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Experimental Study of using Sodium Polyacrylate as a Self-Curing Agent in Fiber Reinforced Concrete

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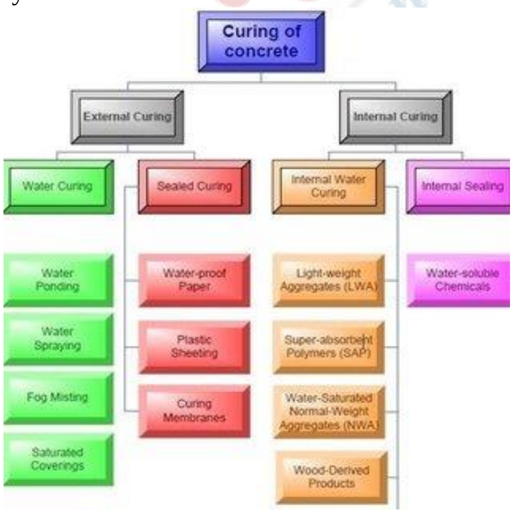
Abstract*— An innovative and environmentally beneficial method to minimize the requirement for external curing in construction is by use self-curing concrete. It avoids the necessity for external curing by regulating moisture levels through specific admixtures or internal water reservoirs. This method is advantageous for producing high-performance and high-strength concrete used in large-scale projects including skyscrapers, tunnels, bridges, and shotcrete. Self-curing concrete uses high-quality components to guarantee the durability and strength of the building. The project's objective is to investigate the physical and mechanical characteristics of sodium polyacrylate as a self-curing agent through trials including standard-sized cubes with concentrations varying from 0.25% to 5%, along with AR Glass Fibers at a concentration of 1%. The results will be compared to those obtained from conventional concrete.

Keywords: AR Glass Fiber, External Curing, Internal Curing, Mechanical Properties, Self-Curing, Sodium Polyacrylate.

I. INTRODUCTION

The importance of concrete as a widely used building material owing to its versatility and strength is discussed in the article. But it also emphasizes how crucial it is to properly cure during the first phases of setting and hardening in order to avoid problems like strength loss and cracking. Conventional curing techniques need a lot of work and resources, as well as frequent care and watering. Self-curing concrete is a recent invention that lessens or eliminates the need for traditional curing methods by adding chemicals that release moisture or hold water to the concrete mix. With the use of this technology, concrete constructions will be stronger, last longer, and be of higher quality while also being easier to construct. For high-performance and high-strength concrete used in massive constructions like skyscrapers, tunnels, and bridges—where low water to cement ratios are crucial for stability and durability—self-curing concrete is especially well suited.



A. Principles of Self-Curing Concrete

Concrete that cures on its own is a technique that keeps the structure's moisture content constant without outside help. Even under severe circumstances, it maintains a steady moisture content in the structure by using chemicals that either release or hold water. By dispersing the self-curing chemicals uniformly throughout the concrete mixture, they guarantee constant hydration and lessen regional dryness. The materials that store moisture gradually release water over time to match the rate at which moisture is lost through evaporation and hydration. Throughout the early phases of setting and hardening, this controlled release guarantees constant hydration. Self-curing concrete lessens the possibility of cracking, which might compromise the longevity and structural integrity of the building.

B. Materials and Technologies in Self-Curing Concrete

Self-curing concrete may be produced using a range of materials and procedures, depending on the specific use and desired results. Self-curing concrete incorporates many crucial components:

- **Use of Lightweight Aggregates:** Porous aggregates like expanded shale, clay, slate are used for internal curing. They absorb and hold onto moisture, releasing it gradually into the concrete mixture.
- **Superabsorbent Polymers (SAPs):** These polymers preserve moisture in concrete, aiding self-curing.
- **Chemical Admixtures**: These additives can improve concrete's self-curing ability by altering water's surface tension.
- **Biological Agents**: Bacteria can generate calcium carbonate, sealing fissures and increasing durability when exposed to moisture.
- **Shape Memory Polymers:** These materials revert to

a predetermined shape in response to heat, aiding in structural rehabilitation.

- **UV Light-Cured Materials:** These materials, including coatings and adhesives, can be cured without moisture or heat.

C. Benefits of Self-Curing Concrete

Numerous advantages provided by self-curing concrete have the potential to revolutionize the building sector are:

- **Increases Strength:** Self-curing concrete maintains continuous moisture levels, enhancing its strength.
- **Reduces Cracking:** Maintaining proper moisture levels reduces the likelihood of internal and external cracking, enhancing structure longevity.
- **Enhances Durability:** Self-curing concrete is more resistant to environmental elements like chemical exposure and freeze-thaw cycles.
- **Enhances Workability**: Self-curing concrete is easier to work with and finish, making it suitable for various applications.
- **Promotes Environmental Sustainability:** Self-curing concrete uses less water and has a less environmental impact.
- **Allows Weather Independence:** Self-curing concrete is less reliant on weather.
- **Offers Cost Savings**: Despite initial costs, self-curing agents and technologies can save significant money over time.

D. Applications of Self-Curing Concrete

Self-curing concrete is a versatile and adaptable material used in various construction projects. It is commonly used in high-performance concrete, mass concrete, repair and restoration, sustainable construction, cold weather buildings, and precast and ready-mix operations. It helps regulate temperature differentials, reduce thermal cracking risk, strengthen the relationship between old and new concrete, and achieve green building standards. It is also increasingly used in precast and ready-mix operations for precise control of concrete quality and curing conditions.

