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Comparison Between Waste Fine Material Concrete and Conventional Concrete: A Review

Jayant Satish Mehare[1], Prof. Riyaz Sameer shah[2]
[1]*PG Student Masters of Technology in Structural Engineering, Department of Civil Engineering, Prof. Ram Meghe Institute of Technology & Research, Badnera, Maharashtra, India*
[2]*Assistant Professor, Department of Civil Engineering, Prof. Ram Meghe Institute of Technology & Research, Badnera, Maharashtra, India*

Abstract: ***This review paper presents a comprehensive assessment of previous research on the utilization of waste fine materials in concrete as sustainable alternatives to conventional cementitious materials. The reviewed studies primarily focus on silica fume, fly ash, and other industrial and agricultural by-products used as partial replacements for cement in concrete. The findings indicate that appropriate replacement levels can significantly improve compressive strength, split tensile strength, flexural strength, durability, and overall concrete performance while reducing cement consumption and environmental impact. Several researchers reported that the combined use of supplementary cementitious materials produces better results than individual replacements due to improved particle packing and pozzolanic reactions. The literature also highlights the importance of proper mix proportioning, curing conditions, and material compatibility in achieving optimum strength and workability. Particular attention is given to M25 grade concrete prepared with 100% crushed sand and modified with silica fume and fly ash, where enhanced mechanical properties and economic benefits have been reported. The reviewed studies demonstrate that waste fine material concrete can achieve strength levels comparable to higher-grade conventional concrete while promoting sustainable and cost-effective construction practices. This review provides a foundation for further investigation into the comparative performance of conventional concrete and concrete incorporating combined waste fine materials.***
Keywords: Waste fine material concrete, Conventional concrete, Silica fume, Fly ash, Crushed sand, M25 concrete, Compressive strength, Sustainable construction, Cost-effective concrete.

I. INTRODUCTION

Concrete is the most widely used construction material in the world due to its versatility, durability, strength, and cost-effectiveness. The rapid growth of infrastructure and urban development has significantly increased the demand for concrete, resulting in higher consumption of natural resources and cement. The production of cement is associated with substantial carbon dioxide emissions and energy consumption, which contribute to environmental degradation and climate change. Consequently, the construction industry is increasingly focusing on sustainable materials and environmentally friendly construction practices. In addition to cement replacement materials, the use of crushed sand as a substitute for natural river sand has gained considerable attention due to the depletion of natural sand resources and environmental restrictions on river sand extraction. Crushed sand offers a viable alternative and can contribute to sustainable aggregate utilization when properly incorporated into concrete mixtures. However, the extensive use of conventional cement-based materials contributes to high energy consumption and environmental impacts, including greenhouse gas emissions and resource depletion. To promote sustainability, researchers have focused on incorporating alternative and waste-derived materials into concrete production. These materials can improve concrete performance by enhancing its microstructure, durability, and long-term behavior while reducing dependence on conventional resources. The adoption of sustainable concrete practices supports efficient resource utilization, waste management, and the development of more environmentally friendly construction systems.

A. Key Considerations in Concrete Material Selection

The selection of concrete materials plays a crucial role in determining the performance, durability, and sustainability of construction projects. Conventional concrete primarily relies on cement, fine aggregates, coarse aggregates, and water. However, increasing environmental concerns and the demand for sustainable construction have encouraged the use of waste fine materials such as silica fume and fly ash as partial cement replacement materials.
The key considerations in material selection include:

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1) Strength Performance: The ability of concrete to achieve the required compressive, tensile, and flexural strength for structural applications.
2) Workability: Ensuring adequate consistency and ease of placement without segregation or excessive bleeding.
3) Durability: Resistance to environmental effects such as chemical attack, moisture penetration, and temperature variations.
4) Sustainability: Reduction of cement consumption and utilization of industrial by-products to minimize environmental impact.

