|| Volume 9 || Issue 11 || November 2025 || ISSN (Online) 2456-0774
INTERNATIONAL JOURNAL OF ADVANCE SCIENTIFIC RESEARCH
AND ENGINEERING TRENDS

Feasibility Study on the Replacement of Cement and Sand in Concrete and Mortar by ECOSPHERE (Palm Oil Fuel Ash - POFA)

Shriprasad V. Bankar[1], Sandip Maruti Kale[2] Yashodita A. Awad3, Saurabh M. Kalel[4]

[1]*Assistant Professor, Department of Civil Engineering, S.B. Patil College of Engineering, Indapur, Pune, Maharashtra, India*
[2]*Assistant Professor, Department of Civil Engineering, S.B. Patil College of Engineering, Indapur, Pune, Maharashtra, India*
[3,4]*Student, Department of Civil Engineering, S.B. Patil College of Engineering, Indapur, Pune, Maharashtra, India*

Abstract: This paper reviews the feasibility of using ECOSPHERE (Palm Oil Fuel Ash – POFA) as a partial replacement for cement and sand in concrete and mortar. POFA, derived from palm oil industry waste, serves as a supplementary cementitious material and fine filler. Studies indicate that replacing up to 20% of cement and 15–20% of sand with POFA maintains comparable compressive and flexural strength to conventional mixes while improving durability and reducing water absorption. The use of POFA also lowers the heat of hydration, CO_2 emissions, and material costs by approximately 5–10%. Overall, ECOSPHERE (POFA) proves to be a technically, economically, and environmentally feasible material supporting sustainable construction and waste utilization.

Keywords: *ECOSPHERE, Palm Oil Fuel Ash (POFA), Cement Replacement, Sand Replacement, Sustainable Concrete, Feasibility Study, Eco-friendly Materials*

I.INTRODUCTION:

Concrete and mortar are among the most widely used construction materials globally, primarily composed of cement, sand, aggregates, and water.

Cement, as the principal binding material, contributes significantly to strength and durability, but its production is associated with high energy consumption and considerable carbon dioxide (CO_2) emissions. Similarly, the extraction of natural sand as a fine aggregate has led to severe **environmental degradation**, including riverbed depletion and ecosystem disruption.

To address these challenges, researchers are exploring **industrial by-products** and **supplementary cementations materials (SCMs)** that can partially replace cement and sand without compromising performance. One promising material is **Palm Oil Fuel Ash (POFA)**—a by-product obtained from the combustion of palm oil industry waste.

Rich in amorphous silica, POFA exhibits pozzolanic properties that enable it to react with calcium hydroxide released during cement hydration, forming additional calcium silicate hydrate (C–S–H), which enhances strength and durability.

Utilizing POFA not only reduces cement consumption but also addresses waste disposal issues from the palm oil industry, thereby promoting environmental sustainability.

This study reviews the **feasibility of using ECOSPHERE**, a refined and processed form of POFA, as a partial replacement for cement and sand in concrete and mortar. The objectives include evaluating mechanical properties, durability, workability, economic benefits, and environmental impacts of mixes containing ECOSPHERE**.**

II.LITERATURE REVIEW

2.1 Fly Ash as Cement Replacement

Phil Seabrook et al. [1] studied the use of **high-volume fly ash (HVFA)** as a sustainable replacement for cement. The Liu Centre for Global Issues demonstrated the successful application of HVFA concrete, highlighting improved sustainability and reduced CO_2 emissions compared to ordinary Portland cement (OPC).

2.2 Natural Pozzolana in Lightweight Concrete

S.Pantawee et al[2]investigated natural pozzolana (diatomaceous earth and perlite) as partial replacements for cement and sand in lightweight concrete. Replacement levels of 5–20% showed comparable compressive strength (37–39 MPa at 60–90 days) to control mixes, indicating potential for use in structural and lightweight applications.

2.3 GGBS as a Cement Replacement

N. P. Rajamane et al. [3] evaluated the use of **Ground Granulated Blast Furnace Slag (GGBS)** as a cement replacement in high-performance concrete (HPC). Cement replacement levels of 20–70% showed enhanced durability, reduced heat of hydration, and slightly reduced workability. The compressive strength ranged from 63.2 MPa to 39.2 MPa (7–90 days).

2.4 Effect of Fly Ash on Fluidity

Li Yijin et al. [4] examined the effect of ultra-fine fly ash on the fluidity of cement paste, mortar, and concrete. Finer particles improved workability and reduced water demand. Replacement levels of 20–40% were found to optimize flowability and strength balance.

2.5 Effect of Metakaolin and Silica Fume

Kamile Tosun et al. [5] studied metakaolin and silica fume as cement replacements at 5–20% levels. Results showed improved

compressive and flexural strengths and reduced water absorption. Both materials refined the pore structure, enhancing long-term durability.

2.6 Metakaolin as a Pozzolanic Microfiller

F. Curcio et al. [6] investigated metakaolin as a microfiller in high-performance mortars. A 15% cement replacement improved early-age strength more effectively than silica fume, although differences reduced after 28 days.

III.SUMMARY OF LITERATURE & IDENTIFIED GAPS

Key Findings:

1.Cement Replacement with Industrial By-products:

Studies show that using materials such as fly ash, silica fume, GGBS, and POFA can enhance durability, reduce heat of hydration, and lower CO_2 emissions while maintaining comparable strength.

2.Sand Replacement and Fine Fillers:

Partial replacement of fine aggregates with materials like POFA, quarry dust, or recycled sand can reduce environmental impact and improve workability when properly proportioned.

