Communications on Applied Nonlinear Analysis
ISSN: 1074-133X
Vol 32 No. 10s (2025)

Exploring the Synergistic Effects of Industrial and Agricultural Waste in Concrete

1st **Shashank Shekhar Kamal, 2nd Akshit Lamba**
Research Scholar,
Department of Civil Engineering, Kalinga University Raipur
kamalshashankshekhar@gmail.com

Assistant Professor,
Department of Civil Engineering, Kalinga University Raipur
akshit.lamba@kalingauniversity.ac.in

Article History:

Received: 12-01-2025

Revised: 15-02-2025

Accepted: 01-03-2025

Abstract:

Concrete is widely used in the construction industry due to its cost-effectiveness and superior properties compared to other materials. However, the increasing consumption of Ordinary Portland Cement (OPC) due to infrastructure growth and residential construction has raised environmental concerns. Cement production contributes approximately 7% of global carbon dioxide emissions, exacerbating climate change. Additionally, the large-scale mining of finite natural resources like limestone and river sand for fine aggregate has led to environmental degradation, prompting governments, particularly in developing nations, to regulate sand mining. These challenges highlight the urgent need for sustainable alternatives in concrete production. Research has explored supplementary cementitious materials such as fly ash, slag, silica fume, rice husk ash, and metakaolin, demonstrating enhanced strength, reduced permeability, and improved hydration properties in blended cement concrete. However, many locally available pozzolanic materials remain underutilized due to limited characterization and assessment. Aggregates, which constitute the majority of concrete volume, are extensively extracted, leading to severe environmental impacts. With sand and gravel being the most extracted resources globally, their depletion surpasses even biomass and fossil fuel extraction. In response, researchers and organizations are focusing on sustainable alternatives for concrete production by recycling industrial waste and by-products.

Keywords- Concrete, Ordinary Portland Cement (OPC), Carbon Dioxide Emissions, Environmental Degradation, Sustainable Alternatives, Supplementary Cementitious Materials, Fly Ash, Slag, Silica Fume.

INTRODUCTION

Because it is less expensive than other building materials and has better qualities than other materials, concrete is utilised a lot in the construction industry. Furthermore, a considerable amount of regular Portland cement has been consumed recently due to the growth of the infrastructure and the notable rise in residential building. The release of carbon dioxide during the cement-making process and its consequent influence on global warming are among the main issues. Cement factories provide around 7% of all carbon dioxide emissions into the atmosphere (WBCSD/IEA 2018). The method of making cement is not sustainable due to the large-scale mining of finite natural resources, such as limestone, and the release of carbon dioxide. However, another significant issue is the supply of fine particles needed to produce concrete. The majority of developing nations, including India, have outlawed the use of river sand as a fine aggregate in order to regulate the sand mining process and preserve the natural riverbank. Because of the strict environmental rules and limitations, the concrete sector is directly impacted by the need for fine aggregate and the manufacturing of regular Portland cement, which is carbon intensive. Because of these issues, using substitute materials is required to produce concrete that is both long-lasting and sustainable.

1.1 In India, Sugarcane Bagasse Ash

In India, the sugar sector is regarded as the nation's and farmers' economic backbone. The Indian Sugar Mill Association reports that there are currently more than 500 sugarcane plants operating all throughout the nation. India's sugar industry has just begun producing electricity and selling the excess to the government via the power grid. India has risen to the top in the world for sugarcane output due to its extensive cultivation. In 2016, India produced around 35.5 crore tonnes of sugarcane on average. With a gross calorific value of 2250 kcal/kg in its wet condition, bagasse ash finds optimal use in the production of electricity. In order to do this, boilers that burn bagasse at 400 to 600 degrees Celsius are used to create steam. However, it resulted in a poor fuel value and incomplete burning of bagasse. As a result, India's sugar industry with cogeneration plants began to experience power shortages in the 1980s. Because of the increasing usage of fossil fuels, this cogeneration plant is currently a viable choice for the production of electricity.

