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To Study the Mechanical Behaviour of M30 Grade Concrete Using Light Weight and Self-Healing Concrete with Partial Replacement of Flyash and Coconut Fiber

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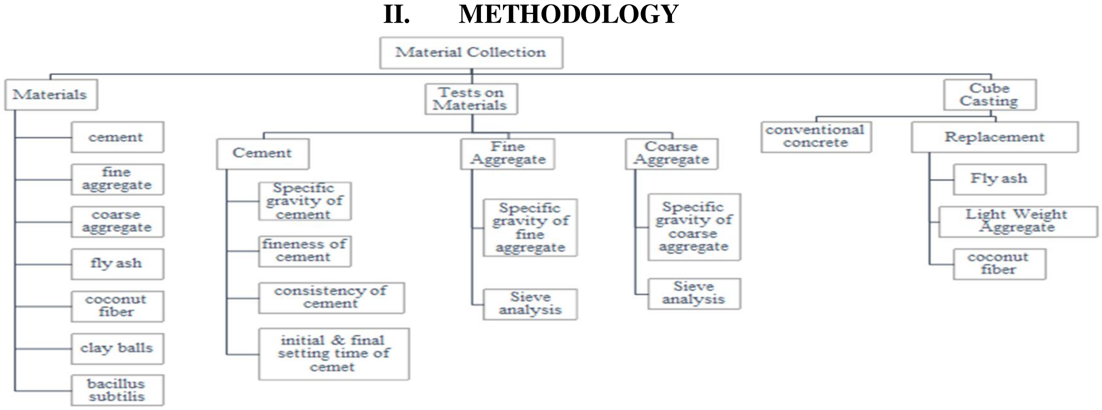
Abstract: Concrete is a widely used construction material due its high strength, durability. Traditional concrete has several limitations, including high weight, low thermal insulation and susceptibility to cracking and damaging. This study investigates various modifications to conventional concrete to enhance its mechanical properties, durability, and sustainability. The research focuses on four distinct approaches: incorporating 1.5% coconut coir fiber by volume to analyse its impact on compressive, tensile, and flexural strength; replacing 25% of cement with fly ash in M30 grade concrete to improve durability and sustainability while reducing cement consumption; utilizing lightweight expanded clay balls as a substitute for traditional coarse aggregates to achieve lower density without compromising strength; and exploring self-healing concrete using Bacillus subtilis, which promotes microbial-induced calcium carbonate precipitation (MICP) to heal cracks and extend service life. These investigations contribute to the development of sustainable and high-performance concrete materials for diverse structural applications. The findings of this study suggest that the use of fly ash, coconut fiber, lightweight aggregate and self-healing bacteria can improve the strength, durability and sustainability of M30 grade concrete.
Keywords: M30 grade concrete, fly ash, coconut fiber, lightweight aggregate and self-healing bacteria, strength behaviour, durability, sustainability.

I. INTRODUCTION

One approach is to use supplementary cementitious materials (SCMs) such as fly ash, which can improve the workability and strength of concrete while reducing its environmental impact. Another approach is to incorporate natural fibers such as coconut fiber, which can enhance the toughness and durability of concrete. Light weight concrete is another innovative approach that uses lightweight aggregates to reduce the density and weight of concrete. This can lead to significant benefits, including improved thermal insulation, reduced structural loads and enhanced sustainability. Self-healing concrete has emerged as a promising technology that can improve the durability and lifespan of concrete structures. This approach uses bacteria such as Bacillus subtilis to produce calcite, which can heal cracks and damage in concrete. To identify these limitations, researchers have been exploring alternative materials and techniques to improve the performance and sustainability of concrete.

II. METHODOLOGY



III. MATERIALS USED

1) Flyash: Fly ash is a byproduct of burning coal in power plants, fly ash's use in concrete is a key part of efforts to promote sustainability, by recycling industrial waste and reducing the environmental impact of concrete production. By the 1980s, various standards and regulations were established, such as ASTMC618 in the United States, which defined the specifications for fly ash as a pozzolanic material in concrete. Fly ash began being used more commonly in ready mix concrete, pavements and high strength concrete. Today, fly ash is widely used as an eco-friendly alternative to cement in concrete mixtures. It improves workability, reduces the heat of hydration and enhances durability by making concrete more resistant to chemical attacks,such as sulphate and chloride attack

Fig 1: Fly ash

2) Coconut Fiber: Coconut coir, the fibrous material from the husk of coconuts, has gained attention as a sustainable reinforcement in concrete. Though it shows promising benefits, the use of coconut coir in concrete is still a subject of research and challenges such as fiber durability and the right mix design for optimal strength need to be addressed before it can be more widely adopted in construction. The use of coconut fiber in M30 grade concrete offers several benefits including improved strength, durability and thermal insulation properties. The optimal dosage of coconut fiber was found to be 1-1.5% by volume of concrete.

