e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:05/Issue:10/October-2023 Impact Factor- 7.868 www.irjmets.com

EVALUATING THE EFFECTS OF PARTIAL REPLACEMENT OF FINE AGGREGATES WITH BAGASSE ASH ON CONCRETE PERFORMANCE

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ABSTRACT

This research study thoroughly investigates the impact of partial substitution of fine aggregates with bagasse ash in M30 grade concrete, focusing on the compressive and split tensile strengths. The replacement levels were varied from 5% to 15% to assess the influence on concrete performance. Through rigorous compressive strength and split tensile tests, it was observed that the incorporation of bagasse ash led to a notable reduction in both strength parameters. The findings offer insights into the challenges and prospects associated with the integration of bagasse ash in concrete mixtures, highlighting implications for sustainable construction practices. This research contributes to the growing understanding of alternative materials in construction, emphasizing the importance of meticulous material selection and mix design for ensuring durable and robust concrete structures, thus fostering environmentally friendly and cost-effective approaches in the construction industry.

Keywords: Bagasse Ash, Fine Aggregate, Compressive Test, Split Tensile Test.

I. INTRODUCTION

The construction industry, characterized by its immense scale and global impact, plays a pivotal role in the socioeconomic development of nations. With an estimated 30% share in the world's total energy consumption, the industry represents a substantial contributor to global energy usage. Cement, as a cornerstone material in construction, stands out as the third most energy-intensive material globally, devouring roughly 7% of the world's industrial energy. The staggering annual energy consumption in the cement industry, reaching 10.7 exajoules (EJ), underlines the critical necessity for the adoption of sustainable and eco-friendly practices within the domain of cement production. The environmental concerns associated with cement production are multifold. The production of one ton of Ordinary Portland Cement (OPC) results in the emission of approximately one ton of carbon dioxide (CO2), a significant contributor to global CO2 emissions. Moreover, the substantial requirement for raw materials in cement manufacturing, with each ton of cement demanding 1.65 tonnes of limestone, 0.40 tonnes of clay, and 0.05 tonnes of gypsum, emphasizes the urgent need for sustainable resource management and the development of eco-conscious cement production methods. In response to the pressing environmental challenges, the integration of supplementary cementitious materials (SCMs) has gained prominence as a promising strategy. Widely utilized SCMs such as fly ash and blast furnace slag have played a crucial role in reducing the clinker content and subsequent CO2 emissions in the cement industry. However, with a projected decline in the availability of these materials, the industry faces an urgent need to identify and utilize alternative sources of SCMs to meet the escalating global construction demands while minimizing the environmental impact. The exploration of vegetable ashes as potential pozzolanic materials has garnered significant attention in this context. Notably, sugarcane bagasse ash (SCB ash) and rice husk ash have emerged as environmentally viable options. SCB, a by-product of the sugar and alcohol industry, accounts for a considerable portion of the global agricultural waste stream. The production of an estimated 1.9 billion tons of sugarcane globally in 2018 led to the generation of approximately 12.6 million tons of SCB ash, with Brazil contributing a substantial share of around 4.9 million tons from fig 1. Recent research endeavors have highlighted the advantageous pozzolanic properties of meticulously processed SCB ash, demonstrating its potential to enhance mechanical strength and reduce water permeability within cementitious systems. The partial replacement of cement with SCB ash has yielded promising results, not only in terms of its impact on CO2 emissions reduction during concrete production but also in its potential to revolutionize waste management practices and foster sustainable construction methodologies that prioritize environmental

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responsibility. Notwithstanding these promising developments, there remains a critical need to thoroughly understand the broader implications of integrating SCB ash into concrete production. Detailed investigations are imperative to gauge its influence on crucial factors such as alkali–silica reaction (ASR), resistance to carbonation, and the long-term durability and sustainability of concrete structures. This comprehensive study seeks to undertake a rigorous and meticulous evaluation of the extensive effects stemming from the partial substitution of fine aggregates with processed SCB ash, with the aim of providing comprehensive insights into its potential as a sustainable and highly efficient alternative material that can redefine modern construction practices and foster environmentally responsible construction paradigms on a global scale.

