ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)

Vol 11, Issue 4, April 2024

Feasibility of using GFRP in Self-Curing Concrete

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Abstract— ***Self-curing concrete is a significant innovative concept for environmental sustainability. Countries are advancing while natural resources are disappearing. Water, a fundamental resource for living, is also depleting rapidly. To minimize this loss, Self-Curing Agents are utilized to eliminate the requirement for a curing procedure.***

This study will conduct an experiment on a slab of standard size to assess the viability of PEG-600 as a self-curing agent and its consequences. We will conduct fundamental Material Testing to determine its specifications for the Design Mix. Subsequently, the Slump concrete test will be carried out to assess workability, followed by Flexural and Compressive Strength studies by entirely substituting reinforcing with GFRP.

Index Terms— ***Aggregate, Composition, Glass Fiber Reinforced Polymer (GFRP), Mechanical Properties, PEG-600, Self-Curing.***

I. INTRODUCTION

A. General

Concrete is an essential construction material for contemporary infrastructure and building projects because of its adaptability, robustness, and longevity. Proper curing is essential for ensuring its long-term function. Self-curing concrete is a potential option that provides improved durability, sustainability, and efficiency. This article delves into the concepts, mechanisms, benefits, and prospective uses of self-curing concrete with the goal of comprehending its impact on the future of building and the development of more durable, environmentally friendly infrastructure.

B. GFRP

Glass Fiber-reinforced polymers (GFRPs) are plastic materials that enhance the rigidity and durability of plastics by the incorporation of glass Fiber components. The Fibers are created by pulling molten glass from an electrically heated furnace through platinum brushings at a rapid pace. GFRPs are a type of Fiber reinforced polymers that, when combined with a Fiber matrix, create fiberglass or glass reinforced polymer. The Fibers are created by extruding molten glass through a bushing constructed of a platinum alloy that is erosion-resistant. Following fib erization, the Fibers are attenuated, gathering the extruded glass into filaments.

Figure 1. GFRP

C. Properties of GFRP

GFRP is a glass fiber known for its great mechanical strength, lightweight properties, and resistance to corrosion. The material has a tensile strength ranging from 44 to 2358 MPa and a compressive strength ranging from 140 to 350 MPa. It is water and moisture resistant, although very concentrated acids can damage it. GFRP has superior resistance to corrosion and fungus, and does not undergo hazardous reactions when exposed to water, air, or gasses. The moisture level is less than 1%, unlike basalt materials that exhibit great resistance to fungus and bacteria. GFRP has a hardness range of 5 to 4 on Mohr's scale, leading to improved abrasion resistance and resistance to water abrasion in bars.

D. Composition of GFRP

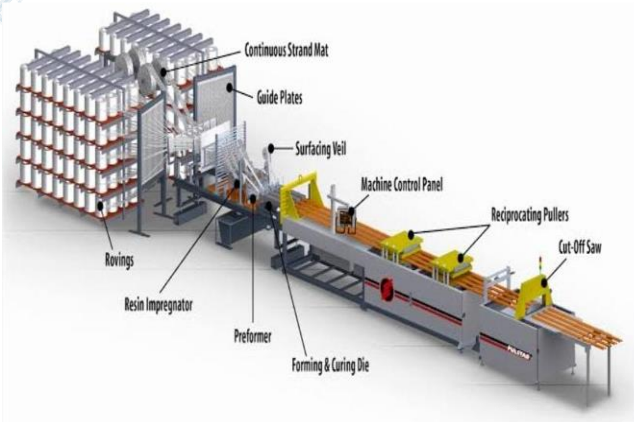

Figure 2. Composition of GFRP

Glass fiber reinforced polymer (GFRP) has been identified as a significant advancement in concrete technology for strengthening purposes. GFRP rebars are produced by combining longitudinal glass fibers as the reinforcing material with unsaturated polyester resin with 1% MEKP as the matrix material through a manual process.

II. AIMS AND OBJECTIVES

A. Aim

The aim is to investigate the viability of using Glass Fiber Reinforced Polymer (FRP) in Self-curing concrete.

B. Objectives

The study seeks to explore the viability of Glass FRP in self-curing concrete through tests, evaluate the mechanical characteristics of slabs reinforced with Glass FRP, and analyses the material properties of the components.

