Analytical Study on Lightweight Ferrocement slab Using Partial Replacement of Pumice Fine Aggregate

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***Abstract*—The research focuses on evaluating the influence of pumice fine aggregate on the structural behaviour of ferrocement slabs through analytical modelling. Various replacement levels of pumice fine aggregate, namely 10%, 20%, and 30%, were initially considered to determine the optimum replacement range. Based on the selected optimum percentage, lightweight ferrocement slabs were analysed using finite element modelling in ABAQUS software. The study compares conventional ferrocement slabs and pumice-based ferrocement slabs in terms of density, dead load, bending moment, maximum deflection, stress distribution, crack resistance, structural efficiency, and sustainability.The analytical results indicate that replacing conventional sand with pumice significantly reduces the dead load of the slab while maintaining satisfactory structural performance. Although the pumice slab exhibits a slightly higher deflection than the conventional slab, the reduction in self-weight contributes to lower bending moments and improved structural efficiency. Furthermore, the reduced consumption of natural sand enhances sustainability and promotes environmentally responsible construction practices. The findings demonstrate that lightweight ferrocement slabs incorporating pumice fine aggregate represent a technically feasible and environmentally friendly alternative for modern structural applications, particularly where reduction in dead load and improved sustainability are primary design considerations.**

***Index Terms*—Ferrocement Slab, Lightweight Concrete, Pumice Stone, Fine Aggregate Replacement, ABAQUS, Structural Behaviour, Sustainable Construction**

I. INTRODUCTION

The construction industry is continuously seeking innovative materials capable of improving structural efficiency while simultaneously reducing environmental impacts. Reinforced concrete remains the most widely adopted construction material because of its versatility, durability, and economic viability. However, one of its primary limitations is its relatively high self-weight, which increases dead loads acting on structural members and foundations. The increased dead load consequently results in larger structural sections, higher reinforcement requirements, and greater construction costs.

Lightweight concrete has emerged as an effective solution to overcome these challenges by reducing the density of concrete without substantially compromising its structural performance. Various lightweight aggregates have been investigated worldwide to replace conventional aggregates, among which pumice has received considerable attention because of its naturally porous internal structure, low density, and excellent thermal insulating characteristics.

Ferrocement is another advanced cementitious composite widely recognized for its high tensile strength, crack resistance, ductility, and ease of construction. It consists of rich cement mortar reinforced with multiple layers of closely spaced wire mesh. Ferrocement slabs are commonly used in roofing systems, precast elements, water tanks, shell structures, marine structures, and lightweight floor systems owing to their superior mechanical properties and economical construction.

II. LITERATURE REVIEW

1) Abdul Gaus et al. (2022) investigated the influence of pumice sand as a partial replacement for natural fine aggregate in lightweight concrete mixtures. Their research demonstrated that lightweight concrete significantly reduces structural dead load while maintaining acceptable

compressive strength and tensile strength. The study concluded that pumice sand can effectively produce lightweight structural concrete with improved efficiency.

2) Nurhayat Degirmenci et al. (2011) examined the utilization of pumice fine aggregate in lightweight cement mortar. Experimental investigations included compressive strength, flexural strength, sulphate resistance, freeze-thaw durability, water absorption, and dry density. Their findings showed that pumice mortar achieved satisfactory strength with considerably reduced density, making it suitable for structural and non-structural applications.
3) Imran et al. (2020) experimentally studied reinforced concrete beams containing partial replacement of fine aggregate by pumice. Their research reported that moderate pumice replacement did not significantly reduce structural capacity, while the load-deflection behaviour remained comparable with conventional concrete beams.
4) Karthika R. B. et al. (2020) evaluated lightweight concrete produced using pumice aggregate and concluded that pumice considerably decreases concrete density while maintaining adequate compressive strength. The investigation also highlighted the excellent thermal insulation characteristics offered by pumice aggregate.
5) Muhammad Jahanzaib et al. (2021) investigated lightweight concrete incorporating pumice aggregate at various replacement levels. Their study reported improved workability, reduced dead load, better fire resistance, and enhanced sustainability. The researchers recommended pumice concrete for precast members, bridge decks, and high-rise structures where weight reduction is advantageous.
6) N. Ramanjaneyulu et al. (2019) investigated self-compacting lightweight concrete incorporating pumice aggregate. Their research demonstrated that pumice effectively reduced concrete density while preserving satisfactory workability and structural behaviour.

III. MATERIAL PROPERTIES

The structural analysis requires accurate representation of material behaviour. Material properties adopted for finite element modelling were obtained from the project data.

TAB 1: Material Properties of Conventional Ferrocement Slab

Property	Value
Density	2200 kg/m³
Young's Modulus	25,000 N/mm²
Poison's Ratio	0.20
Yield Stress	415 MPa

TAB 2: Material Properties of Pumice Ferrocement Slab

Property	Value
Density	1700 kg/m³
Young's Modulus	22,000 N/mm²
Poison's Ratio	0.22
Yield Stress	415 MPa

IV.EXPERIMENTAL INVESTIGATION

An experimental investigation was carried out to evaluate the structural performance of conventional ferrocement slab and pumice ferrocement slab under static loading conditions. The primary objective of the investigation was to compare the load-carrying capacity, deflection characteristics, cracking behavior, and failure mechanism of both slab types. The experimental results were further compared with the numerical results obtained from ABAQUS finite element analysis to validate the analytical model.