B. *Performance Characteristics of Waste Fine Material Concrete*

Waste fine material concrete incorporates supplementary cementitious materials such as silica fume and fly ash to enhance concrete properties. Numerous studies have demonstrated improvements in both fresh and hardened concrete performance.
Important characteristics include:

1) Improved Compressive Strength: Silica fume contributes to higher early-age strength through pozzolanic reactions and pore refinement.
2) Enhanced Workability: Fly ash particles improve concrete flowability and reduce water demand.
3) Better Durability: Reduced permeability and improved resistance to sulfate attack and chloride penetration increase service life.
4) Microstructural Improvement: The filler effect of fine particles leads to a denser concrete matrix and reduced voids.

C. *Comparative Assessment of Conventional and Waste Fine Material Concrete*

A comparison between conventional concrete and waste fine material concrete reveals significant differences in performance and sustainability.

1) Mechanical Properties: Waste fine material concrete generally exhibits higher compressive, split tensile, and flexural strength when optimum replacement levels are used.
2) Environmental Impact: The use of industrial by-products reduces carbon emissions associated with cement production and supports waste utilization.
3) Economic Benefits: Partial cement replacement can reduce material costs and improve resource efficiency.
4) Long-Term Performance: Fly ash-based concrete often demonstrates superior long-term strength development and durability compared to conventional concrete.

D. *Importance of Sustainable Concrete Technology*

Sustainable concrete technology has become essential for modern construction due to increasing environmental challenges and resource depletion. The incorporation of waste fine materials provides an effective approach to achieving sustainable development goals in the construction industry.
Major benefits include:

1) Reduction in Carbon Footprint: Lower cement consumption results in decreased greenhouse gas emissions.
2) Waste Management: Industrial by-products are effectively utilized instead of being disposed of in landfills.
3) Resource Conservation: Reduced dependence on natural raw materials supports sustainable resource management.
4) Improved Structural Performance: Properly designed waste fine material concrete can meet or exceed the performance requirements of conventional concrete.

II. RESEARCH GAP AND OBJECTIVES

A. *Research Gap*

Previous studies have extensively investigated the use of supplementary cementitious materials such as silica fume, fly ash, rice husk ash, biochar, and other industrial by-products as partial replacements for cement in concrete. Most researchers reported improvements in strength, durability, and sustainability at optimum replacement levels. However, the majority of these studies focused on the individual use of waste materials or conventional fine aggregates. Limited research has been reported on the combined utilization of silica fume and fly ash in concrete prepared with 100% crushed sand as a replacement for natural fine aggregate. Furthermore, insufficient attention has been given to evaluating whether such combinations can improve the performance of M25 grade concrete to achieve strength levels comparable to M30 grade concrete while maintaining economic feasibility and sustainability. Therefore, further investigation is required to assess the mechanical, durability, and cost characteristics of concrete incorporating combined waste fine materials and crushed sand.

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B. Objectives of the Study

To review the performance of waste fine materials used in concrete production.

1) To evaluate the effects of silica fume and fly ash on the strength and durability properties of concrete.
2) To compare the characteristics of conventional concrete and waste fine material concrete.
3) To assess the suitability of 100% crushed sand as a replacement for natural fine aggregate.
4) To investigate the potential of achieving higher strength performance in M25 concrete through the combined use of silica fume and fly ash.
5) To examine the economic and environmental benefits associated with the use of waste fine materials in concrete.
6) To identify research findings that support the development of sustainable and cost-effective concrete for future construction applications.

III. LITERATURE REVIEW

The use of waste materials in concrete has become an important area of research due to the need for sustainable and eco-friendly construction practices. Many studies have explored the replacement of cement with industrial and agricultural by-products to improve concrete performance and reduce environmental impact. This chapter presents a review of previous research on materials such as silica fume, fly ash, rice husk ash, biochar, glass powder, and other waste fine materials. The effects of these materials on strength, workability, and durability are discussed. The reviewed studies help in understanding the behaviour of waste fine material concrete and identifying research gaps for the present investigation.