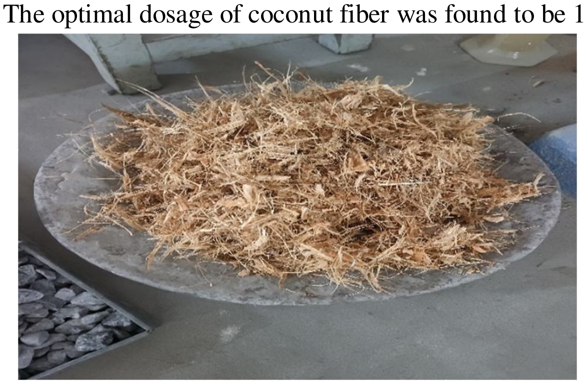


Fig2: Coconut fiber

3) Clay Balls: Clay balls are made by heating natural clay at high temperatures (1100°C-1200°C) in a rotary kiln, causing them to expand and form porous, lightweight aggregates. Makes concrete up to 40% lighter than conventional concrete which eventually helps in reduction of weight. Due to its ceramic nature, it withstands high temperatures. In mix design consideration typically replaces 20-50% of coarse aggregate in concrete.

Fig3: Clay balls

4) Bacillus Subtilis: Bacillus subtilis is a type of bacteria that has been found to have potential application in concrete technology. It produces calcite, which fills in cracks and pores, repairing the concrete. It also improves the durability of concrete by reducing its permeability and improving its resistance to cracking. This enables concrete to self-heal after cracking or damage, reducing the need for repair and maintenance.

Fig4: Bacillus subtilis & calcium lactate powder

IV. COMPRESSIVE STRENGTH

Compressive strength is the ability of concrete to withstand loads when compressed. It is measured in pounds per square inch(psi) or megapascals (MPa). It is influenced by the properties of the materials such as density, porosity and composition. Testing of compressive strength at 7days and 28days. Calculate the compressive strength by dividing the maximum load by the cross-sectional area.

Fig5&6: Compressive strength test

V. SLUMP TEST

Slump test is used to measure the workability of fresh concrete by measuring how much it settles after being poured into cone shaped mould and then lifted. It ensures that the concrete has the correct consistency for placement and finishing.

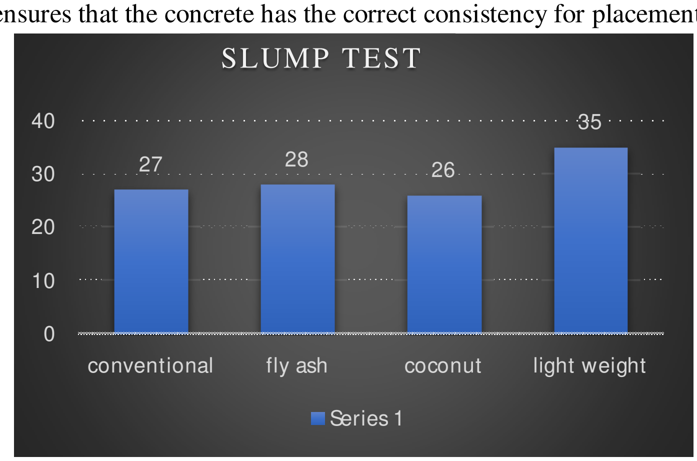


Chart 1: Slump test results

From chart 1 graph shows,

- In fly ash it is observed that the slump result is good

VI. RESULTS AND DISCUSSIONS

Table showing 7 days strength of conventional, fly ash, coconut fiber, lightweight for M30 grade

CUBES

S.No	MATERIAL	STRENGTH (N/mm^2)
1	Conventional	21.54
2	Fly ash	26.26
3	Coconut fiber	18.19
4	Light weight	12.14

Table 1

CYLINDERS

S.No	MATERIAL	STRENGTH (N/mm^2)
1	Conventional	1.98
2	Fly ash	2.12
3	Coconut fiber	1.83
4	Light weight	0.99

Table 2

Table showing 28 days strength of conventional, fly ash, coconut fiber, lightweight for M30 grade

