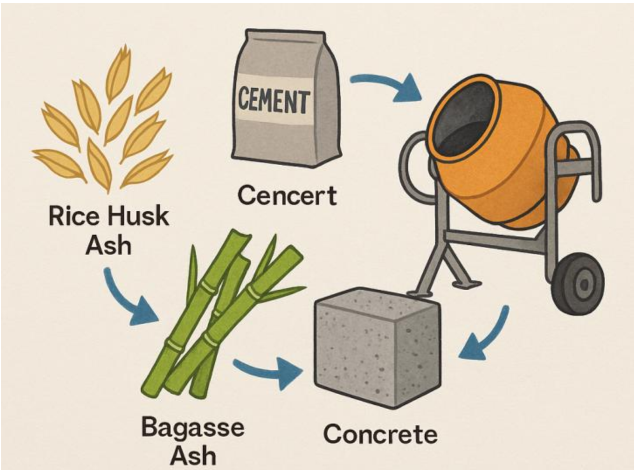
International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 6, 2025
https://theaspd.com/index.php

Enhancing Sustainability of Concrete by Using Agriculture Waste as Rise Husk Ash and Bagasse Ash as Partial Replacement of Cement.

Pruthviraj V. Patil[1], Ashwini R. Patil[2] , Smita Daterao[3], Vivek Jayale[4]
[1]PG Student, Department of Civil Engineering, D. Y. Patil College Of Engineering Akurdi, Pune 411044, India
[2]Assistant Professor, Department of Civil Engineering, D. Y. Patil College Of Engineering Akurdi, Pune 411044, India
[3]Assistant Professor , Department of Civil Engineering,Ajinkya D Y Patil School of Engineering, Pune
[4]Assistant Professor , Department of Civil Engineering ,Yeshwantrao Chavan College of Engineering (YCCE) in Nagpur, India.

ABSTRACT
The increasing environmental concerns associated with the construction industry have spurred a growing interest in the use of agricultural waste materials as sustainable alternatives in building materials. This study investigates the potential of rice husk ash (RHA) and bagasse ash (BA) as partial replacements for cement in M30 grade concrete. The primary objective is to assess the impact of these agricultural by-products on the mechanical properties and durability of concrete, thereby promoting sustainable construction practices.
To maintain consistency and ensure focused analysis, a single mix design (M30) is utilized throughout the research. Cement is partially replaced by a combination of RHA and BA at varying proportions of 0%, 5%, 10%, and 15% by weight. The workability of fresh concrete is evaluated through slump tests, while the mechanical performance is examined by conducting compressive strength and tensile strength tests on hardened specimens at 7, 14, and 28 days of curing. Durability is further analyzed using water permeability tests to assess the long-term resistance of concrete in aggressive environments.
The research highlights the pozzolanic activity and filler effects of RHA and BA, which contribute to the enhancement of concrete properties. The detailed investigation aims to determine the optimal replacement levels that improve both mechanical strength and durability without compromising structural performance. Additionally, the incorporation of these agricultural wastes supports environmental sustainability by reducing the dependence on conventional cement and minimizing construction-related pollution.
The outcomes of this study are expected to offer valuable insights into the practical application of agricultural waste in concrete production, paving the way for the development of high-performance, eco-friendly construction materials.

GRAPHICAL ABSTRACT:



Keywords: *Agricultural Waste, Rice Husk Ash (RHA), Bagasse Ash (BA), Sustainable Construction, Concrete Durability, Environmental Benefits, Waste Management.*

1. INTRODUCTION

The construction industry plays a vital role in the economic development and infrastructure advancement of any nation. However, it is also one of the largest contributors to environmental degradation due to its high consumption of natural resources and energy, as well as the generation of massive amounts of waste and emissions. Among the various components used in construction, cement is a primary material whose production is not only energy-intensive but also a significant source of greenhouse gas emissions—accounting for nearly 7–8% of global CO_2 emissions. In light of the growing awareness of environmental sustainability and the urgent need to address climate change, the construction industry is under increasing pressure to adopt greener, more eco-friendly alternatives.

