exhibited increased compressive strength (by 2.6% at 120 days) and enhanced mechanical properties compared to control concrete. However, higher replacement percentages led to an increase in water absorption and reduced flexural strength. The study suggests that 10% SCBA replacement provides the best performance for structural applications, enhancing concrete’s durability and sustainability while reducing CO2 emissions associated with cement production.

R. Lima Figueiredo et al. (2020): This paper explores the pozzolanic reactivity of sugarcane bagasse ash (SCBA), emphasizing key factors such as fineness, specific surface area, and amorphous content. The study demonstrated that despite the presence of crystalline phases like quartz, SCBA is pozzolanic and can contribute to cementitious reactions. The analysis showed that SCBA’s reactivity is more influenced by its specific surface area than its amorphous content. The presence of carbon did not hinder its pozzolanic behavior. The study concludes that SCBA’s reactivity can be optimized through careful selection based on surface area and amorphous silica content, making it viable for cement replacement.

Chidanand Patil et al. (2020): This research investigates the effect of sugarcane bagasse ash (SCBA) on M30 grade concrete, with SCBA replacing cement at varying percentages (0%, 5%, 10%, 15%, 20%). The study found that up to 20% SCBA replacement enhanced compressive strength, but higher percentages reduced concrete’s performance. Water absorption increased significantly with SCBA content, indicating a reduction in concrete density. The results also showed that SCBA’s pozzolanic activity contributes to strength gains but negatively impacts flexural strength and carbonation resistance at higher replacement levels. The findings suggest that SCBA is a viable alternative for sustainable concrete when used at optimal replacement levels.

Marcos A. S. Anjos et al. (2020): This study explores the impact of sugarcane bagasse ash (SCBA) on the rheological, physical, and mechanical properties of self-leveling mortar (SLM). The mortars were produced by replacing 15-30% of Portland cement with SCBA. Results showed that SCBA improved the flowability, viscosity, and stability of the fresh mortars, making them more suitable for self-leveling applications. In the hardened state, the addition of SCBA up to 25% improved compressive and flexural strength, as well as bond strength. However, higher SCBA content led to a decline in performance, indicating that optimal SCBA levels are crucial for enhancing mortar properties.
A.S. Vijay Vikram et al. (2019): This research investigates the use of sugarcane bagasse ash (SCBA) in concrete to improve its corrosion resistance and durability. Concrete mixtures with 20% SCBA and 40% steel slag exhibited enhanced resistance to corrosion initiation and improved durability in tests involving rapid chloride penetration and sulfuric acid exposure. The study highlights that SCBA significantly reduces the corrosion rate of steel reinforcement in concrete, thereby improving the long-term performance of concrete structures. The combination of SCBA with steel slag also contributed to increased strength and resistance to aggressive environmental conditions, making it a sustainable and durable construction material.

O G Mark et al. (2019): This review paper examines the influence of twelve supplementary cementitious materials (SCMs), including sugarcane bagasse ash (SCBA), on concrete properties. It was found that the incorporation of SCMs significantly enhances both the strength and workability of concrete. The study highlighted that SCMs such as SCBA can effectively replace ordinary Portland cement (OPC), reducing the need for virgin materials and minimizing environmental impact. The review further emphasized the potential of SCBA to improve the mechanical and durability properties of concrete, contributing to greener construction practices and offering an alternative to traditional cement in concrete production.

Suvash Chandra Paul et al. (2019): This paper summarizes the potential of agricultural wastes, including sugarcane bagasse ash (SCBA), as supplementary cementitious materials (SCMs) in concrete production. The study reveals that SCBA can effectively replace a portion of ordinary Portland cement (OPC) without compromising the mechanical properties of concrete. The use of SCBA contributes to sustainability by reducing CO2 emissions associated with cement production and minimizing agricultural waste. The paper suggests that, when properly designed, concrete containing SCBA can have comparable or even superior mechanical and durability properties, making it a viable alternative to traditional cement-based materials in construction.

Challa Hari Sravan et al. (2019): This research investigates the effect of partial replacement of Portland cement with sugarcane bagasse ash (SCBA) on concrete exposed to sulfuric acid. The study found that concrete containing SCBA demonstrated improved resistance to sulfuric acid attacks, with 20% SCBA replacement showing significant durability benefits. The study highlights SCBA's potential to reduce the impact of aggressive environments, making it a viable material for durable concrete production. The results also suggest that SCBA's pozzolanic properties contribute to the formation of secondary hydrates, which help protect the concrete matrix from the corrosive effects of sulfuric acid exposure.

Qing Xu et al. (2018): This comprehensive review examines the potential of sugarcane bagasse ash (SCBA) as a sustainable construction material. SCBA is a byproduct of the sugar and ethanol industry and possesses pozzolanic properties, making it suitable as a partial replacement for cement in concrete production. The review discusses the impacts of SCBA on concrete's fresh and hardened properties, including its effect on mechanical strength, microstructure, and durability. The paper highlights key factors influencing SCBA's pozzolanic activity, such as calcination temperature, fineness, and amorphous silica content. It concludes that SCBA is a promising material for developing sustainable and environmentally friendly construction materials.

Seyed Alireza Zareei et al. (2018): This study investigates the effect of incorporating sugarcane bagasse ash (SCBA) as a partial replacement for cement in concrete. Various concrete specimens with 5-25% SCBA replacement were tested for mechanical properties, including compressive strength, tensile strength, and impact resistance. The results indicated that replacing cement with up to 5% SCBA improved concrete's strength and impact resistance, particularly in lightweight concrete. However, higher SCBA content led to reduced compressive strength and durability. The study concludes that SCBA is most effective in improving the mechanical properties of lightweight concrete, while its inclusion in conventional concrete may require careful optimization.

