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Experimental Study to Increase the Strength of Perlite Concrete using Flyash

Sabitha K[1], Amal Hiba K[2], Mohammed Fawaz C[3], Najith Hanan C[4], Sneha Mohan V[5]
[1,2,3,4, 5]*Department of Civil Engineering, MEA Engineering College*

Abstract: ***The perlite concrete has generally low compressive strength. Lightweight and thermally efficient perlite is used in construction for its ecological benefits, though it typically offers reduced load-bearing capacity compared to conventional concrete. The living planet earth has encountered global warming due to various issues. Coal power plants produce solid waste called fly ash whose disposal is difficult. Therefore, urgent changes are required relating to emissions, production, and the application of sustainable and eco-friendly materials. This led to the concept of perlite concrete with fly ash. This paper aims to increase the strength of perlite concrete by adding fly ash. Different mix proportions of 10%, 20%, and 30% fly ash were added to each mix. The perlite concrete developed is tested for compressive tests, slump tests and weight comparison. The experimental phase involves compressive strength tests, split tensile strength tests and weight comparison that were carried out to investigate the influence of different proportions of fly ash with perlite concrete for use in structural construction. The findings reveal that the addition of fly ash is suitable to increase the compressive strength but can't be used for structural construction.***
Keywords: Perlite, Fly ash, Compressive strength, Split tensile strength, Slump value

I. INTRODUCTION

Perlite is a versatile and sustainable material with numerous benefits, including its lightweight nature, thermal and acoustic insulation properties, and resistance to fire and freeze-thaw cycles. However, its lower compressive strength limits its use in load-bearing structures. The incorporation of fly ash in perlite concrete presents an opportunity to enhance its compressive strength while also promoting environmental sustainability by utilizing industrial by-products.

This study highlights that adding fly ash to perlite concrete improves its compressive strength, with the highest strength observed at a 30% fly ash content. Additionally, using fly ash helps reduce the heat of hydration and mitigates environmental issues associated with its disposal from thermal power plants. While perlite concrete is costlier than traditional concrete on a small scale, it becomes more economical in large-scale applications due to its ease of transport, reduced labour costs, and faster construction process. Despite these advantages, further research is needed to explore additional lightweight aggregates and supplementary cementitious materials that could further enhance perlite concrete's properties. Additionally, durability studies and the examination of higher fly ash percentages can provide more insight into its long-term performance. The findings from this study contribute to the development of eco-friendly construction materials and support the wider application of perlite concrete in sustainable building practices.

II. SPECIFIC OBJECTIVES

1) To check whether it is applicable for structural construction.
2) To evaluate the influence of fly ash on the workability of perlite concrete.

III. MATERIALS AND METHODS RESULTS AND DISCUSSION

Materials used for this study are perlite, fly ash, and cement. Laboratory test such as compressive strength test, Split tensile strength test, weight comparison and slum test were conducted to determine the basic properties of a perlite concrete.

A. Perlite

Perlite is a lightweight, white, granular material that's made from volcanic glass that's been heated and expanded. Perlite's expanded nature makes it extremely porous, so it can absorb water, but it also improves drainage, so it is ideal to mix into compost to ensure water drains freely. Expanded perlite is the type typically used in perlite concrete.

B. Fly ash

Class F Fly ash is used in perlite concrete, and it is passed from the 600-micron IS sieve. The burning of harder, older anthracite and bituminous coal typically produces Class F fly ash. This fly ash is pozzolana in nature and contains less than 20% lime. Fly ash is defined as the finely divided residue resulting from the combustion of powdered coal, which is transported from the firebox through the boiler by fuel gases. Fly ash is a by-product of coal-fired electric plants.