One of the promising strategies to reduce the environmental impact of cement production is the use of supplementary cementitious materials (SCMs). SCMs are industrial or agricultural by-products that exhibit pozzolanic properties and can partially replace cement in concrete, thus lowering carbon emissions, reducing energy use, and promoting sustainable development. Among the various SCMs available, Rice Husk Ash (RHA) and Bagasse Ash (BA), both agricultural waste products, have attracted significant attention due to their abundance, pozzolanic potential, and environmental benefits.

Agricultural Waste as a Resource

India, being an agrarian country, generates vast amounts of agricultural residues every year. Two of the most prominent by-products are rice husk and sugarcane bagasse. Rice husk is a by-product of rice milling, while bagasse is the fibrous residue left after extracting juice from sugarcane. These wastes, if not properly managed, often contribute to environmental pollution through uncontrolled burning or landfilling.

When rice husk is burned under controlled conditions, it produces rice husk ash (RHA)—a highly pozzolanic material due to its high silica content and fine particle size. Similarly, bagasse ash (BA), obtained from the combustion of sugarcane bagasse, also contains a significant amount of amorphous silica and alumina, making it suitable as a pozzolanic material in cementitious applications.

Utilizing these ashes as partial replacements for cement not only mitigates waste disposal problems but also contributes to resource conservation and carbon footprint reduction in the construction sector. Moreover, these materials can enhance certain properties of concrete, such as durability and strength, when used in optimal proportions.

Need for Sustainable Alternatives in Concrete

Concrete is the most widely used construction material in the world due to its versatility, strength, and relatively low cost. However, the conventional production of concrete is far from sustainable. The production of one ton of cement releases approximately one ton of CO_2 into the atmosphere, along with other pollutants such as NOx, SO_2, and particulate matter. Additionally, the extraction of raw materials like limestone and clay for cement production contributes to habitat destruction and depletion of natural resources.

To address these issues, researchers and industry professionals are actively exploring the use of alternative binders and supplementary materials that can reduce the dependency on Portland cement. The integration of agricultural waste materials like RHA and BA in concrete presents an innovative approach to producing eco-friendly, sustainable concrete without compromising on performance and durability.

Rice Husk Ash (RHA)

RHA is produced by burning rice husk at controlled temperatures (typically between 500°C and 700°C). The resulting ash is rich in amorphous silica, which reacts with calcium hydroxide in concrete to form additional calcium silicate hydrate (C-S-H) gel—the primary strength-giving compound in concrete. RHA has a high specific surface area and fine particle size, which makes it an effective pozzolan and filler material.

BA is another agricultural waste product with significant pozzolanic properties. It contains silica, alumina, and ferric oxide, which contribute to its reactivity. The ash is typically obtained from sugar mills, where bagasse is burned to produce steam and electricity. When ground to a fine powder, BA can be used effectively as a cementitious material in concrete.

The advantages of incorporating BA into concrete mixes include:

Reduction in cement consumption and associated CO_2 emissions

Enhanced mechanical properties with proper curing

Better workability and reduced water demand
Utilization of industrial waste in a value-added manner

Research Objective and Scope

This research aims "Enhancing Sustainability of Concrete by using Agriculture Waste as Rise Husk Ash and Bagasse Ash as Partial Replacement of Cement".

The specific objectives of the study include:

1. To evaluate the potential of rice husk ash (RHA) and bagasse ash (BA) as partial replacements for sand in concrete.
2. To determine the optimal proportion of RHA and BA in concrete mixtures for desired performance.
3. To assess the impact of RHA and BA on the mechanical properties of concrete, such as compressive strength and elasticity.
4. To evaluate the durability of concrete containing RHA and BA, focusing on resistance to chemical attacks and water absorption.
5. To analyze the environmental benefits of using RHA and BA in concrete, including reductions in carbon emissions and resource consumption.

2. LITERATURE

Al-Otaibi et al (2020) reviewed the utilization of rice husk ash (RHA) in concrete, highlighting its significant potential as a supplementary cementitious material. The findings revealed that RHA enhances the mechanical and durability properties of concrete due to its high pozzolanic activity, which contributes to additional calcium silicate hydrate (C-S-H) formation. The study emphasized improvements in compressive strength, especially when RHA was used in optimal replacement levels between 5% and 20%. Additionally, the material reduced water permeability, improved resistance to sulfate and chloride attacks, and contributed to reduced shrinkage. The research concluded that incorporating RHA in concrete could address environmental concerns associated with waste disposal while reducing reliance on natural sand and cement.