1.2 Scope of Work This study aims to explore sustainable alternatives to traditional concrete materials by evaluating the use of supplementary cementitious materials (SCMs) and recycled industrial by-products in concrete production. The research will focus on identifying locally available pozzolanic materials and assessing their potential to enhance concrete performance while reducing environmental impact. Additionally, the study will investigate alternative fine aggregates to mitigate the depletion of natural sand resources.

I. LITERATURE REVIEW

- **Vasudha D. Katare et at(2017),** This research examines the characterisation of sugarcane biomass ash through experimentation as a pozzolanic binder for the production of sustainable concrete. A framework is proposed to guide the process of developing pozzolanic binder from sugarcane crop. The pozzolanic characteristic of

sugarcane biomass ash is examined in relation to the temperature at which it burns and the conditions under which it is ground. This study examines the rheological performance, pozzolanic reactivity, heat of hydration, and physico-chemical characteristics of sugarcane biomass ash.

- **Almir Sales et al (2010),** nowadays, sugarcane has a significant impact on the global economy, and Brazil is the world's top producer of both sugar and alcohol, two vital commodities. Bagasse is a waste product of the production process that is utilised as fuel in boilers to create steam for the cogeneration of electricity. Remaining sugarcane bagasse ash (SBA), which is typically utilised as fertiliser in sugarcane crops, is the end result of this burning. Ash is unique among agroindustrial wastes since it is produced by processes that generate energy. Several varieties of ash can be utilised as inert materials in civil construction even though they lack pozzolanic or hydraulic reactivity. The ash utilised in this study was gathered from four sugar mills in the São Carlos, SP, Brazil region—one of the biggest sugarcane producers in the world. Chemical characterisation, sieve analysis, specific gravity measurement, X-ray diffraction, scanning electron microscopy, and solubilisation and leaching tests were performed on the ash samples.

- **Mst. Shanjida Sultana et al(2013)** Some of the environmental issues and issues related to waste management can be satisfactorily resolved by using waste material. In this investigation, sugarcane waste and bagasse ash were calcined for two hours at temperatures of 4000, 6000, 8000, and 10000 degrees Celsius.These samples have undergone physical and chemical characterisation to assess their potential application in the materials and metallurgical industries. In order to determine the chemical composition of the samples and the presence of crystalline material, researchers have examined XRF analysis, XRD analysis, and physical property analysis. An elemental analyser has determined the carbon content.
- **Joan Manuel Rodríguez-Díaz et al(2015),** The purpose of this study is to fully characterise the ashes produced by burning bagasse at two distinct sugarcane ethanol plants: SBA1 in the Brazilian state of Pernambuco and SBA2 in Villa Clara, Cuba. The ashes are then used as adsorbing agents to remove various organic impurities and heavy metals. The chemical makeup of the ash samples as well as any structural characteristics that would facilitate their utilisation were examined. The chemical characterisation was carried out thermally using thermogravimetric and differential thermal analysis, and spectrally using Fourier transform infrared spectroscopy, X-ray fluorescence and diffraction analysis, and so on. Scanning electron microscopy, helium pycnometry, and N2-physisorption were used to characterise the structure and surface. Every analysis's findings were contrasted with those of known or possible adsorbent materials. The two ashes are comparable structurally, with varied morphologies, uneven surfaces, and a high concentration of superficial polar groups (hydroxyl, carboxyl, and carbonyl).
- **S. Deepika, G. Anand et al (2017),** An industrial by- product produced in significant amounts by the sugar industry via the cogeneration process is sugarcane bagasse ash (SCBA). Typically, landfills are used for its disposal. In India and other developing nations, the usage of cogeneration plants has led to a large rise in the amount of ash created and disposed of. Additionally, the dumping of bagasse ash from sugarcane reduces the amount of useful land and pollutes the environment. Numerous past investigations have documented the exceptional pozzolanic properties of sugarcane bagasse ash in concrete. The performance evaluation of sugarcane bagasse ash as a component of unburned bricks, paver blocks, and alkali-activated concrete is the main emphasis of this work.