Dr. Y. S. Patil, and M. S. Kuttimarks (2015) [1] observed the effect of silica fume as a partial replacement of cement in M40 grade concrete. Silica fume was incorporated at replacement levels ranging from 0% to 15%, and tests such as compressive strength, split tensile strength, flexural strength, and slump were conducted. The results indicated that silica fume significantly enhanced early-age and long-term strength due to its pozzolanic activity. The optimum replacement level was found to be around 10–12.5%, beyond which strength gains were marginal. The study also reported improved durability and reduced permeability; however, workability decreased with increasing silica fume content.

Regan J. Case and Kai Duan (2012) [2] studied the influence of fly ash on the compressive strength of concrete by replacing cement at levels of 15%, 30%, and 45%. Experimental observations at 7 and 28 days revealed that fly ash concrete exhibited lower early-age strength compared to conventional concrete because of slower pozzolanic reactions. However, significant strength development was observed at later ages, with approximately 30% fly ash replacement producing optimum performance. The study concluded that fly ash improves workability, reduces heat of hydration, and contributes to sustainable concrete production.

Ali Hassaan, Muhammad Tariq Ali, Muhammad Zain Abdullah (2014) [3] evaluated concrete containing fly ash as a partial cement replacement from 0% to 30%. Compressive strength and ultrasonic pulse velocity tests were performed to assess concrete quality. The results showed that strength increased up to 15% fly ash replacement and then decreased at higher replacement levels. The highest compressive strength achieved was approximately 3699 psi. The study concluded that moderate fly ash replacement improves concrete performance while reducing cement consumption and environmental impact.

G. V. V. Raj Kishore (2021) [4] studied the combined use of silica fume and fly ash in high-strength concrete. Silica fume contents of 6% and 9% were used with fly ash replacements ranging from 30% to 50%. Mechanical and durability properties were evaluated up to 90 days. The results demonstrated that the combination of 6% silica fume and 30% fly ash produced the highest strength and durability. Reduced permeability and improved internal concrete quality were observed due to the synergistic action of both supplementary cementitious materials.

Vidhyapayhi R, Mani Kandhan KU (2022) [5] studied the utilization of coconut shell as a partial replacement of coarse aggregate along with silica fume as a cement replacement material. Experimental results showed that silica fume enhanced compressive strength by more than 25% compared with conventional concrete. The optimum combination provided balanced mechanical performance and economic benefits. However, excessive coconut shell content reduced strength because of its lower stiffness characteristics.

Vijeta Verma1, Harshit Varshney2 (2014) [6] investigated the combined use of glass powder and fly ash as partial cement replacement materials. The study revealed that a replacement level of 10% (5% glass powder and 5% fly ash) produced maximum compressive and flexural strength. Improved particle packing and reduced void content contributed to the enhanced performance. The researchers concluded that industrial waste materials can effectively improve concrete properties while reducing environmental impact.

M. Arivazhagan, T. Balakrishnam (2019) [7] examined the effect of groundnut shell ash as a partial replacement of cement up to 15%. Compressive strength and density tests were conducted at 7 and 28 days. The results indicated a slight improvement in strength compared to conventional concrete due to pozzolanic activity and filler effects. The study highlighted the potential of agricultural waste materials for sustainable and economical concrete production.

K. Gopala Rao, Dr. B. Krishna Rao (2018) [8] evaluated the combined influence of GGBS and fly ash on concrete properties. Fly ash content was maintained at 20% while GGBS replacement varied from 10% to 40%. The results showed that compressive and split tensile strengths decreased beyond 20% GGBS replacement. The study emphasized the importance of optimizing replacement levels to achieve satisfactory mechanical performance.

Umapathy U, Mala C. (2014) [9] studied the utilization of rice husk ash (RHA) and waste ceramic tiles as partial replacement materials in concrete. The replacement levels varied from 10% to 50% for waste tiles and from 10% to 20% for RHA. Experimental results showed that compressive strength was maintained up to 20–30% replacement levels. Beyond these limits, strength gradually decreased due to reduced bonding and cementitious content. The study demonstrated that sustainable waste materials can be incorporated into concrete without significantly affecting structural performance while promoting environmental conservation.