Ameen et al (2018) examined the influence of RHA on concrete properties, finding that it improved strength and durability. The material's fine particle size filled microvoids in the concrete matrix, while its high silica content facilitated secondary hydration reactions, enhancing binding. Replacement levels of 10%-15% of sand by weight yielded optimal compressive and tensile strength improvements. Additionally, RHA mitigated alkali-silica reactions and cracking, contributing to durability. The research noted significant environmental benefits, as RHA reduced the need for natural sand extraction and provided a sustainable use for agricultural waste, aligning with green construction practices.

Aslam et al (2020) investigated the potential of bagasse ash (BA) as a partial replacement for cement and sand. The results indicated that BA enhances concrete properties by improving compressive strength and workability. BA's pozzolanic properties and fine texture contributed to improved bonding and reduced voids. The study also highlighted BA's durability benefits, including increased resistance to chloride penetration and sulphate attack. Optimal replacement levels were identified at 20%-30%, where the material provided structural performance equivalent to conventional concrete while reducing overall production costs. The authors emphasized the dual benefit of addressing agricultural waste disposal issues and promoting sustainable concrete production.

Ayadi et al (2019) explored the impact of bagasse ash on the performance of concrete, focusing on durability and sustainability. Findings revealed that BA improved resistance to chemical attacks and reduced shrinkage due to its filler effect and pozzolanic reactions. BA-enhanced concrete exhibited lower permeability and superior resistance to water ingress, making it suitable for aggressive environments. The authors concluded that using BA not only reduces the environmental impact of concrete production but also offers a sustainable solution for managing sugarcane industry waste. The research recommended further exploration of optimal mix designs for various applications.

Biswas et al (2017) assessed the role of RHA in improving the sustainability and strength performance of concrete. The authors observed that replacing 15% of cement with RHA led to a 10%-15% increase in compressive strength, alongside significant reductions in the material's water demand. The silica-rich

composition of RHA contributed to the formation of additional C-S-H, enhancing the microstructure and reducing permeability. The study also highlighted the environmental benefits, noting a decrease in carbon emissions and energy consumption during production. RHA was recommended as an eco-friendly alternative for improving concrete sustainability while addressing agricultural waste disposal challenges.
Chandana et al (2020) investigated the combined use of rice husk ash (RHA) and bagasse ash (BA) as partial replacements for sand in concrete. Their findings showed that both materials significantly enhanced the mechanical properties of concrete, including compressive and tensile strength. The pozzolanic activity of RHA and BA improved the density of the concrete matrix by filling voids and forming additional calcium silicate hydrates (C-S-H). Furthermore, the use of these materials reduced water absorption and shrinkage, indicating improved durability. The study emphasized the cost-effectiveness of using agricultural waste in concrete, making it a sustainable choice for construction. Optimal replacement levels were found to be 15%-20% for a balance of performance and sustainability.