R. Gopalakrishnan et al. (2017): This study focuses on the early-age properties of sugarcane bagasse ash (SCBA) cement, specifically its setting time and compressive strength. Concrete mixtures with SCBA replacing cement at 5-20% were tested, and the effects of seawater, distilled water, and groundwater on hydration were also evaluated. The results showed that SCBA enhanced compressive strength, particularly when using seawater, which accelerated early-stage hydration. The study concluded that SCBA can be a viable cement replacement, offering increased strength at early ages, especially in marine environments, and improving the sustainability of concrete production.

Venustiano Ríos-Parada et al. (2017): This research investigates the impact of Mexican sugarcane bagasse ash (SCBA) on concrete prepared with blended Portland cement (CPC) and fly ash (FA). The study involved preparing ternary concrete mixtures with varying SCBA content and evaluating their properties in both fresh and hardened states. Results showed that while SCBA reduced workability, it improved the mechanical properties and modulus of elasticity over time. The study found that SCBA is beneficial at later stages due to its pozzolanic activity, especially when combined with FA, contributing to the overall durability and strength of concrete.

Alireza Joshaghani et al. (2017): This study examines the combined use of nanosilica and sugarcane bagasse ash (SCBA) in mortar mixtures, focusing on mechanical and durability properties. The mortar specimens were prepared with varying percentages of SCBA and nanosilica as cement replacements. The results indicated that while nanosilica enhanced strength and durability, SCBA negatively impacted early-age performance, especially at higher replacement levels. However, a ternary mixture with both nanosilica and SCBA showed the best long-term performance, suggesting that SCBA can be effectively used in combination with nanosilica for improving mortar durability and strength over time.

Elisabeth Arif et al. (2016): This study investigates the pozzolanic behavior of sugarcane bagasse ash (SCBA) and its potential as a cement replacement. The research found that SCBA from high-efficiency boilers contains less amorphous silica and more quartz, which limits its pozzolanic activity. However, at low replacement levels (5%), SCBA improved the resistance of concrete to sulfuric acid. The study concluded that while SCBA's pozzolanic activity may not be as strong as other materials, it still offers benefits such as enhancing durability against acid attack, making it suitable for specific applications requiring acid-resistant concrete.

Alireza Joshaghani et al. (2016): This research focuses on the sulfur resistance of mortars containing sugarcane bagasse ash (SCBA). Mortar specimens with 0-30% SCBA were exposed to sulfate solutions (Na_2SO_4 and $MgSO_4$) for six months. The results showed that SCBA enhanced the compressive strength and durability of mortar, particularly against sulfate attacks. Mortars with up to 20% SCBA exhibited higher strength compared to control samples. The study concluded that SCBA's pozzolanic properties contribute to improved sulfate resistance, making it a valuable material for constructing durable, sulfate-resistant concrete in aggressive environments.

Dr. Shanthala B et al. (2016): This study explores the impact of sugarcane bagasse ash (SCBA) on the compressive strength of M25 grade concrete. The concrete was prepared by partially replacing cement with SCBA at different percentages (0%, 5%, 10%, 15%). The results showed that 10% SCBA replacement provided the optimal balance of strength and durability. Higher replacement levels, however, reduced concrete strength and increased water absorption. The study concluded that SCBA is an effective pozzolanic material for low-grade concrete, offering both environmental benefits and enhanced concrete performance when used in optimal proportions.

Sagar Dhengare et al. (2015): This review paper examines the use of sugarcane bagasse ash (SCBA) in concrete, focusing on its physical and mechanical properties. The study concludes that SCBA can be an effective supplementary cementitious material when used in varying proportions (typically up to 20%) in concrete. It enhances durability and reduces environmental impact by recycling agricultural waste. The paper emphasizes SCBA's ability to improve concrete's sustainability while maintaining or improving strength, making it a viable alternative to traditional cement, particularly in developing countries facing environmental concerns associated with agricultural waste disposal.

2.1 Research gap

The studies on sugarcane bagasse ash (SCBA) as a supplementary cementitious material (SCM) have demonstrated great potential in improving the mechanical properties and durability of concrete. Nonetheless, some gaps in research exist. For one, the ideal calcination temperature and time for SCBA to achieve maximum pozzolanic reactivity must be investigated further, since these variables greatly affect its performance. Although investigations have considered the influence of SCBA on compressive strength and durability, not much research has been conducted on its long-term behavior, especially in the presence of changing environmental conditions like high temperatures, humidity, and chemicals. The effect of various sources of SCBA, including regional differences, on concrete properties also needs to be explored. Interactions of mixing SCBA with other SCMs, for example, silica fume or fly ash, are not well understood. In addition, the influence of SCBA on microstructure and long-term performance, including chloride penetration resistance, carbonation resistance, and alkali-silica reaction (ASR) resistance, need more in-depth studies to thoroughly explore its capability in sustainable construction.

IV.CONCLUSION:

The research confirms that both SCBA and hydrated lime, when used as supplementary cementitious materials, significantly enhance the mechanical and durability properties of concrete. SCBA's pozzolanic activity, combined with hydrated lime's ability to improve workability and chemical resistance, offers a promising alternative to traditional cement. The incorporation of these materials helps reduce the environmental footprint of concrete production by lowering CO_2 emissions and utilizing agricultural waste. Further research is needed to optimize SCBA processing conditions, explore its long-term performance under varying environmental conditions, and study its interaction with other SCMs to maximize its potential in sustainable concrete production.

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