B G Naresh Kumar, Punith, N, A P Puneeth Raj (2019) [10] investigated the use of poultry waste as a partial replacement of cement in M20 grade concrete. A replacement level of 5% poultry waste was evaluated and compared with conventional concrete. The results revealed improvements in both compressive and split tensile strengths at different curing ages. The study concluded that poultry waste can serve as a sustainable supplementary material while maintaining acceptable engineering properties of concrete.

Dr. Pranab Jyoti Barman, Manash Pratim Deka, Anikita Gogoi (2025) [11] examined the performance of biochar as a partial replacement of cement at replacement levels ranging from 1% to 13%. Compressive strength and slump tests were conducted at 7 and 28 days. The results indicated that 5% biochar replacement produced optimum strength and workability characteristics. Higher replacement levels resulted in strength reduction due to increased porosity and lower cementitious content. The study highlighted biochar as an environmentally friendly alternative material capable of reducing carbon emissions in concrete production.

S. Menaka, C. Monisha and V. Naveen (2022) [12] investigated the feasibility of using PVC plastic waste as a partial replacement of cement in concrete. Replacement levels of 2.5%, 5%, 7.5%, and 10% were considered. The results showed a slight increase in compressive strength at 2.5% replacement, while higher percentages resulted in strength reduction due to poor bonding between plastic particles and the cement matrix. The study also observed lower water absorption, indicating improved durability characteristics. The researchers concluded that PVC waste can be effectively utilized in limited quantities for sustainable construction.

Mohammed Ramshad, Salmanul Faris, Shefin K (2018) [13] studied the combined use of red mud and fly ash as partial replacement materials in concrete. Replacement levels of 5%, 10%, and 15% were examined to evaluate compressive strength performance. The results revealed that compressive strength increased up to 10% replacement and decreased thereafter. The study concluded that red mud can be successfully utilized as a supplementary cementitious material when used at optimum levels, contributing to sustainable waste management practices.

Lica Siqueira Javier Forero, Miguel Bravo (2022) [14] investigated the combined effect of magnesium oxide (MgO) and fly ash as partial cement replacement materials. Durability performance was assessed using chloride ion migration tests. The results showed that fly ash improved resistance to chloride penetration, whereas MgO exhibited slower hydration and lower early-age strength. Despite this, the combined use of MgO and fly ash produced acceptable durability performance and contributed to reducing the environmental impact associated with cement production.

Pamarthi Gowtham Sri Harsha (2016) [15] evaluated the use of cow dung ash (CDA) as a partial replacement of cement in M20 grade concrete. Replacement levels of 5%, 10%, and 15% were considered. Compressive strength tests conducted at 7, 14, and 28 days indicated that strength increased up to 10% CDA replacement and decreased at higher replacement levels. The improvement was attributed to the pozzolanic nature of the ash. The study concluded that cow dung ash can be effectively utilized as a low-cost and eco-friendly construction material.

