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Investigation of Effect on Strength Parameters of Concrete by Replacing Ingredients by Environment-friendly Materials

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Abstract: This project looks at how we can make M20 grade concrete more environmentally friendly by changing some of its basic ingredients without losing strength. In place of using only ordinary cement and natural stone, part of the cement is replaced with fly ash and GGBS, and part of the coarse aggregate is replaced with coconut shells, which are usually treated as waste. The work includes testing all the materials, designing mixes as per IS 10262:2019, preparing both modified and conventional concretes, and then checking slump, density, and compressive, split tensile, and flexural strength at different ages. The results show that the modified concrete can still meet M20 strength requirements, has slightly lower weight, and benefits from the combined effect of the added materials, while a basic cost comparison indicates that higher replacement levels can also reduce overall concrete cost. Overall, the study suggests that using industrial by-products and agricultural waste in concrete is a practical way to support more sustainable and economical construction.

Keywords: Eco-friendly concrete; M20 grade concrete; fly ash; ground granulated blast furnace slag (GGBS); coconut shell aggregate; workability; compressive strength; split tensile strength; flexural strength; cost analysis; environmentally sustainable concrete.

I. INTRODUCTION

Concrete is a widely used construction material known for its strength, durability, and versatility. Its properties depend on the type and proportion of cement, water, aggregates, and other additives used in the mix. However, cement production and raw material extraction contribute significantly to carbon emissions and environmental damage. To reduce this impact, sustainable alternatives such as fly ash, slag, geopolymer concrete, and recycled aggregates are being explored. This research aims to study the mechanical performance of eco-friendly materials and promote low-carbon concrete solutions for sustainable construction. Also, it is tried to keep cost of concrete as low as possible. It will provide more benefits. The study focuses on achieving an optimal balance between strength, durability, sustainability, and economy. The findings are expected to contribute toward the development of environmentally responsible and cost-effective construction practices for future infrastructure projects.

II. METHODOLOGY

A. Introduction

This chapter presents the experimental methodology adopted to study the strength parameters of M20 grade concrete by partially replacing OPC with fly ash and GGBS, and replacing a portion of coarse aggregate with coconut shells.

B. Materials

1) Cement: Ordinary Portland Cement (OPC 53 Grade) was used as the primary binder. Class F fly ash and GGBS were used as partial replacements.
2) Aggregates: River sand (Zone II as per IS 383) was used as fine aggregate. Crushed stone (20 mm) was used as conventional coarse aggregate. Coconut shell aggregate was used as a partial replacement of coarse aggregate to promote sustainability and reduce density.
3) Water: Potable water satisfying IS 456:2000 requirements was used for mixing and curing, maintaining a water–binder ratio of 0.4.
4) Chemical Admixture: A polycarboxylate-based superplasticizer (up to 0.8%)

C. Properties and Tests on Materials

All materials were tested as per relevant IS codes. Tests included specific gravity, fineness, setting time, grading, water absorption, and impact value. Coconut shell aggregate showed higher water absorption, which was compensated during mix preparation. All materials satisfied standard requirements for experimental use.

D. Equipment Used

Equipment included digital weighing balance, slump cone apparatus, universal testing machine (UTM), compression testing machine (CTM), impact testing machine, split tensile and flexural testing setups, standard cube/cylinder/prism moulds, and curing tanks.

III. CONCRETE MIX DESIGN

Component	Conventional Mix	Mix 1 (20% FA, 15% GGBS)	Mix 2 (10% FA, 10% GGBS)
OPC	420 kg/m³	273 kg/m³	336 kg/m³
Fly Ash	0 kg/m³	84 kg/m³	42 kg/m³
GGBS	0 kg/m³	63 kg/m³	42 kg/m³
Water	149kg/m³	140 kg/m³	145 kg/m³
Superplasticizer	0 kg/m³	3 kg/m³	3 kg/m³
Fine Aggregate	648.72 kg/m³	685 kg/m³	670 kg/m³
Coarse Aggregates	1175 kg/m³	998.75 kg/m³	998.75 kg/m³
Coconut Shell	-	176.25 kg/m³	176.25 kg/m³
Air Content	~2%	~2%	~2%