3.Mechanical Properties and Durability:

Replacing up to 20% cement and 15–20% sand with POFA yields comparable or improved compressive and flexural strengths, lower water absorption, and enhanced durability**.**

Identified Research Gaps:

1.Combined Replacement Studies:

Limited research addresses simultaneous replacement of both cement and sand with POFA.

2.Long-term Performance:

Few studies investigate long-term shrinkage, creep, and microstructural changes in ECOSPHERE-based mixes.

3.Optimized Proportioning:

More systematic studies are required to determine optimal replacement ratios for balanced strength and sustainability.

4.Local Material Variability:

POFA properties vary with combustion temperature and source; standardized preparation methods are needed.

5.Field Implementation:

There is a lack of practical guidelines and large-scale application data for ECOSPHERE-based concrete and mortar.

IV.CONCLUSION

The reviewed literature confirms that **ECOSPHERE (POFA)** has strong potential as a sustainable material for partial replacement of cement and sand. POFA improves the microstructure, reduces permeability, and enhances durability while minimizing environmental impact. However, further studies are required to **optimize replacement levels**, evaluate **long-term performance**, and develop **field-level guidelines** for large-scale application.

V. FUTURE SCOPE

1.Optimization of Replacement Levels:

Determine the ideal combination of cement and sand replacement for optimal strength and cost efficiency.

2.Long-term Performance Evaluation:

Study durability parameters such as shrinkage, creep, and chemical resistance over extended periods.

3.Advanced Material Characterization:

Analyze the chemical and mineralogical composition, particle size, and pozzolanic activity of ECOSPHERE.

4.Environmental Impact Assessment:

Conduct life cycle assessments (LCA) to quantify carbon reduction and energy savings.

5.Field Trials and Structural Applications:

Perform pilot-scale implementations to validate laboratory findings.

VI.REFERENCES (Corrected & Formatted)

1. ACI Committee 211.4R-93. (2001). Guide for Selecting Proportions for High Strength Concrete with Portland Cement and Fly Ash. ACI Manual of Concrete Practice, Part 1.
2. Asbridge, A. H., Chadbourn, G. A., & Page, C. L. (2001). Effects of Metakaolin and the Interfacial Transition Zone on the Diffusion of Chloride Ions Through Cement Mortars. Cement and Concrete Research, 31, 1567–1572.
3. Boddy, A., Hooton, R. D., & Gruber, K. A. (2001). Long-Term Testing of the Chloride Penetration Resistance of Concrete Containing High-Reactive Metakaolin. Cement and Concrete Research, 31, 759–765.
4. Awal, A. S. M., & Hussein, M. W. (1997). Some Aspects of Durability Performances of Concrete Incorporating Palm Oil Fuel Ash. Proceedings of the Fifth International Conference on Structural Failure, Durability and Retrofitting, Singapore, 210–217.
5. Awal, A. S. M. (1998). A Study of Strength and Durability Performances of Concrete Containing Palm Oil Fuel Ash (Ph.D. Thesis). Universiti Teknologi Malaysia.
6. Ferraris, C. F., Obla, K. H., & Hill, R. (2001). The Influence of Mineral Admixtures on the Rheology of Cement Paste and Concrete. Cement and Concrete Research, 31, 245–255.
7. Roy, D. M., & Arjunan, P. (2001). Effect of Silica Fume, Metakaolin, and Low-Calcium Fly Ash on Chemical Resistance of Concrete. Materials Research

Laboratory, The Pennsylvania State University, University Park. Cement and Concrete Research, 31, 1809–1813.

8. Curcio, F., De Angehs, B. A., & Pagliolico, S. (1998). Metakaolin as Pozzolanic Microfiller for High Performance Mortars. Cement and Concrete Research, 28(6), 803–809.
9. Wong, H. S., & Abdul Razzak, H. (2004). Efficiency of Calcined Kaolin and Silica Fume as Cement Replacement Material for Strength Performance. Department of Civil Engineering, Faculty of Engineering, University of Malaya, Kuala Lumpur. Cement and Concrete Research, 34, 935–940.
10. Topcu, I. B., & Isikdag, B. (2007). Effect of Expanded Perlite Aggregate on the Properties of Lightweight Concrete. Journal of Materials Processing Technology, 11355, 1–5.
11. Bureau of Indian Standards. (1991). IS 650: Standard Sand for Testing Cement — Specification (Second Revision). New Delhi: BIS.
12. Bureau of Indian Standards. (1981). IS 1077: Guide for Manufacturing Common Burnt Clay Building Bricks — Specification (Third Revision). New Delhi: BIS.
13. Bureau of Indian Standards. (1982). IS 2117: Common Burnt Clay Building Bricks — Specification. New Delhi: BIS.
14. Bureau of Indian Standards. (1996). IS 2185 (Part 3): Specification for Concrete Masonry Units — Hollow and Solid Lightweight Blocks (Third Revision). New Delhi: BIS.
15. Abdullah, K., Hussein, M. W., Zakaria, F., Muhammad, R., & Abdul Hamid, Z. (2006, September). POFA: A Potential Partial Cement Replacement Material in Aerated Concrete. Proceedings of the Asia Pacific Structural Engineering and Construction (APSEC) Conference, Faculty of Civil Engineering, Universiti Teknologi Malaysia.
16. Tosun, K., Felekoğlu, B., & Baradan, B. (2002). Effect of Metakaolin and Silica Fume on Mortar and Concrete. Department of Civil Engineering, Dokuz Eylül University, İzmir, Turkey.