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EXPERIMENTAL INVESTIGATION ON BENDABLE CONCRETE (ECC) FOR M-25 GRADE

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Abstract: Engineered Cementitious Composite (ECC), also known as bendable concrete, is a type of mortar-based composite material that incorporates specially chosen short, randomly distributed fibers—typically polymer fibers—for reinforcement. Unlike traditional concrete, which is brittle and has a very low strain capacity of about 0.01%, ECC can undergo strains of around 3% to 7%, making it behave more like a ductile metal than fragile glass. This unique property makes ECC highly suitable for a wide range of structural and repair applications. In this study, one standard concrete mix was prepared using 70% cement, 30% fly ash, 100% fine aggregate (FA), and 100% coarse aggregate (CA), resulting in a total of 36 samples. Alongside this, three modified ECC mixes were produced by partially replacing components—specifically using 68.5% to 67.5% cement, 30% fly ash, 1.5% to 2.5% alkali-resistant glass fibers (ARGF), 100% fine aggregate, and eliminating coarse aggregate entirely—yielding 108 samples. Each mix consisted of 27 cube specimens (150×150×150 mm), 27 beam specimens (100×100×500 mm), and 27 cylinder specimens (150×300 mm). Additionally, 9 more samples of each type were prepared for durability testing, enabling performance comparisons across different ECC compositions.

Keywords: *Cement, Bendable Concrete, Alkali Resistant Glass Fiber, Partial Replacement, Durability, Compressive Strength, Flexural Strength, Split Tensile Strength.*

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I.INTRODUCTION:

The development of fiber-reinforced concrete has gone through several important stages over time. Back in the 1960s, researcher Romauldi and his team first showed that adding small steel fibers to concrete could significantly reduce its brittleness. Since then, advancements have led to the use of a wide variety of other fiber types, including glass, carbon, synthetic, and natural fibers. More recently, hybrid mixes combining different fiber types or lengths have also been explored. It's important to note that most of these fiber-reinforced materials typically don't include coarse aggregates, which technically makes them fiber-reinforced cement pastes or mortars rather than full concrete. However, because of their unique ability to bend under stress, they are known as ECC (Engineered Cementitious Composites) or BC (Bendable Concrete). Bendable concrete is quite different from traditional fiber-reinforced concrete. It is part of a specially designed class of materials created using micromechanics and fracture mechanics theories to deliver high tensile ductility. As a result, bendable concrete isn't a single fixed material, but rather a broad and growing category that includes various forms and applications, each at different stages of research and development. Designing and producing bendable concrete involves more than just mixing materials—it requires careful engineering and optimization at multiple levels, including the nano, micro, macro, and composite scales, to achieve its remarkable performance.

II MATERIAL USED

2.1 Cement: Ordinary Portland cement (OPC) is used in this research work.

2.2 Sand: Sand is available near Narmada River. This sand is usedfor the above research work.

2.3 Natural aggregate: 20 mm natural coarse aggregate is used having a specific gravity of 2.72.

2.4 Alkali Resistant Glass Fibre (ARGF): AR stands for Alkali resistant Glass Fiber. Glass fiber (or glass fibre) is a material containing of abundant extremely fine fibers of glass.

Glassmakers in history have conduct experiments with glass fibers, but mass production of glass fiber was only made promising with the creation of finer machine tooling.

Table 1: Properties of ARGF:

Properties	Observed value
Softening Point	850º C
Chemical Resistance	High
Elasticity Modulus	70 GPa x 106 psi
Tensile Strength	1700 Mpa
Dry Density	2.65 gm/cm³
Electrical Conductivity	Very Low
Fibre Diameter	10µm
Length of fibre	10mm

III. METHODOLOGY

3.1 Mix Design for M-25 Grade: The mix proportion for M25 grade concrete has been designed in accordance with IS 10262:2009 and IS 456:2000. The finalized mix ratio for cement, fine aggregate, and coarse aggregate is 1:1:2. A water-to-binder (w/b) ratio of 0.42 has been adopted to ensure adequate strength and workability.