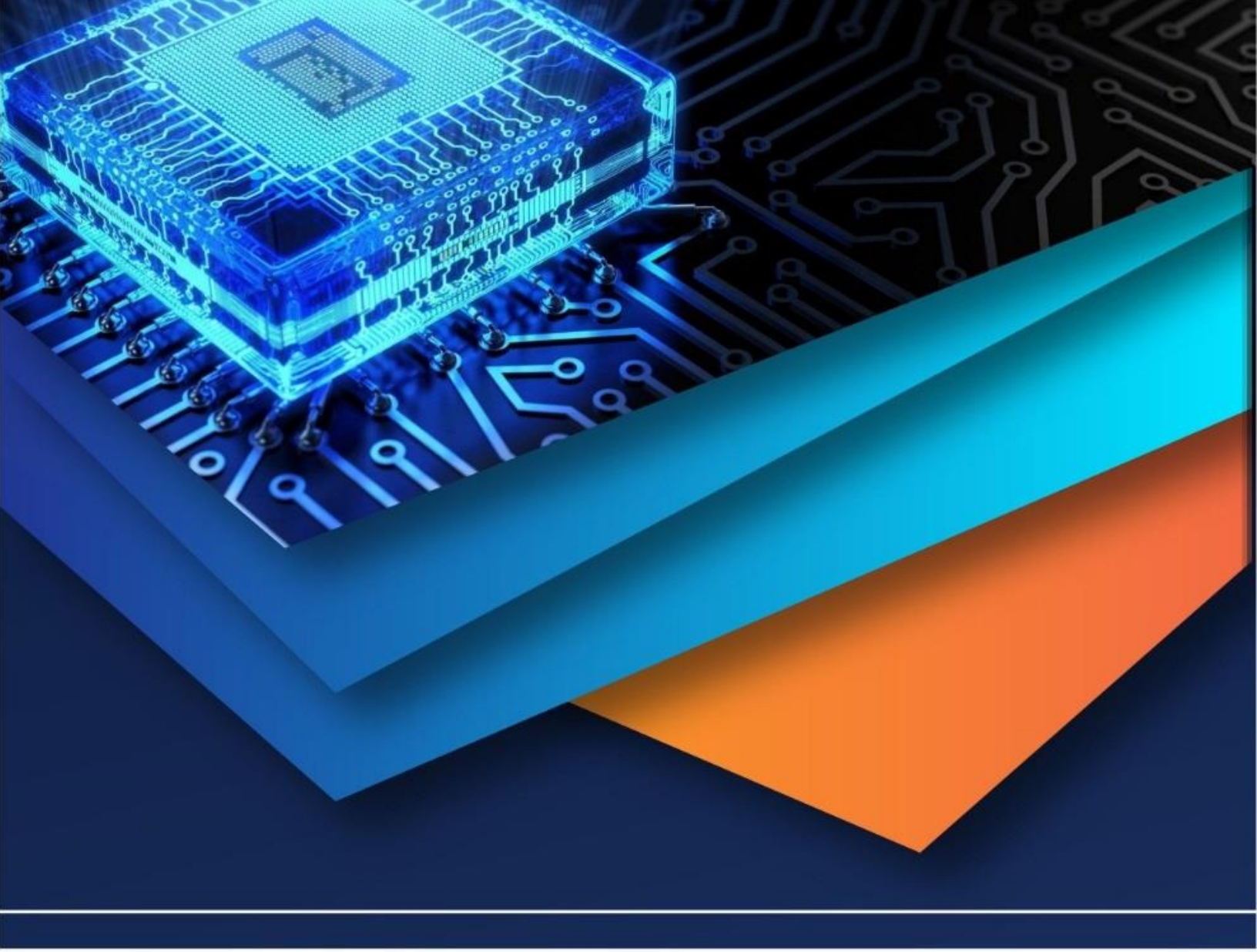
R. Gowri, and V. Lakshmi (2015) [16] investigated the influence of rice husk ash as a partial cement replacement material. Replacement levels varied from 0% to 40%, and mechanical properties were evaluated at different curing ages. The results showed improvements in compressive, tensile, and flexural strengths up to 10–20% replacement. Beyond this range, strength gradually decreased. The study demonstrated that rice husk ash improves concrete microstructure, reduces permeability, and enhances long-term durability while contributing to sustainable waste utilization.

IV. CONCLUSIONS

The reviewed studies demonstrate that waste fine materials such as silica fume, fly ash, rice husk ash, biochar, glass powder, red mud, coconut fibre ash, and other industrial and agricultural by-products can effectively be utilized as partial replacements for cement in concrete. Most researchers reported improvements in compressive, split tensile, and flexural strengths when these materials were used at optimum replacement levels. Silica fume was found to significantly enhance strength and durability due to its high pozzolanic activity, while fly ash improved workability and contributed to long-term strength development. Several studies also highlighted the environmental and economic benefits of reducing cement consumption through the use of waste materials. However, excessive replacement levels generally resulted in reduced mechanical performance due to the dilution of cementitious content. The combined use of supplementary cementitious materials often produced better results than their individual use because of their synergistic effects. The literature further indicates that proper mix proportioning, curing conditions, and material selection play a vital role in achieving the desired concrete performance. Overall, the reviewed research confirms the potential of waste fine material concrete as a sustainable alternative to conventional concrete and provides a strong foundation for further experimental investigation and performance evaluation.

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