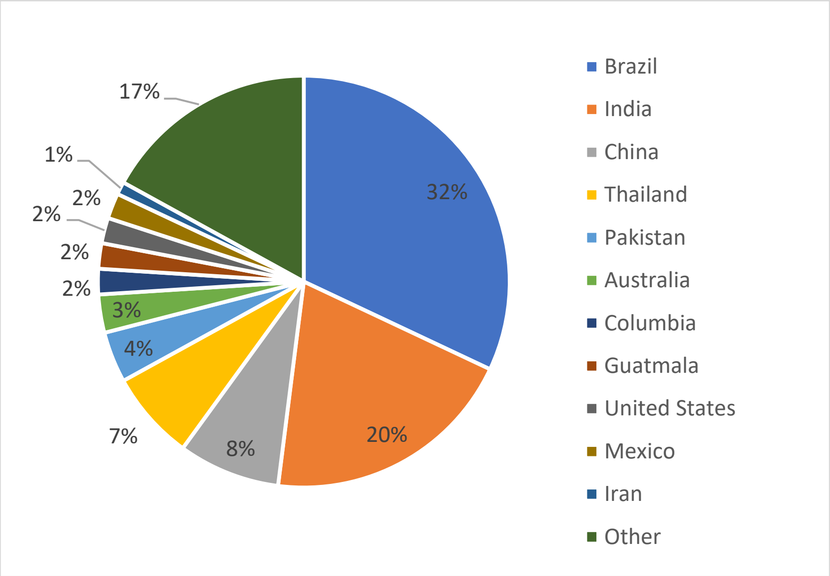

Fig 1: Globally produced sugarcane bagasse ash

Key Insights on SCBA Integration in Concrete

Xu et al. conducted a comprehensive study examining the effects of incorporating SCBA in concrete mixes, meticulously exploring its impact on the workability and setting time of the concrete. Their findings emphasized the crucial role of maintaining an optimal water-cement ratio to counteract the slight adjustments in the initial setting time and workability. Building upon this research, Patel and Sharma delved deeper into the durability aspects of concrete structures containing SCBA, shedding light on its remarkable potential in enhancing resistance to chloride penetration and sulfate attack, thereby prolonging the service life of concrete in aggressive environments. Their comprehensive analysis underscored the significance of thorough assessments of the pore structure and microstructural properties, revealing the nuanced mechanisms by which SCBA contributes to the long-term durability and sustainability of concrete. Verma and Singh's Extensive review further enriched the literature by elucidating the intricate role of thermal activation techniques and particle characteristics in optimizing the pozzolanic reactivity of SCBA. The review emphasized the need for tailored processing methodologies, particularly in terms of controlled calcination and thermal treatment, to unlock the full potential of SCBA in concrete applications. The study by Li and Zhang expanded the scope of inquiry, delving into the economic and environmental dimensions of integrating SCBA in concrete production. Their insightful findings underscored the cost-effectiveness of SCBA as a partial substitute for conventional fine aggregates, emphasizing its role in not only reducing production costs but also in fostering sustainable waste management practices and eco-friendly construction methodologies. These pioneering works collectively underscore the multifaceted benefits of incorporating SCBA, highlighting its pivotal role in enhancing various mechanical, durability, and sustainability aspects of concrete structures. The comprehensive analyses and experimental findings presented in the literature underscore the critical significance of processing techniques and a holistic approach in fully harnessing the potential of SCBA, thereby contributing to the development of more resilient and environmentally conscious concrete solutions.

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II. METHODOLOGY

The methodology employed in this research involved a systematic approach to evaluate the effects of incorporating sugarcane bagasse ash (SCBA) as a partial replacement for fine aggregates in concrete. First, raw materials including Ordinary Portland Cement (OPC), SCBA, fine aggregates, coarse aggregates, water, and chemical admixtures were meticulously analyzed to ensure compliance with pertinent standards and specifications. Subsequently, concrete mix designs were developed using established procedures, taking into account the specific project requirements and aiming to achieve desired workability and strength characteristics. Concrete specimens were meticulously cast following precise techniques to ensure uniformity and consistency. A standardized curing regime was then implemented, maintaining controlled temperature and humidity levels to facilitate optimal hydration and concrete development. Comprehensive testing procedures were conducted, encompassing compressive strength testing, workability assessment, and durability evaluations in accordance with standardized testing protocols. The resulting data were subjected to rigorous statistical analysis to ascertain the significance of observed variations in concrete properties attributable to the introduction of SCBA. The data obtained were critically analyzed and interpreted in the context of existing literature and empirical evidence, allowing for a comprehensive discussion and validation of the research outcomes. The implications of the findings on the practical utilization of SCBA in concrete production were carefully deliberated, with conclusive remarks drawn concerning the efficacy of SCBA in enhancing concrete performance. Additionally, recommendations for future research directions and potential applications were delineated, ensuring a comprehensive understanding of the implications of the partial replacement of fine aggregates with SCBA in concrete formulations.