C. Cement

Cement is a binding material that binds all the materials used in the construction of perlite concrete. It is a material that sets and hardens independently. Ordinary Portland cement (OPC) conforming to IS12269 of 53 grades is used in the construction of perlite concrete. A mixture of perlite along with the cement and water for the construction of perlite concrete. 53-grade OPC provides high strength and durability to structures because of its optimum particle size distribution and superior crystallized structure. Not only is this grade of cement stronger than other grades / types, but it is also more durable.

D. Mix proportion

The mix proportions for the casting of perlite concrete and perlite concrete with fly ash are shown in (TABLE 1).

TABLE1
MIX PROPORTION

TRIAL1	TRIAL 2	TRIAL 3	TRIAL 4
Casting of perlite concrete	Casting of perlite concrete with FA	Casting of perlite concrete with FA	Casting of perlite concrete with FA
1:2 perlite concrete	1:2 with 10% FA	1:2 with 20% FA	1:2 with 30% FA
1:3 perlite concrete	1:3 with 10% FA	1:3 with 20%FA	1:3 with 30% FA
1:4 perlite concrete	1:4 with 10% FA	1:4 with 20% FA	1:4 with 30% FA

IV. RESULTS AND DISCUSSION

A. The Basic properties

Properties of perlite concrete is shown in TABLE 2 in the ratio 1:2, 1:3, and 1:4.

TABLE 2
PROPERTIES OF PERLITE CONCRETE

Mix ratio	Property			
	Compressive strength N/mm^2	Split tensile strength N/mm^2	Weight kg	Slump value cm
1:2	16	1.41	5.5	22.86
1:3	10.67	1.1	5.3	20.32
1:4	7.11	0.84	4.99	17.78

B. Properties of perlite concrete with fly ash

Compressive strength test, split tensile strength, slump test and weight comparison test were conducted to determine the change in properties of perlite concrete with various percentages of fly ash.

1) Variation of compressive strength with varying percentages of fly ash

The variation in compressive strength by adding fly ash is shown in TABLE 3 and graphical analysis is shown in Fig 1.

TABLE 3
COMPRESSIVE STRENGTH OF PERLITE CONCR3ETE WITH FLYASH

Sl no.	Mix designation	Compressive strength Load/area(N/ mm^2)
1	1:2 with 10% fly ash	16.88
2	1:2 with 20% fly ash	17.77
3	1:2 with 30% fly ash	20
4	1:3 with 10% fly ash	11.33
5	1:3 with 20% fly ash	12.35
6	1:3 with 30% fly ash	14.67
7	1:4 with 10% fly ash	7.55
8	1:4 with 20% fly ash	8
9	1:4 with 30% fly ash	8.89

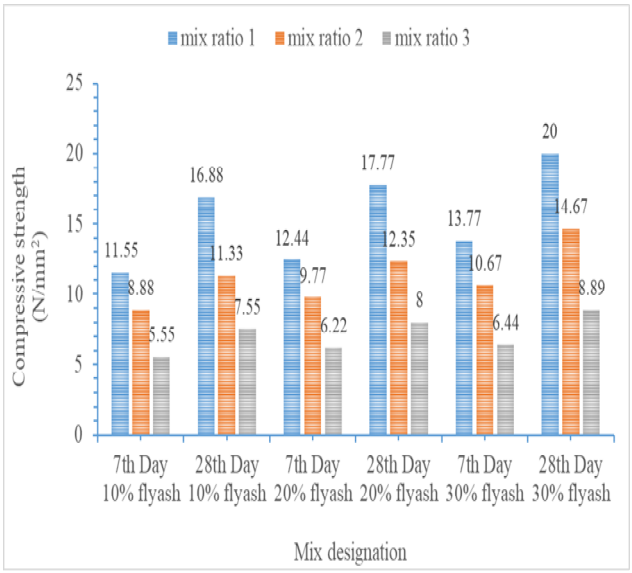

Fig. 1 Graphical analysis of compressive strength of perlite concrete with fly ash

From the experiments, it is clear that the compressive strength of perlite concrete with various percentages of fly ash has higher compressive strength than that of the normal perlite concrete mix. The test results also indicate that the compressive strength slightly increases with an increase in fly ash content. This increases the effective compaction and thereby decreases the voids in it. Maximum compressive strength was obtained for a mix of 30% fly ash with 1:2 perlite concrete. The maximum compressive strength obtained is 20 N/mm^2**.**

2) Variation of split tensile strength with varying percentages of fly ash

The variation in split tensile strength by adding fly ash is shown in TABLE 4 and graphical analysis is shown in Fig 2.