Table No.1: Concrete Mix Design

IV. TEST RESULTS

A. Workability (Slump Test)

Sr. No.	Mix	Slump (mm)
1	Conventional	85
2	Mix 1	79.7
3	Mix 2	85

Table 2: Slump Values (mm)

B. Compressive Strength Test

Sr. No.	Mix	Strength in MPa		
		7 Days	14 Days	28 Days
1	Conventional	14.8	18.7	22.9
2	Mix 1	13.2	16.9	20.6
3	Mix 2	14.1	18.1	21.9

Table 3: Compressive Strength Test Results (MPa)

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C. Flexural Strength Test

r. No.	Mix	Strength in MPa		
		7 Days	14 Days	28 Days
1	Conventional	1.74	2.47	3.23
2	Mix 1	1.6	2.4	3.0
3	Mix 2	1.8	2.6	3.3

Table 4: Flexural Strength Test Results (MPa)

D. Split Tensile Strength Test

Sr. No.	Mix	Strength in MPa		
		7 Days	14 Days	28 Days
1	Conventional	1.27	1.67	2.17
2	Mix 1	1.23	1.6	2.0
3	Mix 2	1.3	1.7	2.2

Table 5: Split Tensile Strength Test Results (MPa)

V. TEST RESULT ANALYSIS

A. Workability Test Results Analysis

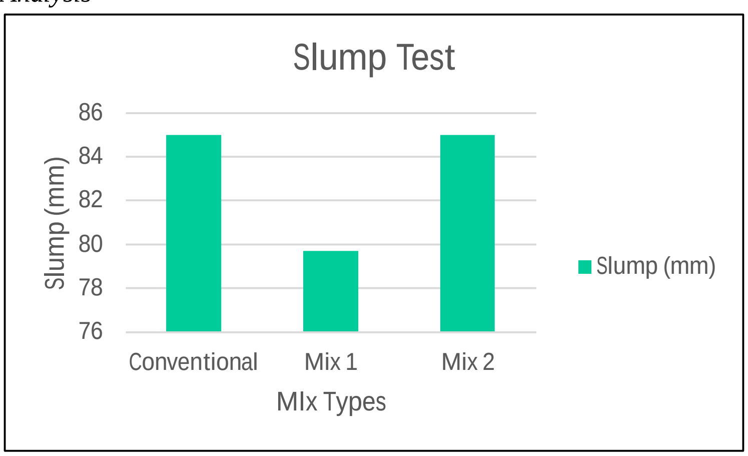

Fig. 1. Workability Test Results Analysis

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The slump values of all mixes were within acceptable limits for M20 grade concrete. Mix 1 showed slightly reduced workability (79.7 mm) compared to the conventional mix (85 mm), while Mix 2 maintained similar workability.

B. Compressive Strength Test Result Analysis

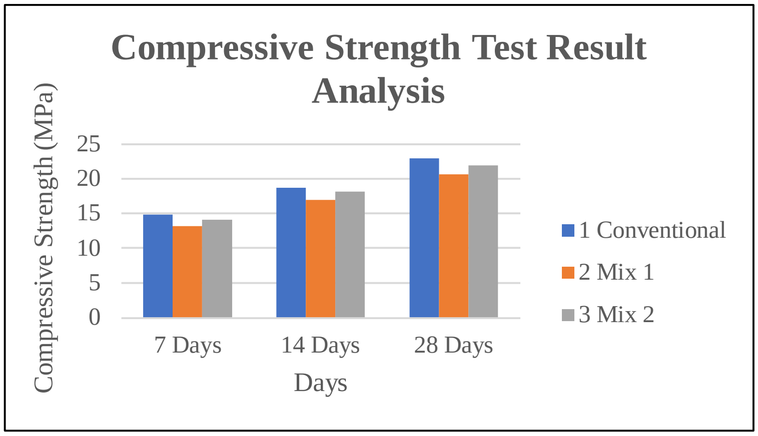

Fig. 2. Compressive Strength Test Results Analysis

At 28 days, conventional concrete achieved the highest compressive strength (22.9 MPa), slightly exceeding the Mix 1 concrete (20.6 MPa) and Mix 2 concrete 21.9 MPa, which is also above the required strength for M20 grade. This confirms that partial replacement of cement with fly ash and GGBS does not adversely affect strength when proportioned properly.