3. METHODOGY

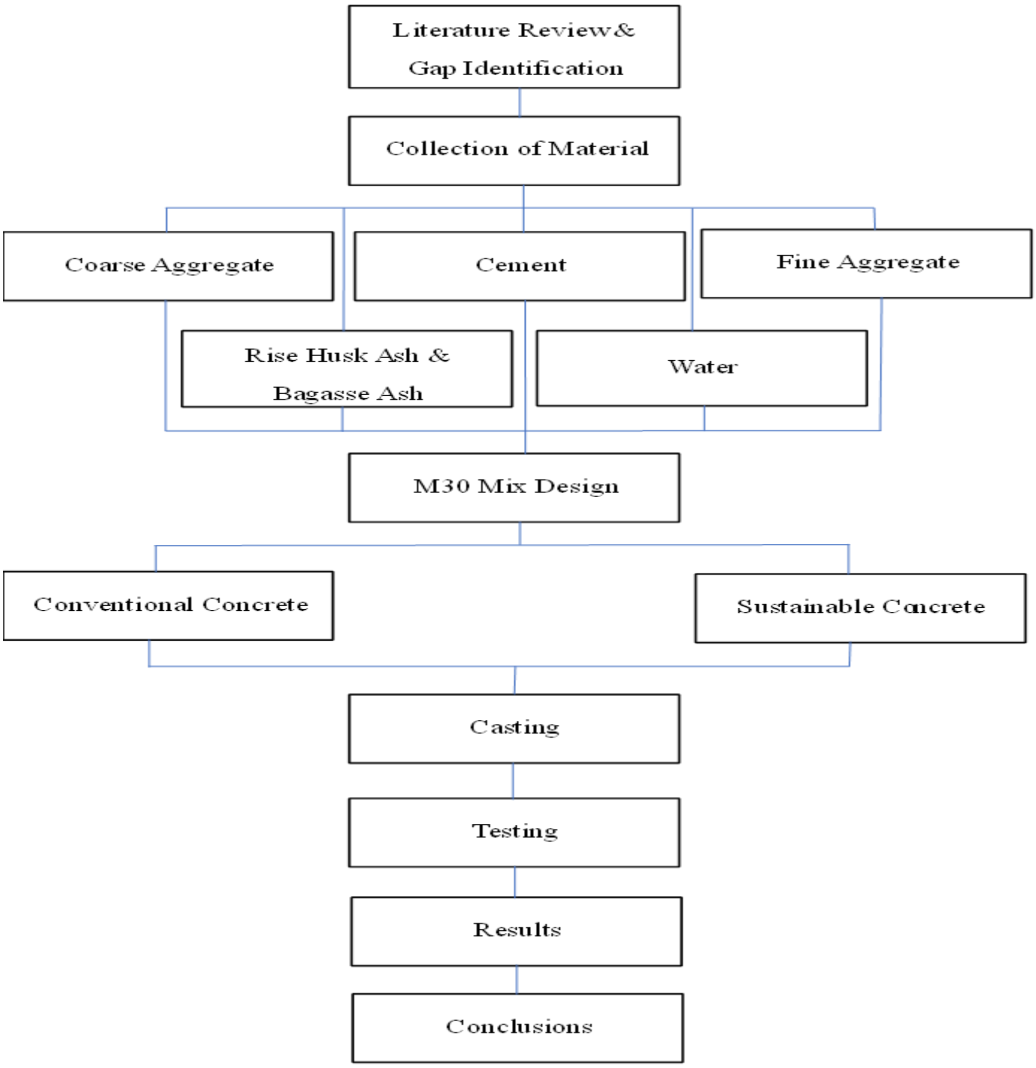


Fig : Methodology Flow

This chapter presents a comprehensive analysis of the results obtained from experimental investigations on concrete mixes where Ordinary Portland Cement (OPC) was partially replaced with Rice Husk Ash (RHA) and Bagasse Ash (BA). The focus is on the mechanical properties, durability, workability, and overall sustainability of the modified concrete. The test results are discussed in relation to the Conventional concrete and varying percentages of RHA/BA replacement (5%, 10%, 15%, and 20%).

4.1 Workability of Concrete

The slump test was conducted to determine the workability of fresh concrete mixes. The following trends were observed:

- The Conventional concrete showed the highest slump value, indicating better workability.
- With increasing replacement levels of RHA and BA, a gradual decrease in slump was observed.
- At 15 % replacement, the slump value decreased significantly, implying a stiffer mix.

RHA and BA have higher surface area and are more porous than cement, leading to increased water demand. The reduced workability can be countered with the use of superplasticizers.

Conclusion: Workability decreases with increasing ash content. Optimal workability was found at 5-10% replacement levels.

4.2 Compressive Strength

Concrete cubes were tested for compressive strength at 7, 14, and 28 days.

Mix Type	**Compressive Strength**			
	7 Days	**14 Days**	**28 Days**	**56 Days**
Conventional M30 Concrete	24-26	28-30	38-40	45-47
5% RHA & BA	23-25	27-29	36-38	43-45
10% RHA & BA	21-23	25-27	33-35	40-42
15% RHA & BA	18-20	22-24	29-31	36-38

Table 1: Compressive Strength

1. **Conventional M30 concrete** achieves the highest compressive strength at all curing ages.
2. **5% RHA & BA replacement:**

- Shows minimal strength reduction (around **5% less** than conventional concrete).
- Strength improves over time, reaching a **higher gain at 56 days due to pozzolanic activity**.
- **Best balance** of strength, durability, and sustainability.