III. LITERATURE REVIEW

A. General

Studies indicate that polyethylene glycol can improve the mechanical characteristics of self-curing concrete, increasing its compressive strength by 41.13 MPa after 28 days and enhancing its flexural and split tensile strengths. The optimal proportions for self-curing concrete are 0.5% polypropylene Fiber and 15% waste marble powder. This technology decreases sand extraction and conserves 2 to 3 cubic meters of water for each cubic meter of concrete.

Self-curing concrete is a viable option for circumstances with limited curing water, as it hydrates more efficiently in dry conditions compared to traditional concrete. Adding 1-2% of polyethylene glycol (PEG) as a chemical addition can increase the slump value and improve strength by 8-15% compared to standard concrete. Self-healing concrete reduces autogenous shrinkage.

Optimal strength and durability are attained by combining 0.48% Poly vinyl alcohol (PVA) with 1% Sodium Lignosulphonate (SL). Spinacea pleracea and Calatropis gigantean are plant-based materials known for their exceptional mechanical properties. LECA enhances workability but decreases compressive and flexural strength.

Research has focused on current curing methods including fly ash, silica fume, GGBS, and 90% recycled cement. The optimal strength growth occurred after 28 days while curing under direct sunshine, but acrylic-based curing chemicals were suggested for water saving.

Studies have shown that self-curing concrete with 1% PEG4000 exhibits greater strength compared to a conventional sample made with M40. Flexural tensile strength decreases over time, with 1% PEG4000 seeing a reduction of 37.57% and 45.65%.

Recycled aggregates like broken concrete and crushed red bricks provide satisfactory durability against chloride and sulphate attacks. This strategy helps save natural resources and reduce its environmental footprint.

B. Summary

PEG-400 solution improves the compressive strength, flexural strength, and split tensile strength of concrete when compared to standard concrete. It enhances strength and slump value by 8-15% when used with 1–2% PEG. Concrete that cures on its own with 1% PEG4000 is stronger than M40 concrete. PEG 400 reduces the maximum loads and early cracking caused by chloride exposure and enhances water retention ability. The ideal proportions for self-curing concrete are 15% residual marble powder and 0.5% polypropylene Fiber. Self-curing concrete maintains moisture, which helps to reduce shrinkage and creep effects in the concrete. The content percentage rises as the intensity decreases, reaching a maximum of 4%. Concrete that cures itself with PEG-400 shows an average 2.25% improvement in compressive strength compared to traditional curing methods. The ideal dose for achieving the highest compressive strengths is 1% of the weight of cement in M25 grade concrete. The peak strength is 36.63 MPa at a concentration of 0.3% calcium lignosulfonate, with a minimum density requirement of 0.35% CLS. Hardened concrete with the ideal amount of PEG400 shows superior mechanical qualities compared to those with the ideal amount of PAM at the same stages of development.

IV. METHODOLOGY

A. Problem Formulation

Experiments often include testing cubes, however there are few instances where other pieces including beams, columns, and slabs are used. This research will involve conducting experiments on slabs to identify their requirements, as there are limited instances of slabs being used in an experimental context.

B. Materials Used:

These are materials which were used while performing these experiments:

- M25 Grade Concrete
- GFRP as Reinforcement &
- PEG-600 as Self-Curing admixture

C. Materials Testing

1) *Properties of Cement:* Testing cement material is an essential quality control procedure in the construction sector, evaluating its physical and chemical characteristics to verify compliance with required standards and specifications. Key tests in cement analysis are the Fineness Test (Blaine Test) for particle size, the Setting Time Test for setting times, the Soundness Test for volume stability, the Consistency Test for water requirement, and the Compressive Strength Test for strength evaluation. Additional tests comprise the Soundness of Cement using the Le-Chatelier Method, Loss on Ignition (LOI), Chemical Composition Analysis, and the Setting Time determined by the Gillmore Needle Test. These tests verify that the cement complies with the prescribed criteria and guarantee appropriate handling and curing.

ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)

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Table 1. Physiacal properties of cement

Sr No.	*Particulars*	*Test Results*	*IS CODES*
1	Fineness Modulus	294 m^2/kg	IS:4031 PART-1-1988
2	Standard Consistency	28.5 (%)	IS 4031
3	Setting Time: Initial Final	 180 min 250 min	IS 8142:1976
4	Soundness: Le-Chat Expansion Autoclave Expansion	 1.0 mm 0.060 mm	IS 5514
5	Compressive Strength: 72 +/- 1hr. (3days) 168 +/- 2hr. (7days) 672 +/- 4hr. (28days)	 40.0 MPa 52.0 MPa 73.0 MPa	IS 4031 PART-6

Table 2. Chemical properties of cement

Sr No.	*Particulars*	*Test Results*
1	CaO – 0.7SO_3 / 2.8Sio_2 + 1.2Al_2O_3 + 0.65 Fe_2O_3	0.88
2	Al_2O_3 / Fe_2O_3	1.23
3	Insoluble Residue (% by mass)	1.87
4	Magnesia (% by mass)	0.86
5	Sulphuric Anhydride (% by mass)	1.73
6	Total Loss on Ignition (% by mass)	1.88
7	Total Chlorides (% by mass)	0.008

2) Properties of Aggregate: Testing aggregates is vital for quality control in construction since they are fundamental elements in concrete, asphalt, and other building materials. Common tests include Gradation Test (Sieve Analysis), Specific Gravity and Absorption Test, Bulk Density Test, Particle Shape and Surface Texture, Clay, Silt, and Dust Content Test, Los Angeles Abrasion Test, Flakiness and Elongation Index Test, Alkali-Silica Reactivity (ASR) Test, Petrographic Analysis, Soundness Test, and Organic Impurities Test. The tests evaluate the physical and chemical characteristics of aggregates to verify compliance with required standards and specifications.

The Gradation Test, also known as Sieve Analysis, assesses particle size distribution, whereas the Specific Gravity and Absorption Test quantifies specific gravity and water absorption. The Bulk Density Test quantifies the mass of a certain volume of aggregates, which impacts the amount of empty space in a concrete mixture. Particle shape and surface texture are visually inspected to confirm they fulfill specified standards. The Alkali-Silica Reactivity (ASR) Test detects possible alkali-silica interactions that may cause concrete to expand and fracture.

Performing Petrographic Analysis is crucial for comprehending any durability concerns. The Soundness Test assesses the ability of aggregates to withstand disintegration or breakdown caused by freeze-thaw cycles. The Organic Impurities Test detects organic substances in aggregates, which might diminish concrete strength if present in high amounts.

Table 3. Physical properties of aggregates

Sr No.	*Particulars*	*Test Results*	*IS CODES*
1	Fineness Modulus: Coarse Aggregate(10mm) Coarse Aggregate(20mm) Fine Aggregate (Sand)	 3.05 3.08 2.77	IS 383
2	Elongation and Flakiness Index: 20 mm 10 mm	 10.77/9.77 13.75/11.96	IS 2386 part-1 1963
3	Bulk Density: 20 mm 10mm Sand	 1.64 1.7 1.68	IS 2386(Part-III)-1963
4	Specific Gravity: 20 mm 10 mm Sand	 2.85 2.85 2.66	IS 2386
5	Water Absorption: 20 mm 10 mm Sand	 1.37 1.39 2.55	IS 2386

3) Properties of GFRP and PEG-600:

Table 4. Properties of gfrp

Sr No.	*Particulars*	*Density*	*Specific Gravity*	*Young's Modulus*
1	GFRP	1.5 – 2.5 gm/cm^3	483 – 4580 MPa	35 – 86 GPa

Table 5. Properties of peg-600

Sr No.	*Particulars*	*Density*	*Specific Gravity*	*Solubility*
1	PEG-600	1.13 kg/cm^3	1.12	Soluble in water

D. Fresh Concrete Test

Testing fresh concrete is crucial to verify it satisfies the specified quality and performance standards prior to being placed. The slump test assesses the consistency and workability of concrete. The data can be used to make modifications to the mix design, placing techniques, or curing operations in order to obtain the required quality and performance. IS: 1199-1959 A Slump Concrete Test was

ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)

Vol 11, Issue 4, April 2024

performed on the concrete with different concentrations of curing agent and GFRP reinforcement. These tests guarantee that the concrete satisfies the precise criteria of the construction project.

E. Hardened Concrete Test

Testing is conducted on hardened concrete to evaluate its strength, durability, and other attributes once it has fully cured. Common tests often involve the compressive strength test, which assesses the maximum load a concrete specimen may withstand before fracturing. This test requires the preparation of cylindrical or cube-shaped specimens and subjecting them to a load until they fail. Tensile strength tests, like splitting tensile and flexural strength tests, evaluate the concrete's ability to withstand being pushed apart or bent. Cylinder specimens are tested using a universal testing machine, whereas beam specimens are used for flexural strength tests. The modulus of rupture indicates the flexural strength and records the maximum load. These tests assess the durability and strength of the concrete after it has been cured.