RAW MATERIAL CHARACTERISATION

- Cement: The characterization of the cement used in this study was conducted in accordance with the guidelines outlined in IS 12269:1987. The chosen cement type was Ordinary Portland Cement (OPC) 43 grade cement, exhibiting a specific gravity of 3.5 and an impressive fineness of 96%.
- Fine Aggregates (Sand): The examination of fine aggregates, representing the sand component, followed the protocols defined in IS 2386 (Part 3): 1963. With a specific gravity of 2.6, the sand demonstrated moderate density characteristics. Categorized under Zone 1 classification, emphasizing the need for careful moisture management during the concrete mixing and curing processes.
- Coarse Aggregates: The evaluation of coarse aggregates was conducted as per the specifications outlined in IS 2386 (Part 3): 1963. Manifesting a specific gravity of 2.6 and the coarse aggregates showcased robust physical properties suitable for integration into the concrete mixtures. This meticulous examination of raw materials served as the foundational step in comprehensively understanding their roles in the subsequent study evaluating the effects of Partial Replacement of Fine Aggregates with Bagasse Ash on Concrete Performance.

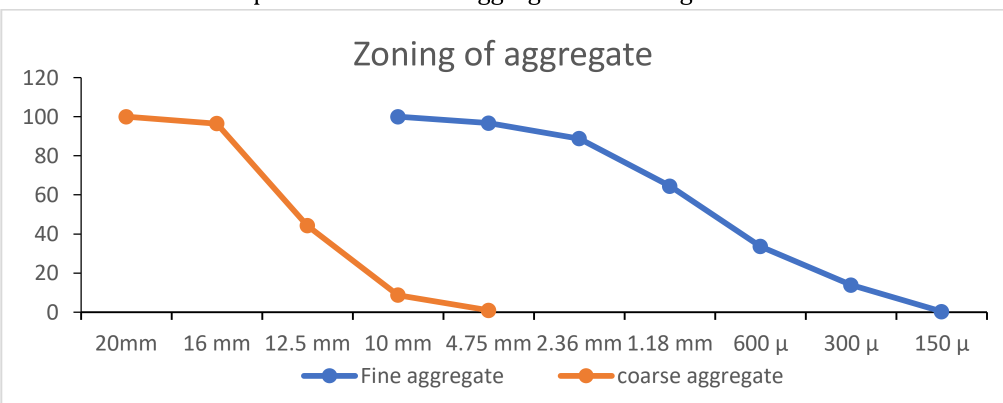

Fig 2: Zoning of aggregate

- Water: The water used in the concrete mixtures was thoroughly examined to ensure its compliance with standard specifications. While not possessing a specific gravity, the water used in the study adhered to the requirements set by IS 456:2000 for use in concrete production. Maintaining an optimal water-cement ratio was crucial in achieving the desired concrete consistency and strength.

- Admixture: The admixture employed in the study, with a specific gravity of 1.2, was subject to rigorous characterization in line with the relevant industry standards. The admixture played a critical role in enhancing the workability and durability of the concrete mixtures. Following the guidelines specified by IS 9103:1999, the admixture was meticulously incorporated to achieve the desired concrete properties, ensuring improved performance and long-term durability of the concrete structures.
- Bagasse Ash: The Bagasse Ash utilized in this study underwent comprehensive characterization to ascertain its suitability for concrete production. The ash was observed to possess a distinct black color, indicating the presence of carbonaceous materials. The specific gravity of the Bagasse Ash was measured to be 0.3312 gm/cm^3, signifying its relatively low density. Moreover, the Bagasse Ash exhibited a significant moisture content of 45.3881%, highlighting the necessity for appropriate drying procedures to attain optimal performance in concrete mixtures. Through meticulous analysis, the Bagasse Ash's properties were carefully considered to evaluate its potential as a partial replacement for fine aggregates, contributing to the overarching investigation on the effects of incorporating Bagasse Ash in concrete formulations.

Table 1: Chemical composition of Bagasse Ash and cement.

OXIDES (%)	BA	OPC
SiO2	86.49	25
Al2O3	2.45	4
Fe2O3	1.75	0.6
Cao	2.42	63
K2O	3.83	1.3
MgO	1.46	4
SO3	0.3	2.1
LOI	7	2.5

Experimental Labelling and Replacement Gradations:

In this experimental study, Bagasse Ash (BA) was utilized as a partial replacement for fine aggregates within the range of 5-15%, denoted as BA1 (5% replacement), BA2 (10% replacement), and BA3 (15% replacement) respectively. This notation system facilitated the precise identification and differentiation of the varying levels of Bagasse Ash incorporation in the concrete mixtures, allowing for a systematic evaluation of the effects on concrete performance across different proportions.