TABLE 4
SPLIT TENSILE OF PERLITE CONCRETE WITH FLYASH

Sl no	Mix designation	Split tensile strength for 28 days $2P/\pi dl$(N/mm^2)
1	1:2 with 10% FA	1.55
2	1:2 with 20% FA	1.83
3	1:2 with 30% FA	2.1

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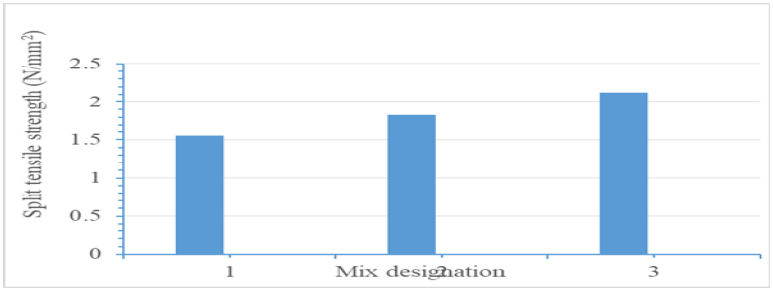


Fig. 2 Graphical analysis of split tensile strength of perlite concrete with fly ash

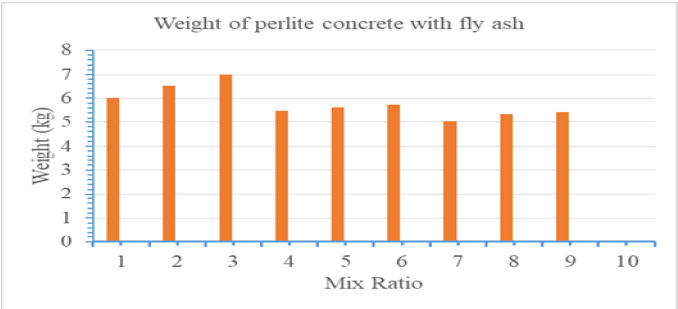
From the experiment, it is clear that the split tensile strength of perlite concrete with various percentages of fly ash has a slight increase compared to that of the normal perlite concrete mix. The split tensile strength of perlite concrete is generally lower than that of normal -weight concrete due to its lightweight nature. The amount of perlite used in the mix directly affects the tensile strength. Higher perlite content generally leads to lower tensile strength. Maximum split tensile strength was obtained for a mix of 30% fly ash with 1:2 perlite concrete. The maximum split tensile strength obtained is 2.1 N/mm^2**.**

3) Weight comparison

The weight of perlite concrete by adding fly ash is shown in TABLE 5 and graphical analysis is shown in Fig 3.

TABLE 5
WEIGHT OF PERLITE CONCRETE WITH FLYASH

Weight of perlite concrete with fly ash (kg)		
1:2 with 10% fly ash 6 kg	1:2 with 20% fly ash 6.5 kg	1:2 with 30% fly ash 6.99 kg
1:3 with 10% fly ash 5.5 kg	1:3 with 20% fly ash 5.63 kg	1:3 with 30% fly ash 5.74kg
1:4 with 10% fly ash 5.01 kg	1:4 with 20% fly ash 5.34 kg	1:4 with 30% fly ash 5.44 kg



Mix 1 = 1:2 with 10% fly ash Mix 2 = 1:2 with 20% fly ash
Mix 3 = 1:2 with 30% fly ash Mix 4 = 1:3 with 10% fly ash
Mix 5 = 1:3 with 20% fly ash Mix 6 = 1:3 with 30% fly ash
Mix 7 = 1:4 with 10% fly ash Mix 8 = 1:4 with 20% fly ash
Mix 9 = 1:4 with 30% fly ash

Fig. 3 Graphical analysis of weight of perlite concrete with fly ash.