V.RESULTS

An experimental investigation was carried out to evaluate the structural performance of conventional ferrocement slab and pumice ferrocement slab under static loading conditions. The ABAQUS finite element results showed good agreement with the experimental findings, validating the numerical model. The pumice ferrocement slab reduced the self-weight by approximately 22-25% compared to conventional slab. The results indicate that both slabs exhibited satisfactory structural performance throughout the loading process. The conventional slab showed relatively lower deflection due to its higher stiffness, whereas the pumice ferrocement slab demonstrated improved lightweight characteristics with acceptable deformation and stress levels.

RESULTS OF CONVENTIONAL SLAB

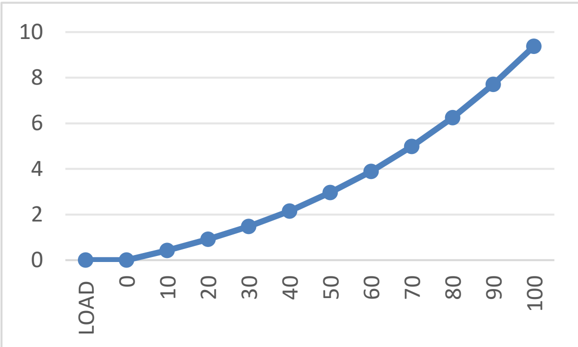

FIG 1: GRAPH RESULTS OF CONVENTIONAL SLAB

The above graph represents the load–deflection behavior of the conventional slab under two-point loading conditions.

RESULTS OF 20% PUMICE REPLACEMENT SLAB

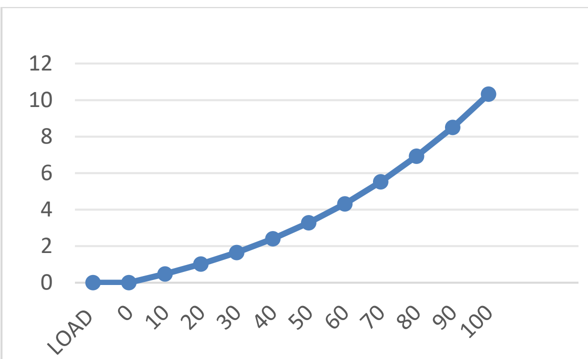

FIG 2: GRAPH RESULTS OF PUMICE SLAB

The above graph represents the load–deflection behavior of the 20% replacement of pumice under two-point loading conditions.

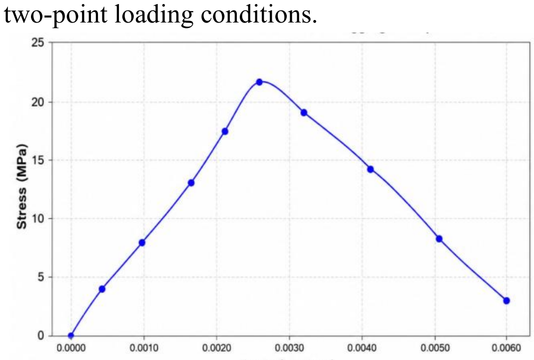

FIG 3: GRAPH RESULTS OF SRESS STRAIN CURVE FOR PUMICE SLAB

TAB 3: COMPARATIVE SUMMARY

Parameter	Conventional slab	Pumice slab
Maximum Displacement(mm)	9.38	10.32
Von Mises Stress(MPa)	18.60	16.90
Principal Stress(MPa)	13.50	12.30
Principal Strain	0.00182	0.00205

VI.CONCLUSION

This analytical investigation evaluated the structural behaviour of lightweight ferrocement slabs produced by partially replacing conventional fine aggregate with pumice stone. The finite element analysis demonstrated that pumice aggregate significantly reduces the density of mortar, resulting in lower dead loads and improved structural efficiency.

The reduction in self-weight led to lower bending moments and decreased equivalent stress while maintaining satisfactory structural behaviour. Although the pumice slab experienced slightly higher deflection due to its lower modulus of elasticity, the increase remained within acceptable limits for lightweight structural applications.

The analytical comparison also indicated improved crack resistance and lower Von Mises stress in the pumice ferrocement slab. From an environmental perspective, replacing natural sand with pumice contributes to sustainable construction by conserving natural resources and reducing the environmental impact associated with aggregate extraction.

Overall, the study concludes that lightweight ferrocement slabs incorporating pumice as a partial fine aggregate replacement provide a technically feasible and sustainable alternative to conventional ferrocement slabs. Future experimental investigations are recommended to validate the numerical results and optimize the replacement percentage for practical structural applications.

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