II. METHEDOLOGY

3.1 Materials

3.1.1 Sugarcane bagasse ash

The cogeneration boilers of sugar factories run on bagasse from sugarcane. Following the bagasse's burning, the leftover ash is gathered as a byproduct using a bag-house filter and dumped on the closest piece of land. In order to eliminate the evaporable water content, bagasse ash was collected for this investigation from a sugar mill in Salem, India, and then dried at 105–110ºC for a whole day. To achieve improved reactive materials, the dried bagasse ash was further sieved using a 300 µm sieve in order to eliminate large unburnt fibrous fractions. The production of blended concrete, bricks, interlocking paver blocks, alkali-activated binder, and the research of the effects of curing with an ideal proportion of waste marble were all done using sieved SCBA.

Table No. 3.1: Physical attributes of raw and sieved bagasse ash

Physical Characteristics	Raw SCBA	Sieved SCBA	Relevant standard
Specific Gravity	1.96	2.16	IS 1727-2004
Specific Surface area (Blaine, m2/kg)	142	296	IS 1727-2004
Soundness, expansion (mm)	3.8	1.36	IS 4031-Part 3-2005
Consistency (%)	50	40	IS 4031-Part 4-2005
Initial setting time (min)	198	192	IS 4031-Part 5-2005
Final setting time (min)	340	300	IS 4031-Part 5-2005

3.2.2 Marble waste

In this experimental study, the waste marble is utilised in part place of both river and crusher sand. The physical attributes of waste marble were discovered in accordance with the guidelines established by Indian Standard IS 383-2016.

Cinque percentiles had a size of less than 75 µm. The unit weight, specific gravity, and water absorption of marble waste are 1.58 g/cc, 2.58, and 0.8%, respectively.

3.2 Test of Strength Activity Index

The strength activity test was used to assess the pozzolanic activity of bagasse ash in accordance with ASTM C311-11b. Six control mortar specimens were poured in accordance with the guidelines. Additionally, six specimens with a 20% mass replacement of SCBA in cement were cast for both raw and sieved bagasse ash independently. After a day, the specimens were demolded and allowed to cure in the saturated lime water. After seven and twenty-eight days of curing, the specimens' compressive strength was measured. The strength activity index was computed as the percentage difference between the mortar specimens made with a blend of bagasse and ash and the mortar specimens used as a control.

3.3 Compressive Strength

Five mixes were cast with marble waste as a replacement for fine aggregate at varying amounts (0%, 25%, 50%, 75%, and 100%) in order to find the ideal percentage of marble waste. Furthermore, in order to compare with marble waste, a mix that contained only crusher sand—also referred to as manufacturing sand because it is produced by crushing rock to a size comparable to river sand—was cast. After seven and twenty- eight days of curing, the compressive strength of six concrete cube specimens, each measuring 100 mm, was ascertained. Furthermore, previous studies found that a 20% substitution of bagasse ash for cement was the ideal level.Combined in varying amounts.

Table No. 3.2:
Combine concrete and paver specimen details

Mix ID	OPC	SCBA (B) (%)	Marble Waste (M) (%)	River Sand (R) (%)
B0M0R	100	0	0	100
B0M25R	100	0	25	75
B10M25R	90	10	25	75
B20M25R	80	20	25	75
B30M25R	70	30	25	75

III. RESULTS AND DISCUSSIONS

4.1 Strength activity Index test

The findings of the determination of the strength activity index for the sieved and raw bagasse ash mixed mortar specimens. According to the test results, the mortar specimens containing sieved bagasse ash had a strength activity index of 78% at 28 days, which was more than the specimens of raw bagasse blended mortar. After 7 and 28 days of curing, respectively, the strength activity index of the mortar specimens containing raw bagasse ash was 66% and 71%.