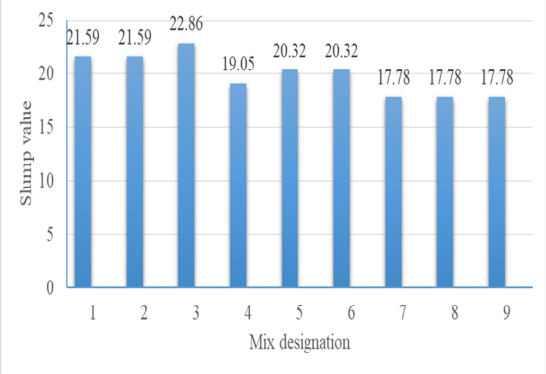
Perlite concrete is significantly lighter than normal concrete, making it ideal for applications where weight is a concern. It offers better insulation and sound absorption properties, reduces structural load on buildings, and is easier to handle, transport, and lay. These advantages lead to faster construction, lower labour costs, and a reduced environmental impact, making perlite concrete a more sustainable and efficient choice.

4) Slump test

The slump value of perlite concrete by adding fly ash is shown in TABLE 6 and graphical analysis is shown in Fig 4.

TABLE 6
SLUMP VALUE OF PERLITE CONCRETE WITH FLYASH

Mix designation	Slump value (cm)
1:2With 10% FA	21.59
1:2With 20% FA	21.59
1:2With 30% FA	22.86
1:3 With 10% FA	19.05
1:3 With 20% FA	20.32
1:3 With 30% FA	20.32
1:4 With 10% FA	17.78
1:4 With 20% FA	17.78
1:4 With 30% FA	17.78



1 - 1:2 with 10%FA 2 - 1:2 with 20%FA 3 - 1:2 with 30%FA
4 - 1:3 with 10%FA 5 - 1:3 with 20%FA 6 - 1:3 with 30%FA
7 - 1:4 with 10%FA 8 - 1:4 with 20%FA 9 - 1:4 with 30%FA

Fig. 4 Graphical analysis of slump value of perlite concrete with fly ash.

From the slump test, it is clear that the slump value of all mix proportions with various percentages of fly ash shows the true slump. When properly mixed, perlite concrete should have a slump of about 7–9 in (17.78–22.86 cm).Here the maximum slump value is for 1:2 with 30% fly ash.

V. CONCLUSIONS

The present study investigated the properties of perlite concrete with varying percentages of fly ash. The results indicate that incorporating fly ash improves the compressive strength of perlite concrete, with the highest strength observed at a 30% fly ash content (20 N/mm² for a 1:2 mix ratio). Additionally, perlite concrete remains significantly lighter than conventional concrete, making it a viable option for applications where weight reduction is crucial. However, due to its relatively lower tensile strength, perlite concrete with fly ash is not suitable for structural applications requiring high load-bearing capacity. While perlite concrete may be more expensive than traditional concrete on a small scale, it becomes more cost-effective in large-scale production due to its ease of transportation, reduced labour costs, and faster placement. The study also highlights the environmental benefits of using fly ash, a waste by-product, in concrete production.

Further research is recommended to explore the potential of alternative lightweight aggregates such as vermiculite, expanded clay, or pumice, as well as supplementary cementitious materials like silica fume and glass powder. Additionally, durability tests and varying fly ash content beyond the tested range (10%, 20%, and 30%) can provide deeper insights into the long-term performance and workability of perlite concrete. This study contributes to the understanding of perlite concrete's properties and lays the foundation for future research aimed at optimizing its composition for broader applications in construction.