C. Flexural Strength Test Result Analysis

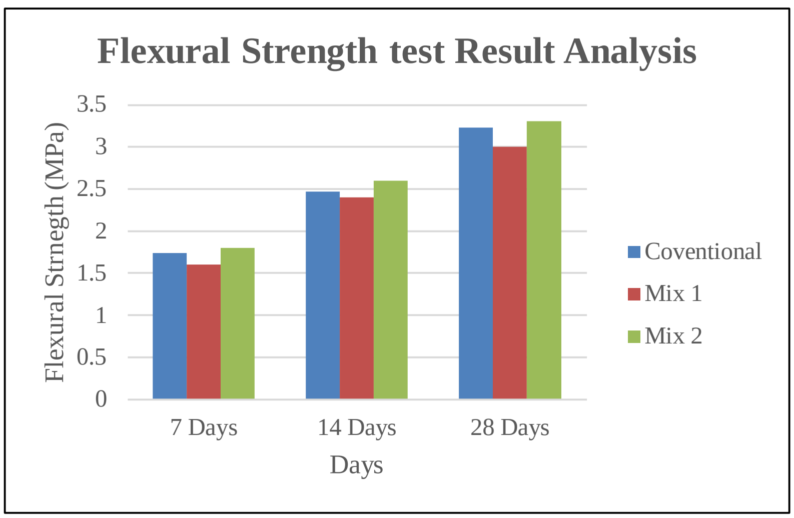

Fig. 3. Flexural Strength Test Results Analysis

Flexural strength followed a similar trend, with Mix 2 achieving the highest value (3.3 MPa), exceeding conventional concrete (3.23 MPa). This suggests enhanced bonding and matrix performance due to supplementary cementitious materials.

D. Split Tensile Strength Test Result Analysis

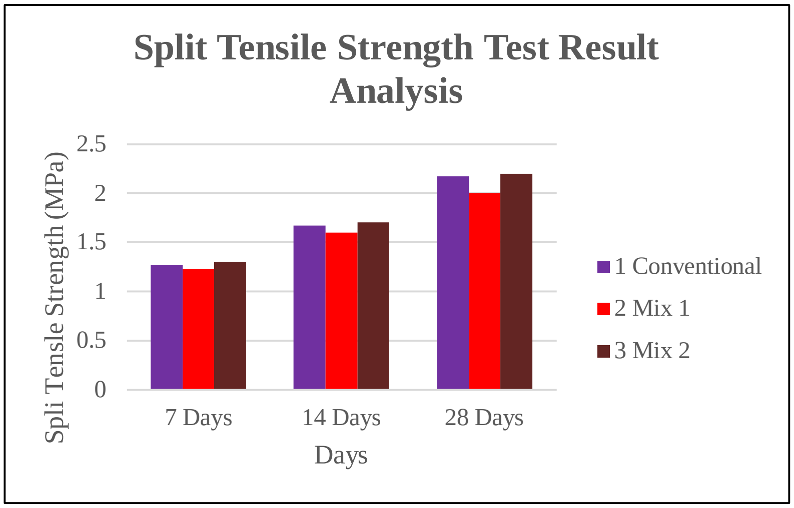

Fig. 4. Split Tensile Strength Test Results Analysis

Mix 2 demonstrated improved tensile performance (2.2 MPa) compared to conventional concrete (2.17 MPa), while Mix 1 showed slightly lower but acceptable values (2.0 MPa). This indicates that the modified binders contribute positively to tensile behaviour.

VI. CONCLUSION

This study examined the possibility of producing eco-friendly M20 grade concrete by partially replacing ordinary Portland cement with fly ash and GGBS, and coarse aggregate with coconut shell aggregate. Based on the experimental results, it was observed that the modified concrete was able to achieve the required strength for M20 grade at 28 days.

Although the early-age strength was slightly lower compared to conventional concrete, the later-age strength improved due to the pozzolanic reaction of fly ash and GGBS. The use of coconut shell aggregate reduced the overall density of concrete, resulting in a lighter mix while still maintaining acceptable mechanical properties. Workability was slightly reduced but was successfully controlled using superplasticizer.