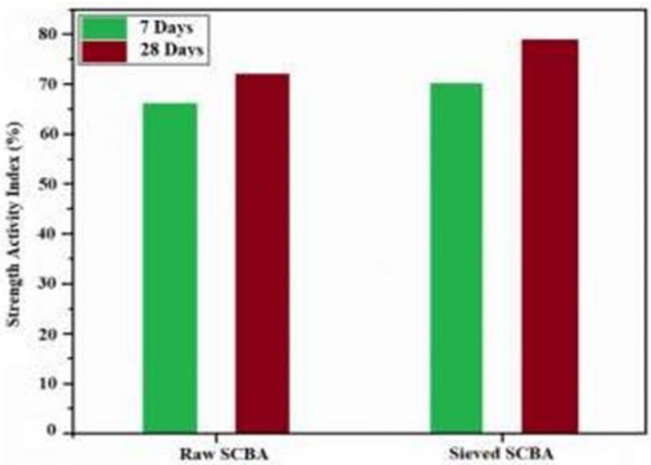

Figure No. 4.1: Mortar specimen's strength activity index after seven and twenty-eight days of curing

Strength activity index of raw bagasse ash after 7 days and 28 days of curing was found to be below the minimum requirement of 75% to be classified as pozzolanic materials as per ASTM C618-12a, despite compressive strength increasing from 7 days to 28 days of curing due to additional pozzolanic reaction of bagasse ash in both cases (raw bagasse ash and sieved bagasse ash).

4.2 Marble waste's effect on compressive strength

The ideal amount of natural river sand replacement with marble waste was found by analysing the compressive strengths of control concrete specimens and specimens with four different replacement levels (25, 50, 75, and 100%). Three concrete specimens were tested for each replacement level in accordance with IS 516-2004, and the average was used to calculate the compressive strength. After 7 and 28 days, respectively, it was discovered that the compressive strength of concrete specimens with a 25% level of replacement marble waste had risen by 4.08% and 2.75% in comparison to the control concrete. This slight increase in compressive strength could be the result of the system's higher packing density with the leftover marble. Comparing the marble waste replacement level of 50% with river sand, there was only a slight decrease in compressive strength when compared to the control specimens.

4.3 Characteristics of SCBA-MW blended concrete

After 28 and 56 days of curing, the compressive strengths of the five mixes—B0M0R (Control), B0M25R (only 25% MW), B10M25R (25% MW and 10% SCBA), B20M25R (25% MW and 20% SCBA), and B30M25R (25% MW and 30% SCBA)—
were assessed.

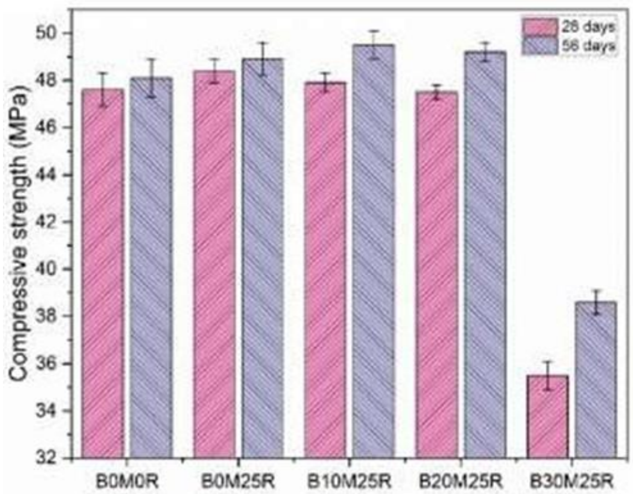

Figure No. 4.2: Compressive strength fluctuation

IV. CONCLUSION

This study included a thorough performance assessment of concrete combined with river sand , bagasse ash and marble waste. The particular conclusions that follow are as follows:

- The pozzolanic reactivity of raw bagasse ash was found to be lower than the normal minimum requirement of 75%, meaning that it is not suitable for direct usage as an additional cementitious material. However, compared to raw bagasse ash, sieved bagasse ash (via a 300µm sieve) used in this study showed increased pozzolanic activity and met the statutory minimum criterion of 75%.