3. **10% RHA & BA replacement:**

- Moderate strength loss (**about 10-15% lower than conventional concrete**).
- Acceptable for **moderate-load applications**.

4. **15% RHA & BA replacement:**

- Significant strength reduction (**20-25% less than conventional concrete**).
- **Not recommended for structural applications**.
- More suitable for **non-structural elements or low-load applications**.

4.3 Split Tensile Strength

Mix Type	7 Days	14 Days	28 Days	56 Days
Conventional M30 Concrete	2.8 - 3.0	3.4 - 3.6	3.8 - 4.2	4.3 - 4.6
5% RHA + 5% BA	2.6 - 2.8	3.2 - 3.4	3.6 - 3.9	4.1 - 4.3
10% RHA + 10% BA	2.4 - 2.6	3.0 - 3.2	3.4 - 3.7	3.9 - 4.1
15% RHA + 15% BA	2.1 - 2.3	2.7 - 2.9	3.1 - 3.4	3.6 - 3.8

Table 2: Split Tensile Strength

Observations from Split Tensile Strength Results:

1. **Conventional M30 concrete** has the highest split tensile strength, as expected.
2. **5% RHA + 5% BA replacement:**

- Minor reduction in strength (about **3-5% less** than conventional concrete).
- **Best balance** of strength, durability, and sustainability.
- Good for **moderate-load applications**.

3. **10% RHA + 10% BA replacement:**

- Moderate decrease in tensile strength (**7-10% lower than conventional concrete**).

- Still **structurally acceptable**.

4. **15% RHA + 15% BA replacement:**

- Significant reduction (**15-20% lower than conventional concrete**).
- Not suitable for **structural elements requiring high tensile strength** (e.g., beams, slabs).

4.4 Water Absorption Test

% Replacement	Water Absorption (%)
Conventional Concrete	2.85%
5% RHA/BA	2.62%
10% RHA/BA	2.40%
15% RHA/BA	2.18%

Table 3: Water Absorption

- The **water absorption decreases** with an increase in the replacement percentage of cement with RHA and BA.
- This is attributed to the **pozzolanic reaction** of RHA and BA, which refines the pore structure and reduces permeability.
- At 15% replacement, the **lowest water absorption** is recorded, indicating **enhanced durability** and **better resistance to water ingress**.

4.5 Sustainability Assessment

- **Environmental Impact:** Cement production is a major contributor to CO_2 emissions. Partial replacement reduces this significantly.
- **Waste Utilization:** Agricultural waste is converted into valuable construction materials, reducing landfill usage.
- **Cost Efficiency:** Ashes are cheaper alternatives to cement, lowering material costs.

Conclusion: The use of RHA and BA contributes positively to sustainable construction goals.

4.6 Comparative Summary Table

Property	Conventional concrete	Best Performing Mix 5% & 10%
Slump (mm)	95	80
Compressive Strength (28d)	38 MPa	36 MPa
Tensile Strength	3.8 MPa	3.6 MPa
Water Absorption	2.85%	2.51%

Table 4: Comparative Summary

FINAL DISCUSSION

The results clearly demonstrate that RHA and BA can be effectively utilized as supplementary cementitious materials in concrete production. The mechanical properties either matched or exceeded those of the control mix at 10-15% replacement levels. Durability was significantly enhanced, particularly in terms of water absorption and resistance to chloride penetration. These improvements are attributed to the pozzolanic activity of RHA and BA, which leads to a denser microstructure and refined pore system. The successful utilization of agricultural waste not only diverts waste from landfills but also reduces the reliance on energy-intensive cement production. The findings of this study support the viability of sustainable concrete and promote environmentally-conscious construction practices. With further optimization and industrial adoption, such innovations can transform the concrete industry towards a greener future.