3.2 Workability test: The workability of the concrete mix was assessed using the slump cone test.

The slump values obtained ranged between 75 mm and 45 mm, indicating a medium degree of workability suitable for most structural applications.

3.3 Compressive Strength Test: Cubic specimens measuring 150 mm × 150 mm × 150 mm were cast for the compressive strength test.

After curing, the specimens were placed in a compression testing machine where load was gradually applied until failure. The load readings were recorded from the dial gauge, and compressive strength was determined at curing intervals of 7 days and 28 days.

3.4 Flexural Strength Test: Beam specimens with dimensions of 100 mm × 100 mm × 500 mm were prepared to evaluate the flexural strength of concrete.

After curing, the beams were subjected to two-point loading using a flexural testing machine. The applied load at failure was noted, and the flexural strength was calculated at both 7 days and 28 days.

3.5 Split Tensile Strength: Cylindrical specimens with a diameter of 150 mm and a height of 300 mm were cast for split tensile strength testing.

The cylinders were placed horizontally in a compression testing machine and loaded along the vertical diameter. The load at failure was recorded using the dial gauge, and tensile strength was computed at 7 days and 28 days of curing.

IV .TEST RESULTS

4.1 Workability

Table 2: Workability Result

Batches	% ARGF	Slump (mm)
Mix-01	0	75
Mix-02	1.5	72
Mix-03	2.0	65
Mix-04	2.5	61

4.2 Compressive Strength:

Table 3: Compressive Strength Result

Mix Design	% ARGF	7 days Compressive Strength	28 days Compressive Strength
Mix-01	0	13.64	24.13
Mix-02	1.5	13.96	28.17
Mix-03	2.0	16.24	27.36
Mix-04	2.5	15.36	28.67

4.3 Flexural Strength

Table 4: Flexural Strength Result

Mix Design	% ARGF	7 days Flexural Strength	28 days Flexural Strength
Mix-01	0	3.95	5.22
Mix-02	1.5	4.41	6.05
Mix-03	2.0	4.56	6.54
Mix-04	2.5	4.49	5.97

4.4 Split Tensile Strength

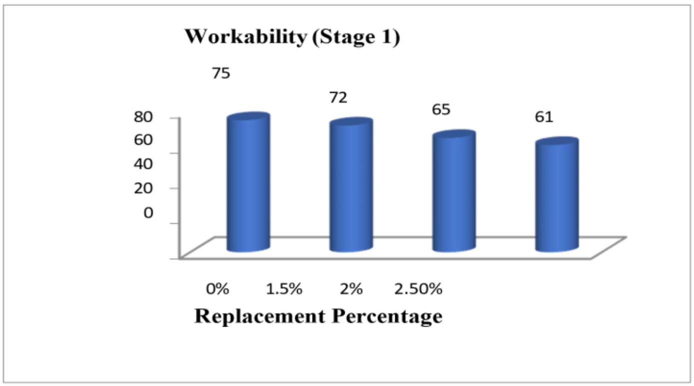
Table 5: Tensile Strength Result

Mix Design	% ARGF	7 days Split Tensile Strength	28 days Split Tensile Strength
Mix-01	0	4.00	4.91
Mix-02	1.5	4.95	5.70
Mix-03	2.0	5.51	6.84
Mix-04	2.5	6.22	6.69

V. DISCUSSION ON TEST RESULTS

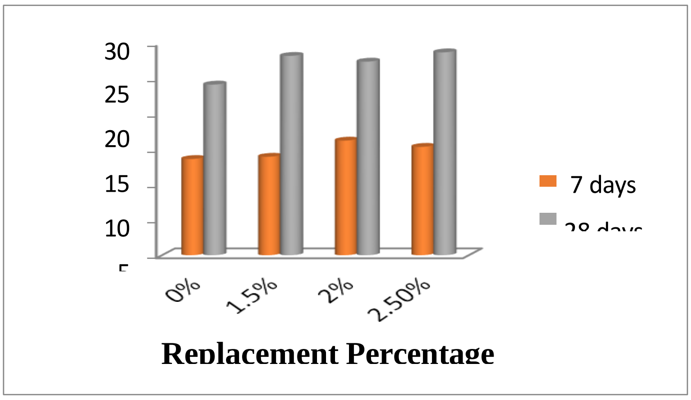
5.1 Workability:

As shown in Graph 1, the workability of the concrete mix decreases with an increase in the percentage of AFRG (Alkali-activated Fiber-Reinforced Glass).