V. RESULTS

A. Compressive Strength

The compressive strengths of each combination are presented in the table that may be found below. As can be observed in Figure 4.1, the addition of self-curing chemicals to concrete mixes is associated with an increase in compressive strength throughout the process of self-curing. A range of PEG-600 concentrations, from 0% to 5%, was utilized in the process of conducting experiments. An observation was made about the behavior of PEG-600, which revealed a progressive increase in Compressive Strength Value up to a concentration of 1.25% concentration. A concentration of 1.25 percent was found to produce the highest value, which was then followed by a drop in value as the concentration of the substance in concrete increased.

Table 6. Compressive strength (N/mm^2)

Sr No.	*Mix*	*7th Day*	*28th day*
1	N0	17.28	28.2
2	P0.25	17.52	28.33
3	P0.50	17.44	28.57
4	P0.75	17.64	28.72
5	P1.00	18.14	28.55
6	P1.25	18.29	28.83
7	P1.50	18.12	29.11
8	P1.75	17.94	28.83
9	P2.00	17.54	28.57
10	P2.25	17.67	28.14
11	P2.50	17.23	27.57
12	P2.75	17.22	27.39
13	P3.00	17.13	27.14
14	P3.25	16.99	26.98
15	P3.50	16.98	27.00
16	P3.75	16.86	26.86
17	P4.00	16.80	26.80
18	P4.25	16.60	26.74
19	P4.50	16.42	26.31
20	P4.75	16.45	26.44
21	P5.00	16.28	26.36

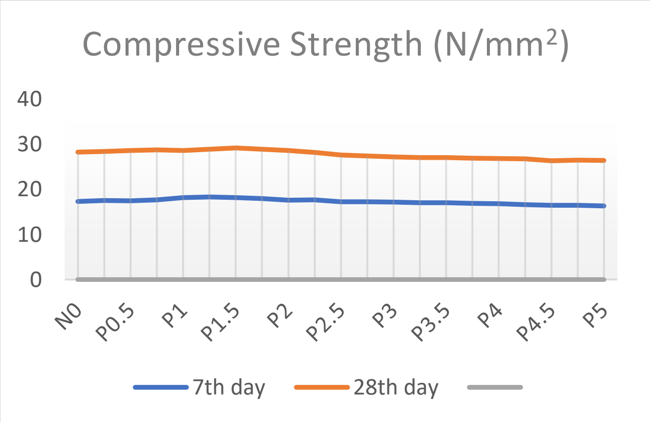

Figure 3. Graphical representation of Compressive Strength

B. Split tensile Strength

In order to evaluate cylinder specimens with dimensions of 150 millimetres in diameter and 300 millimetres in height, a universal testing apparatus was utilized. The weight was applied in a smooth and consistent manner throughout the vertical diameter of the cylinder until it finally broke. By putting a load along the generatrix element on the vertical diameter of the cylinder while it is under tension in the horizontal direction, the split tensile strength may be calculated. Throughout the course of the experiment, concentrations ranging from 0% to 2% were utilized, and it was noted that the value increased up to 2%, reaching its highest point. The figure was then reduced as a consequence of the subsequent rise in concentration, which was brought up to 5%.value.

Table 7. Split tensile strength (N/mm^2)

Sr No.	*Mix*	*7th Day*	*28th day*
1	N0	2.03	3.08
2	P0.25	2.04	3.14
3	P0.50	2.12	3.19

ISSN (Online) 2456-1290
International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
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Sr No.	Mix	7th Day	28th day
4	P0.75	2.19	3.29
5	P1.00	2.24	3.33
6	P1.25	2.31	3.39
7	P1.50	2.37	3.45
8	P1.75	2.46	3.84
9	P2.00	2.57	3.85
10	P2.25	2.5	3.75
11	P2.50	2.45	3.6
12	P2.75	2.36	3.52
13	P3.00	2.26	3.41
14	P3.25	2.19	3.25
15	P3.50	2.09	3.16
16	P3.75	2.01	3.04
17	P4.00	1.96	3.00
18	P4.25	1.96	2.93
19	P4.50	1.81	2.92
20	P4.75	1.77	2.84
21	P5.00	1.71	2.80

