Investigating Concrete Properties with Partial Replacement of Cement by Alccofine and Eggshell Powder

PRAVEEN KUMAR.K[1], SHILPA.B[1], PREETHI.S[1], PRANAV KUMAR REDDY.N[1], VISWA TEJA.B[1], VENKATASUNEEL PITTI[2]

[1]U.G Students, Department of Civil engineering & Srinivasa Ramanujan Institute of Technology (Autonomous), Anantapur

[2]Assistant Professor, Department of Civil engineering & Srinivasa Ramanujan Institute of Technology (Autonomous), Anantapur

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Abstract - In this study, we investigate the effect of substituting cement with Alccofine and eggshell powder on the strength properties of concrete. Cement production is a significant source of carbon dioxide emissions, prompting the search for sustainable alternatives. Our research aims to address this environmental concern by evaluating the potential of Alccofine and eggshell powder as partial cement replacements while maintaining or enhancing concrete quality. We prepared various concrete mixtures with a constant 10% substitution of Alccofine, combined with different proportions of eggshell powder replacing cement (ranging from 0% to 20%). Through thorough testing including compressive, split tensile and flexural strength assessments, we analyzed the mechanical performance of these mixtures. Our findings demonstrate that Alccofine and eggshell powder can effectively substitute cement in concrete, providing a more environmentally friendly option that improves material strength. However, further research is needed to optimize the mix proportions and assess long-term durability in diverse environmental conditions. Notably, combining eggshell powder with Alccofine presents a promising approach to enhancing concrete performance while reducing the environmental impact of cement production. This study contributes to advancing sustainable practices in concrete construction, promoting the use of eco-friendly building materials.

***Key Words*:** Alccofine, eggshell powder, compressive, split tensile and flexural strength.

1. INTRODUCTION

Alccofine an ultrafine powder derived from finely ground silica and alumina-rich minerals like metakaolin or fly ash, is added to concrete mixtures. Its pozzolanic properties react with calcium hydroxide to form new cementitious compounds, enhancing concrete strength and durability. It is commonly used as a partial cement replacement to improve workability and reduce permeability. Eggshell powder, produced by crushing and grinding eggshells, finds various applications in concrete. With its high calcium carbonate content, eggshell powder serves as filler in concrete mixtures, increasing compressive strength and durability. Additionally, it offers an eco-friendly solution by repurposing waste material and reducing environmental impact.

Amarnath Yerramala[1] studied the incorporation of eggshell powder (ESP) in concrete, replacing 5-15% of cement. Results suggest ESP enhances strength, with 5% replacement optimal, and performance akin to control concrete up to 10%. Afolayan[2] investigates the use of eggshell ash as a partial cement replacement in concrete, focusing on compressive strength, workability, and setting time properties. Kalyana Chakravarthy et al.[3] explore the impact of Alccofine on concrete compressive strength through partial cement replacement at varying percentage. Kaviya et al.[4] study the mechanical properties of Alccofine in concrete, observing increased strength at 15% cement replacement. Parthasarathi et al.[5] examine eggshell powder and silica fume as cement replacements, enhancing concrete strength properties through partial substitution. Parvathy Karthika[6] investigates high-strength concrete using fly ash and Alccofine, achieving improved mechanical properties through partial cement replacement. Sanjeev Kumar et al.[7] investigate coconut shell aggregate and Alccofine in concrete, achieving reduced density without compromising strength. Boobalan et al.[8] provide a comprehensive review of Alccofine-based high-performance concrete, highlighting its advantages in strength, durability, and workability.

2. RESEARCH APPROACH

Cement a hydraulic material from limestone and clay, includes Ordinary Portland Cement (OPC), known for its strength properties conforming to IS:12269-1987 standards.

Table -1: Physical Properties of Cement

S. No	Description of Test	Results	Limit as per IS 269/IS456
1	Finess of Cement	7	10 (Max)
2	Initial Setting Time	35	30 (Min)
3	Normal Consistency (%)	30	-
4	Specific gravity	3.15	-

Alccofine 1203, a cementitious material, originates from Chennai and was procured from Astrra Chemicals Factory.

Fig -1: Alccofine1203

Eggshell Powder, another cementitious ingredient sourced from Karnataka, was obtained from Arman Agro Foods.