CUBES

S.No	MATERIAL	STRENGTH (N/mm^2)
1	Conventional	32.9
2	Fly ash	34.6
3	Coconut fiber	30.81
4	Light weight	21.24

Table 3

CYLINDERS

S.No	MATERIAL	STRENGTH (N/mm^2)
1	Conventional	2.54
2	Fly ash	3.25
3	Coconut fiber	3.11
4	Light weight	1.98

Table 4

Cube compressive strength

1) For cubes

- The compressive strength of concrete of mix proportion 1:1.46:2.50 with the water cement ratio of 0.45

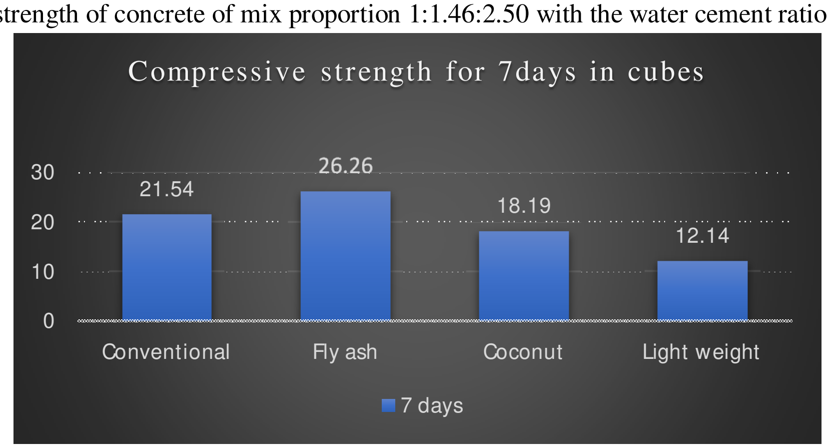


Chart 2

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From the above chart 2 the compressive strength for 7 days

- In Fly ash cubes we observe that the compressive strength of cube is better compared to the coconut Fiber, conventional and lightweight concrete
- In Light weight cubes we observed that the compressive strength is lesser compared to the conventional, coconut fiber and fly ash concrete
- We observed that the compressive strength of light weight cubes is too less

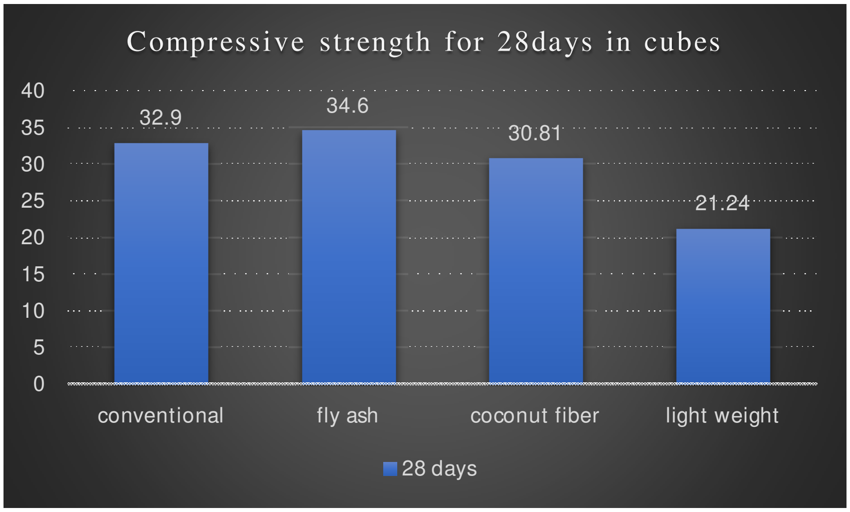

Chart 3

From the above chart 3 the compressive strength for 28 days

- In Fly ash cubes we observe that the compressive strength of cube is better compared to the coconut Fiber, conventional and lightweight concrete
- It is observed that the compressive strength for 28days in all cubes is similar in strength expect in lightweight cubes