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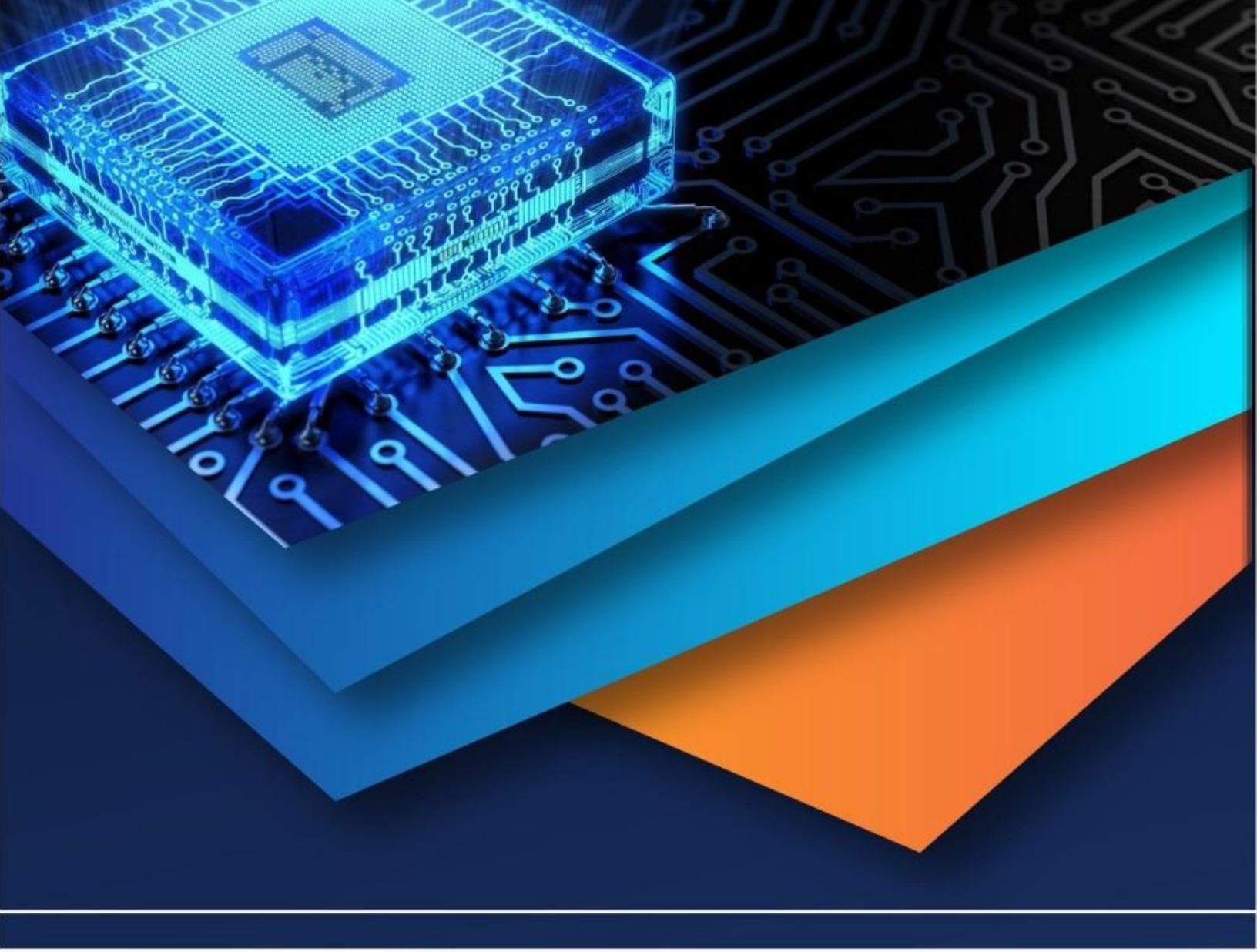

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