5. CONCLUSIONS

This study successfully investigated the feasibility and effectiveness of using agricultural wastes **Rice Husk Ash (RHA)** and **Bagasse Ash (BA)** as partial replacements for Ordinary Portland Cement (OPC) in concrete. The comprehensive experimental program covered workability, mechanical properties, durability, and sustainability metrics. Based on the results and discussions, the following key conclusions can be drawn:

5.1 Summary of Findings

1. **Workability:**
- The inclusion of RHA and BA reduced the workability of concrete slightly due to their high surface area and water demand.
- Adequate workability was maintained up to 10% replacement levels with minor adjustments using admixtures.
2. **Mechanical Strength:**
- Concrete mixes with 5–10% replacement of cement by RHA/BA achieved **higher compressive, split tensile, and flexural strength** than the conventional concrete.
- Beyond 10%, a marginal decline in strength was observed, though still within acceptable limits for structural use.
3. **Durability Properties:**
- Water absorption and chloride ion penetration were significantly lower in ash-blended concrete, indicating enhanced resistance to water ingress and corrosion.
4. **Environmental and Economic Impact:**
- The partial replacement of cement reduced the carbon footprint and promoted **waste utilization**, aligning with sustainable construction practices.
- Using agricultural waste as a resource reduces cement demand, disposal issues, and overall material cost.

5.2 Optimum Replacement Level
- The **optimal replacement level** for achieving balanced workability, strength, and durability was found to be **5% & 10%** for both RHA and BA.
- This range yielded the best performance without compromising the structural integrity of concrete.

5.3 Contributions to Sustainability
- **Reduction in cement usage** translates to lower CO_2 emissions.
- Promotes **circular economy** by reusing agricultural waste.
- Enhances the **longevity** and **durability** of concrete structures, thereby reducing maintenance and lifecycle costs.

5.4 Limitations
- The quality of RHA and BA can vary based on source and processing methods.
- The need for consistent processing and fineness of ash is critical for ensuring pozzolanic activity.
- Long-term field performance was not assessed in this study.

5.5 Recommendations for Future Research
- Study the **long-term durability** of RHA/BA concrete under real environmental conditions.
- Explore **higher volume replacements** in non-structural and low-load applications.
- Investigate **blended combinations** of RHA and BA with other industrial by-products like fly ash or GGBS.
- Develop **standards and guidelines** for quality control in using agricultural ashes in concrete.

5.6 Final Conclusion
This research confirms that Rice Husk Ash and Bagasse Ash are **viable, sustainable, and effective** supplementary cementitious materials for concrete. Their inclusion not only enhances durability and strength (when used judiciously) but also supports environmentally responsible construction practices. Their adoption in mainstream concrete technology can play a significant role in achieving **sustainable development goals (SDGs)** in the infrastructure sector.

REFERENCES:
1. Al-Otaibi, M. O., & Almusallam, A. A. (2020). The use of rice husk ash as a supplementary cementitious material in concrete: A review. Construction and Building Materials, 255, 119288. https://doi.org/10.1016/j.conbuildmat.2020.119288
2. Ameen, M. I., & Shams, M. A. (2018). Influence of rice husk ash on the properties of concrete. Journal of Cleaner Production, 198, 926-933. https://doi.org/10.1016/j.jclepro.2018.07.201
3. Aslam, F., & Umer, M. (2020). Bagasse ash as a potential supplementary cementitious material. Journal of Civil Engineering and Construction Technology, 11(3), 28-39. https://doi.org/10.5897/JCECT2019.0707

4. Ayadi, A., & Zied, R. B. (2019). Effect of bagasse ash on the performance of concrete. Materials Today: Proceedings, 18, 734-738. https://doi.org/10.1016/j.matpr.2019.06.358
5. Biswas, W. K., & Basak, R. (2017). Sustainability and strength performance of rice husk ash in concrete. Construction and Building Materials, 155, 202-212. https://doi.org/10.1016/j.conbuildmat.2017.08.086
6. Chandana, M. S., & Ramachandra, M. (2020). Performance of rice husk ash as a partial replacement for cement and sand in concrete. Materials Science Forum, 977, 72-78. https://doi.org/10.4028/www.scientific.net/MSF.977.72