2) For Cylinders

The compressive strength of cylinders is observed from chart 4, chart 5

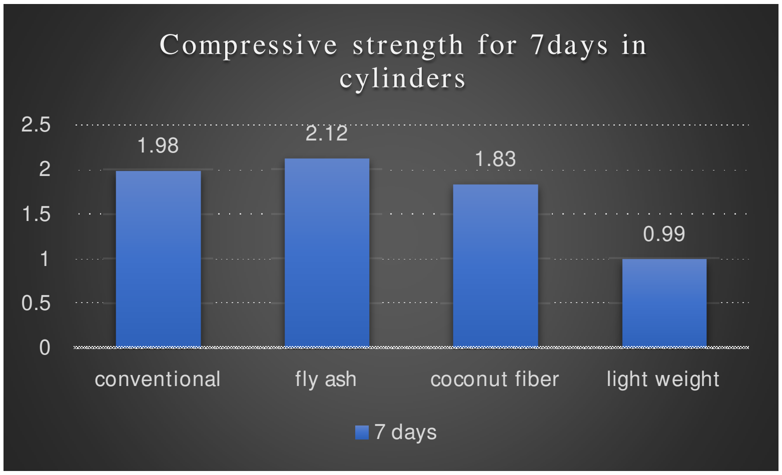

Chart 4

From the above chart 4, the compressive strength for 7 days

- In Fly ash cylinders we observe that the compressive strength of cylinder is better compared to the coconut Fiber, conventional and lightweight concrete
- In light weight cylinder we observed that the compressive strength is lesser compared to the conventional, coconut fiber and fly ash concrete cylinders

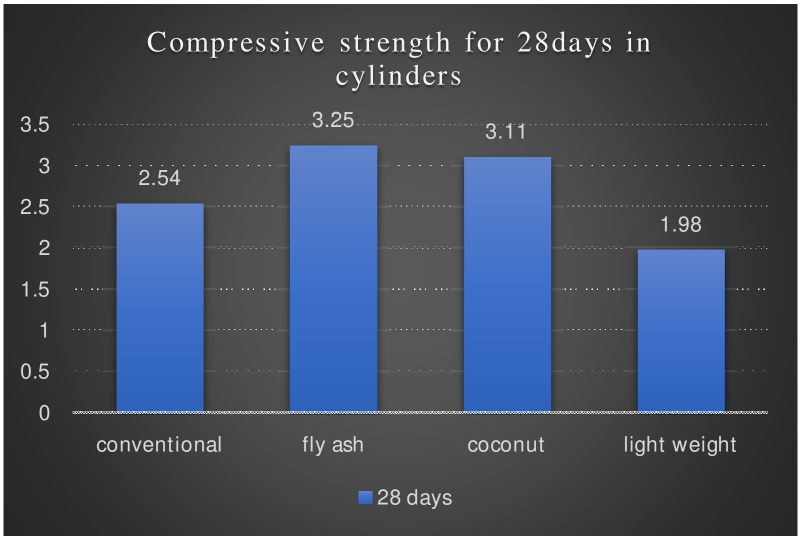

Chart 5

From the above chart 5 the compressive strength for 28days

- In Fly ash cylinders we observe that the compressive strength of cylinder is better compared to the coconut Fiber, conventional and lightweight concrete
- It is observed that the compressive strength for 28days in all cylinders is similar in strength expect in lightweight cubes

Self-Healing


Fig7&8: Filling of cracks in cubes

The improved self-healing efficiency of the self-healing concrete can be attributed to the use of bacteria, which produce calcite and fill in the cracks and damages. The bacteria are able to survive in the concrete for extended periods of time, allowing the concrete to self-heal over time. We observe that the Bacillus Subtilis bacteria is heal the cracks by releasing the calcium carbonate as a healing material. It takes 7 to 28 days for healing process to occur, in our case it took nearly 18 days to fill up the cracks (i.e 0.5-1mm)

VII. CONCLUSION

A comparative study on conventional, fly ash, coconut coir, light weight concrete and self-healing concrete reveal significant enhancement in compressive strength with increasing fly ash, coconut fiber, clay balls. Replacement of fly ash, coconut fiber levels of 25%, 1.5%.the results showed that the compressive strength increased progressively with the edition of fly ash, coconut fiber. these materials demonstrated a substantial improvement in compressive strength.

Specifically, at 7days the conventional concrete cubes exhibited a compressive strength of 21.54 Mpa at a load of 550KN. In contrast, the fly ash concrete, coconut fibre concrete cubes showed varying compressive strength based on the partial replacement of fly ash and coconut fibre percentage level. Furthermore at 28 days the compressive strength of conventional concrete cubes was 38.8mpa at a load of 875KN. in comparison of fly ash concrete, coconut fibre concrete was maximum strength of 32.9mpa at a load of 750KN. however the cylinders of conventional concrete was a compressive strength 28days 2.54mpa at a load of 225KN.

We observed that the light weight concrete can decrease the 40% of the actual concrete density by replace the light aggregate (clay balls). Compared to other cubes the light weight concrete has gained lesser compressive strength because of it's light weight components

VIII. ACKNOWLEDGMENT

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