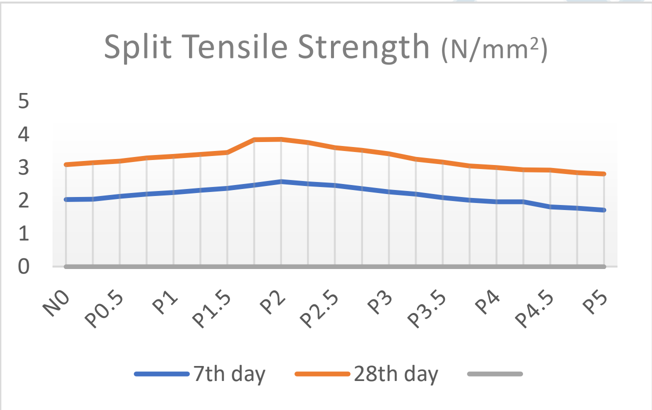

Figure 4. Grphical representation of Split Tensile Strength

C. Flexural Strength

The capacity of a beam or slab to provide resistance to failure brought on by bending is referred to as its flexural strength. Utilizing a compression testing equipment, beam specimens with dimensions of 100 millimetres by 100 millimetres by 700 millimetres were examined. There is a relationship between the flexural strength and the modulus of rupture, which is measured in N/mm2. After the specimen's resistance to the load was overcome and it could no longer be sustained, the force that was delivered to the specimen steadily increased at a steady pace until it reached its maximum capacity. There was documentation of the specimen's maximum load capacity. The data shown in the table reveals that concentrations ranging from 0.5 percent to 5 percent were employed. The data demonstrates that the value increased up to a point of 2%, but subsequently reduced when the concentration reached a point of 5%.

Table 8. Flexural strength (N/mm^2)

Sr No.	Mix	7th Day	28th day
1	N0	3.15	3.91
2	P0.25	3.13	3.89
3	P0.50	3.23	3.98
4	P0.75	3.39	4.08
5	P1.00	3.43	4.08
6	P1.25	3.45	4.21
7	P1.50	3.51	4.36
8	P1.75	3.55	4.37
9	P2.00	3.56	4.42
10	P2.25	3.45	4.31
11	P2.50	3.36	4.26
12	P2.75	3.29	4.18
13	P3.00	3.28	4.09
14	P3.25	3.2	3.92
15	P3.50	3.12	3.81
16	P3.75	3.01	3.69
17	P4.00	2.93	3.64
18	P4.25	2.88	3.62
19	P4.50	2.85	3.54
20	P4.75	2.77	3.47
21	P5.00	2.73	3.43

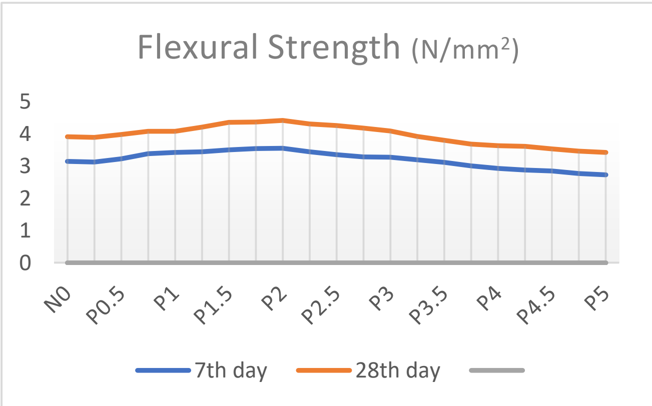

Figure 5. Graphical representation of Tensile Strength

VI. CONCLUSION

- Compressive strength is increased by self-curing additives in concrete mixtures. PEG-600 concentrations ranging from 0% to 5% were utilized in the tests.

- PEG-600 exhibited a continuous rise in Compressive Strength Value till reaching a concentration of 1.25%.
- The maximum value was achieved at a concentration of 1.25 percent, followed by a decrease as the chemical concentration rose.
- Cylinder specimens were evaluated using a universal testing instrument.
- Tensile strength was determined by applying a force along the vertical diameter of the cylinder.
- The flexural strength and modulus of rupture were measured in N/mm2. The maximum load capacity was determined with concentrations ranging from 0.5% to 5%.

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