Fig -2: Eggshell powder

Fine aggregates, like sand, are essential in concrete and mortar production, typically finer than 4.75 mm sieve. The study's sand, with a particle size around 0.07 mm, conforms to IS: 383-1970 Zone II standards, crucial for optimal concrete properties.

Table -2: Physical Properties of Fine Aggregate

S. No	Properties	Results
1	Specific Gravity	2.56
2	Fineness Modulus	3.05

Coarse aggregates, larger than 4.75 mm, significantly impact concrete properties. Cleanliness and shape affect bonding with cement paste, influencing strength and durability. Angular aggregates may enhance interlock but reduce workability. Graded aggregates with nominal sizes of 20 mm and 10 mm are commonly used in this research work.

Table -3: Physical Properties of Coarse Aggregate

S. No	Properties	Results
1	Specific Gravity	2.8
2	Fineness Modulus	4.39

Water is crucial in concrete production, hydrating cement for hardening. Portable tap water, meeting quality standards, should be impurity-free to prevent voids or weak spots, with pH within desired range for optimal strength

3. RESULTS AND DISCUSSIONS

The research examines the strength characteristics of concrete when cement is partially substituted with Alccofine and Eggshell Powder in M20 Grade Concrete, employing various mix proportions. Laboratory assessments encompass Compressive Strength, Split Tensile Strength, and Flexural Strength, with results tabulated and graphically depicted for clarity.

Table -4: Compressive strength results for M20 Grade concrete

Mix	MIX Details	Compressive strength (N/mm^2) 28Days
M0	C 100% + AL 0% + ESP 0%	33
M1	C 90% + AL 10% + ESP 0%	34.81
M2	C 85% + AL 10% + ESP 5%	47.27
M3	C 80% + AL 10% + ESP 10%	38.51
M4	C 80% + AL 10% + ESP 15%	35.55
M5	C 80% + AL 10% + ESP 20%	28.44

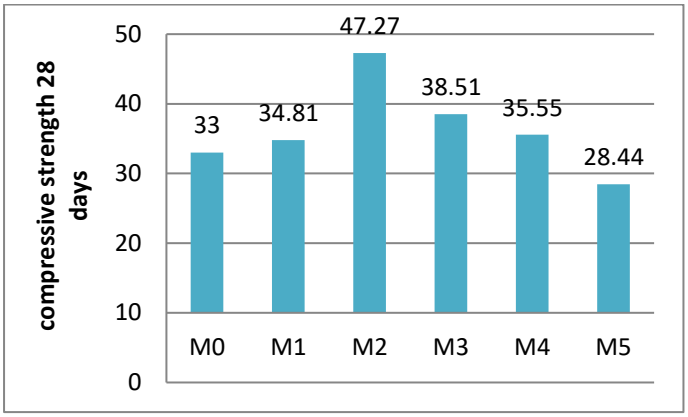

Fig -3: Compresive strength results for 28 days

The figure provided displays the compressive strength of concrete mixes with varying proportions of Eggshell Powder (ESP) alongside a consistent 10% Alccofine content. The nominal mix concrete shows an average compressive strength of 33 N/mm² at 28 days. Comparative analysis with the M0 mix indicates that mixes M1 through M4 exhibit increased compressive strengths, whereas M5 demonstrates a decrease. Notably, mix M2 displays the highest strength among all variations. Thus, it is concluded that the M2 mix achieves maximum concrete strength with 10% Alccofine and 5% Eggshell Powder.

Table -5: Split tensile strength results for M20 Grade concrete

Mix	MIX Details	Split tensile strength (N/mm^2) 28Days
M0	C 100% + AL 0% + ESP 0%	4.3
M1	C 90% + AL 10% + ESP 0%	7.26
M2	C 85% + AL 10% + ESP 5%	10.29
M3	C 80% + AL 10% + ESP 10%	5.09
M4	C 80% + AL 10% + ESP 15%	4.82
M5	C 80% + AL 10% + ESP 20%	4.13