Graph 1: Slump Test for workability (mm)

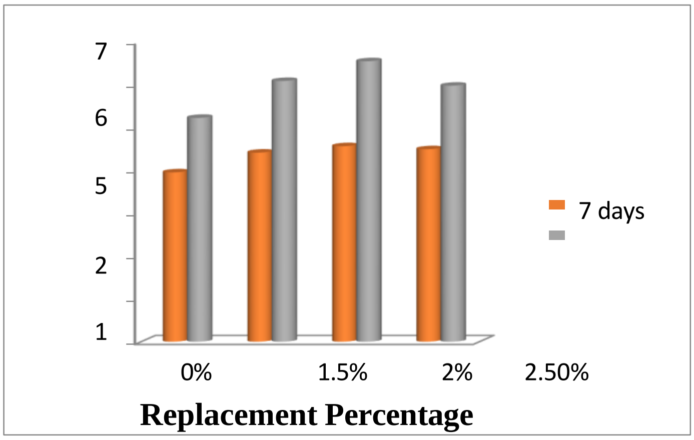
5.2 Compressive Strength Test: From Graph 2, it is evident that the compressive strength of the concrete increases with the addition of AFRG up to 2.5%. Specifically, the 7-day compressive strength shows an improvement of approximately 14.89%, while the 28-day strength increases by around 9.85% compared to the control mix.



Graph: 2. Compressive Strength in N/mm^2

5.3 Flexural Strength

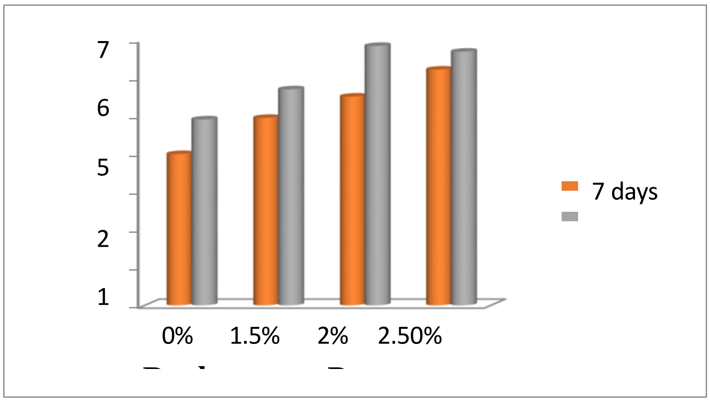
The flexural (bending) strength of the concrete also exhibits significant improvement with AFRG addition up to 2.5%. At this optimum percentage, the 7-day flexural strength increases by 16.14%, and the 28-day flexural strength increases by 13.77% over the control specimen.



Graph: 3 Flexural Strength in N/mm^2

5.4 Split Tensile Strength

Similarly, the split tensile strength of the concrete enhances with AFRG incorporation up to 2.5%. At this level, the 7-day tensile strength increases by 31.12%, and the 28-day tensile strength improves by 25.89% compared to the mix without AFRG.



Graph: 4 Split Tensile Strength in N/mm^2

VI .CONCLUSIONS

Based on the findings of this study, the following conclusions can be drawn:

A significant improvement in both flexural strength and compressive strength was observed when 2.0% of cement was partially replaced with ARGF (Alkali-Resistant Glass Fiber). However, there was a slight reduction in durability and split tensile strength at this same replacement level.

Despite the minor decrease in these properties, the overall performance of the concrete at 2.0% fiber replacement is considered optimal, offering enhanced mechanical strength while maintaining acceptable durability. Therefore, the partial replacement of cement with ARGF at 2.0% is found to be an effective and practical solution for improving concrete performance.

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