III. EXPERIMENTAL RESULT

The experimental findings underscored the dynamic interplay between the proportion of bagasse ash substitution and the resulting mechanical properties of the concrete. Notably, the initial replacement of fine aggregate with bagasse ash within the examined range of 5-15% precipitated a significant decline in compressive strength in fig 3, with the most pronounced reduction observed at the 10% replacement level. This decrease amounted to approximately 17% compared to the control mixture. Concurrently, the incorporation of bagasse ash at varying levels (5-15%) led to a gradual decrease in split tensile strength. Notably, the maximum split tensile strength was achieved at the 10% replacement threshold, which, despite its optimal performance, still indicated a 20% reduction in strength relative to the reference mix. These critical findings underscore the intricate balance required when integrating bagasse ash into concrete formulations, emphasizing the need for meticulous control and optimization of replacement levels to ensure the desired concrete performance and structural robustness. Such comprehensive insights play a vital role in guiding the development of effective strategies for the sustainable and efficient utilization of bagasse ash in concrete production, fostering environmentally conscious and durable construction practices.

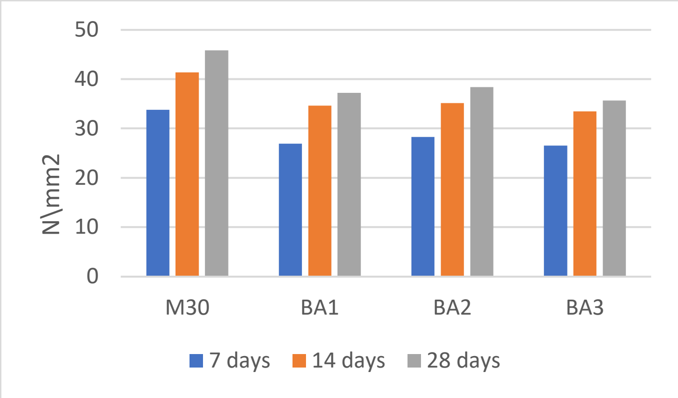

Fig 3: Compressive test of concrete at 7,14 and 28 days

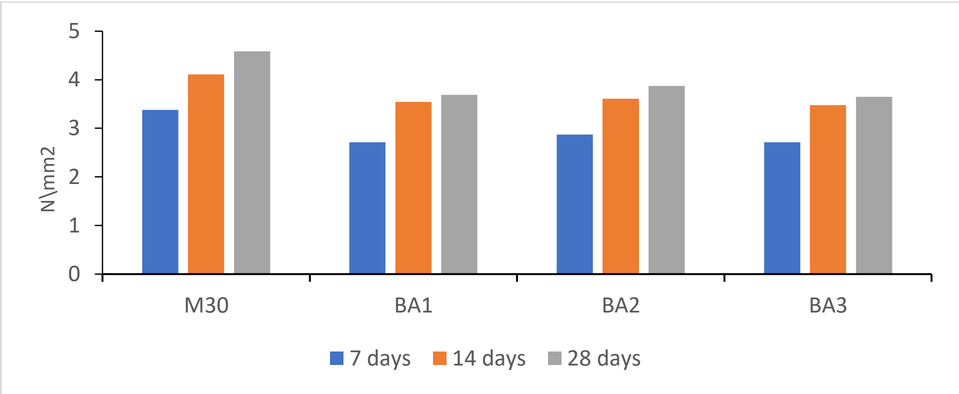

Fig 4: Split tensile test of concrete at 7,14 and 28 days

IV. CONCLUSION

- The study underscores the delicate balance required when integrating bagasse ash as a partial replacement for fine aggregate in concrete.
- The observed reduction in compressive and split tensile strength at varying replacement levels emphasizes the need for careful optimization of bagasse ash proportions.
- While the incorporation of bagasse ash offers environmental benefits, the compromise in mechanical properties highlights the necessity for precise control over replacement levels to ensure structural integrity.
- A nuanced approach is essential in the utilization of bagasse ash, maintaining a balance between sustainability goals and the fundamental performance characteristics of concrete.
- These findings serve as a guide for the development of refined strategies, promoting the efficient and environmentally conscious use of bagasse ash in concrete production, aligning with contemporary sustainability standards.

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