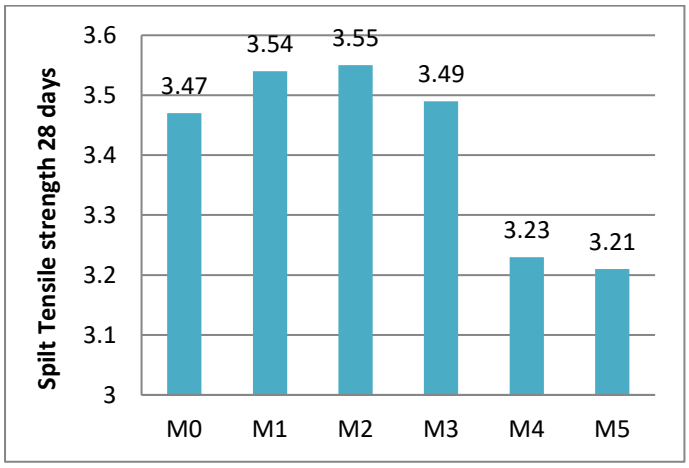

Fig -4: Split tensile strength results for 28 days

The depicted figure illustrates the Split Tensile Strength of concrete mixtures with varying proportions of Eggshell Powder (ESP) alongside a constant 10% Alccofine content. The nominal mix concrete exhibits an average split tensile strength of 4.3 N/mm² at 28 days. In comparison with the nominal mix concrete M0, other mixes (M1, M2, M3, and M4) show increased split tensile strengths, while M5 displays a decrease. Notably, mix M2 demonstrates the highest strength among all variations. Thus, it is concluded that the M2 mix achieves the maximum split tensile strength of concrete with 10% Alccofine and 5% Eggshell Powder.

Table -6: Flexural strength results for M20 Grade concrete

Mix	MIX Details	Flexural strength (N/mm²) 28Days
M0	C 100% + AL 0% + ESP 0%	3.47
M1	C 90% + AL 10% + ESP 0%	3.54
M2	C 85% + AL 10% + ESP 5%	3.55
M3	C 80% + AL 10% + ESP 10%	3.49
M4	C 80% + AL 10% + ESP 15%	3.23
M5	C 80% + AL 10% + ESP 20%	3.21

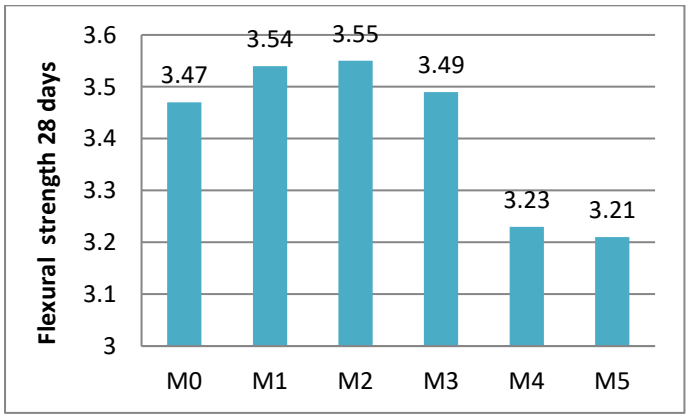

Fig -5: Flexural strength results for 28 days

The graph above depicts the Flexural Strength of concrete with varying proportions of Eggshell Powder, maintaining a constant 10% Alccofine content. At 28 days, the nominal mix concrete exhibits an average flexural strength of 3.47 N/mm². Comparing with the nominal mix concrete M0, other mixes (M1, M2, M3, and M4) demonstrate increased flexural strengths, while M5 exhibits a decrease. Notably, mix M2 displays the highest strength among all variations. Thus, it is concluded that the M2 mix achieves the maximum flexural strength of concrete with 10% Alccofine and 5% Eggshell powder.

4. CONCLUSIONS

In this research work, several key conclusions can be drawn. Firstly, the use of Alccofine emerges as an economically viable and eco-friendly alternative. When coupled with Eggshell Powder as a cement substitute, it markedly boosts concrete strength compared to conventional mixes. Specifically, the inclusion of 10% Alccofine and 5% Eggshell Powder enhances compressive, split tensile, and flexural strengths of concrete. This not only reduces construction costs but also promotes the safe application of Alccofine, thereby advancing sustainability goals. The considerable decrease in production expenses underscores the practicality of this approach. Thus, a combination of 10% Alccofine and 5% Eggshell Powder in concrete formulations demonstrates significant promise for real-world implementation. Moreover, this research underscores the effective resolution of waste disposal challenges and the mitigation of environmental risks. In essence, Alccofine and Eggshell Powder offer substantial potential for bolstering structural construction while addressing environmental considerations.

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