- Concrete's compressive strength was equivalent when marble debris was substituted for fine aggregate up to a 75% replacement level. Nevertheless, a decrease in the level of workability was noted when the replacement of marble waste exceeded 25%. Hence, it is recommended that marble waste be used to substitute fine aggregate to an extent of 25% without sacrificing workability or strength.
- In comparison to control concrete and concrete specimens made solely of marble waste, sieved bagasse ash blended concrete exhibits a compressive strength increase of up to 20% cement replacement level with SCBA.
- According to the sorptivity index, the pozzolanic reaction of SCBA at a later age results in a notable improvement in the durability performance of sieved SCBA and MW blended concrete paver specimens against water penetration.

REFERENCES

1. Katare, V. D., & Madurwar, M. V. (2017). Experimental characterization of sugarcane biomass ash–A review. *Construction and Building Materials*, *152*, 1-15.
2. Sales, A., & Lima, S. A. (2010). Use of Brazilian sugarcane bagasse ash in concrete as sand replacement. *Waste management, 30*(6), 1114-1122.
3. Sultana, M. S., & Rahman, M. A. (2013). Characterization of calcined sugarcane bagasse ash and sugarcane waste ash for industrial use. In *International conference on Mechanical and Material Engineering (ICMIME2013)* (pp. 1-3). Bangladesh: RUET Rajashahi.
4. Rodríguez-Díaz, J. M., García, J. O. P., Sánchez, L. R. B., da Silva, M. G. C., da Silva, V. L., & Arteaga-Pérez, L. E. (2015). Comprehensive characterization of sugarcane bagasse ash for its use as an adsorbent. *Bioenergy Research, 8*, 1885-1895.
5. Deepika, S., Anand, G., Bahurudeen, A., & Santhanam, M. (2017). Construction products with sugarcane bagasse ash binder. *Journal of Materials in Civil Engineering, 29*(10), 04017189.
6. Payá, J., Monzó, J., Borrachero, M. V., Díaz-Pinzón, L., & Ordonez, L. M. (2002). Sugar-cane bagasse ash (SCBA): studies on its properties for reusing in concrete production. *Journal of Chemical Technology & Biotechnology: International Research in Process, Environmental & Clean Technology*, *77*(3), 321-325.
7. Teixeira, S. R., De Souza, A. E., de Almeida Santos, G. T., Vilche Peña, A. F., & Miguel, A. G. (2008). Sugarcane bagasse ash as a potential quartz replacement in red ceramic. *Journal of the American Ceramic Society, 91*(6), 1883-1887.
8. Souza, A. E., Teixeira, S. R., Santos, G. T. A., Costa, F. B., & Longo, E. (2011). Reuse of sugarcane bagasse ash (SCBA) to produce ceramic materials. *Journal of Environmental Management, 92*(10), 2774-2780.
9. VERMA, S., LAMBA, A., AGRAWAL, S., BIRBAL, P., & RAO, E. (2025).

PRESENT SCENARIO AND CHALLENGES OF SMALL HYDRO POWER DAM IN INDIA. A REVIEW. LARHYSS Journal P-ISSN 1112-3680/E-ISSN 2521-9782, (61), 287-320.

10. Grau, F., Choo, H., Hu, J. W., & Jung, J. (2015). Engineering behavior and characteristics of wood ash and sugarcane bagasse ash. *Materials*, *8*(10), 6962-6977.
11. Stem, A. D., Rogers, K. L., Roede, J. R., Roncal-Jimenez, C. A., Johnson, R. J., & Brown, J. M. (2023). Sugarcane ash and sugarcane ash-derived silica nanoparticles alter cellular metabolism in human proximal tubular kidney cells. *Environmental Pollution*, *332*, 121951