Overall, the results indicate that industrial by-products and agricultural waste materials can be effectively used in concrete without significantly affecting strength performance. In addition to meeting structural requirements, the modified mix contributes to reduced environmental impact and potential cost savings. Therefore, the use of such eco-friendly materials can be considered a practical and sustainable alternative for future construction practices.

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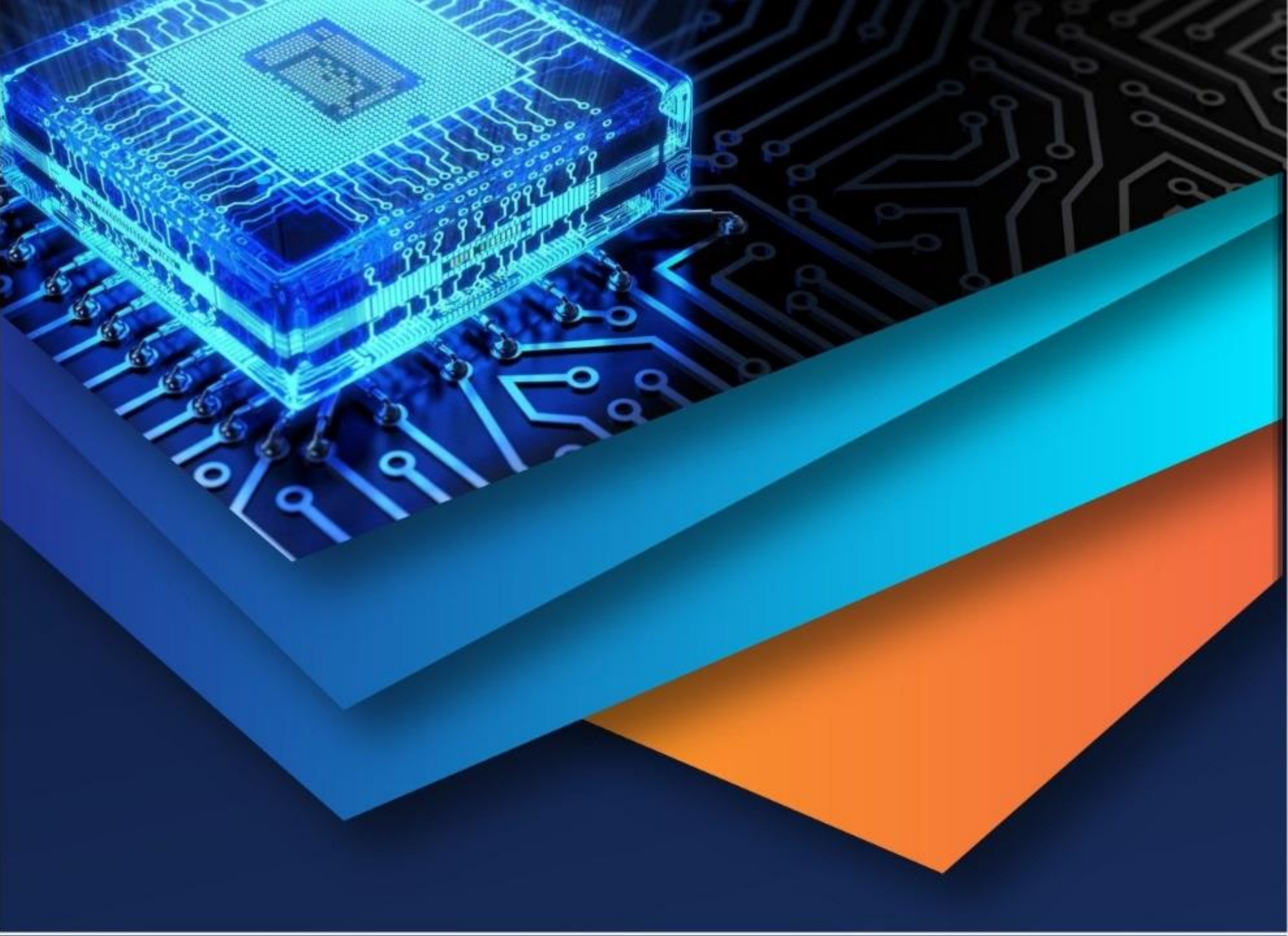

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