E. AR Glass Polymer Fibers

AR glass polymer is a composite material made from glass fibres and a polymer matrix. It is robust, lightweight, and resistant to corrosion, making it suitable for various industries such as infrastructure, automotive, marine, and construction. AR glass polymer is particularly useful in situations with harsh chemicals or alkaline materials, such as boat construction, concrete building reinforcement, and lightweight automobile components. The material's strength, durability, and resistance to corrosion make it a great choice for applications where weight and strength are equally important. The production process involves pultrusion, filament winding, and resin infusion, where the polymer resin is infused into the glass fibres and allowed to cure. This process reduces the weight of transportation and building components, saving energy and potentially improving the environment. The material's alkali resistance makes it ideal for use in areas like marine and offshore environments, where it can improve overall performance and fuel efficiency. AR glass polymer not only offers variety but also contributes positively to the environment by decreasing the weight of transportation and building components. Its lightweight design and ease of handling make it an attractive option for various applications. Overall, AR glass polymer offers a balance between strength, durability, and corrosion resistance, making it a valuable choice for various industries.

Fig. 1. AR Glass Fibers

F. Sodium Polyacrylate

Sodium polyacrylate, a water-absorbing polymer, can significantly enhance the moisture retention in self-curing concrete. It helps maintain the concrete's hydration during the initial stages of setting and hardening, reducing the risk of internal and surface cracking. This enhances the concrete's structural integrity and durability. Sodium polyacrylate also ensures even moisture distribution, minimizing localized drying and providing reliable curing conditions. Its use is convenient, as it doesn't require external curing techniques, making it suitable for various building uses, including infrastructure, industrial, residential, and commercial projects. Additionally, sodium polyacrylate-cured self-curing concrete is environmentally friendly, saving energy, resources, and water resources. This method ensures equal moisture distribution throughout the concrete mix, making it a valuable addition to the building sector when traditional curing methods are difficult or unfeasible. Overall, sodium polyacrylate is a valuable addition to the self-curing concrete industry, offering numerous benefits in terms of quality, convenience, and sustainability.

Fig. 2. Sodium Polyacrylate

II. AIMS AND OBJECTIVES

A. Aim

The aim is to conduct an experimental investigation on the effects of Sodium Polyacrylate as a self-curing agent on fiber-reinforced concrete utilizing AR Glass fiber.

B. Objectives

The goals are to conduct experiments on a standard cube and determine its characteristics:

- Finding Material Properties including Chemical Composition, Cement Grade 53, sizes, zone, source, and specific gravity of Aggregates.
- Performing Design Mix for grade M35 concrete.
- Evaluate the workability of concrete by performing a Slump Concrete Test.

The objective is to assess the mechanical properties, namely the compressive and tensile strength, of self-cured concrete with M35 grade. Additionally, the self-curing capabilities will be evaluated by including AR glass fibres as reinforcements.

III. LITERATURE REVIEW

A. General

Research has been conducted on self-curing concrete to analyse its characteristics and behaviour under different curing methods. The optimal dose of PEG400 was found to be 1% for M20 class concrete and 0.5% for M40 class concrete, resulting in an increase in slump as the percentage rose. Self-curing compound (PEG-400) blends for M25 and M40 grade concrete exhibit compressive strengths comparable to conventional curing techniques. Prakash Mandiwal and Sagar Jamle's studies revealed that PEG400 concrete achieves a peak strength of 1.6% for Mix-25 and 2.4% for Mix-20 grade, similar to M25 and M20 mix. Utilizing 15% silica fume and self-curing chemicals in concrete mixes improves qualities under different curing conditions by enhancing water retention, reducing voids and pores, and increasing the binding strength between cement paste and aggregate. Concrete with 15% silica fume exhibited excellent performance under several curing conditions such as air, 5% CO2, wet and dry cycles, and 8% NaCl solution. Nevertheless, it negatively impacts traditional concrete by leading to a consistent decrease in strength. Stella Evangeline observed that self-curing concrete compositions demonstrate enhanced water retention and superior hydration in dry environments as compared to conventional concrete. The efficacy of the self-curing agent is impacted by the composition of the mixture, particularly the quantity of cement and the water-to-cement ratio. Polyvinyl alcohol has enhanced compressive, tensile, and flexural strength in comparison to conventional combinations.

Experimental research demonstrated that both additives adversely affected the workability of SCC. Up to 8% silica fume-containing lime stone powder, 30% quarry dust, and 14% clinkers might be used as a mineral admixture without affecting the material's self-compactability. Self-curing concrete has demonstrated promise in enhancing its performance across several applications. Ravinder, Kumar, Prakash, Al Saad, and Tayeh's study shown that using a self-curing agent (SAP) in concrete mixes results in enhanced water retention compared to conventional concrete mixes. For optimal results, internal curing is most effective when 45 kg/m3 of water is mixed with 1 kg/m3 of superabsorbent polymer (SAP). Self-cured concrete containing superabsorbent polymers (SAP) is a more economical option compared to conventionally cured concrete. The efficacy of the self-curing agent is controlled by the composition of the mixture, specifically the amount of cement and the water-to-cement ratio (w/c ratio). The optimal dosage for SAP is 0.3%.

Combinations that include Lightweight Aggregate (LWA) have a greater capacity to improve compressive strength in comparison to combinations that do not include LWA. The production of ettringite is advantageous for increasing compressive strength, as the degree of hydration is contingent upon the quantity of water inside the moist cement paste. The addition of LWA and SAP to the mixture improves the compressive strength of HPC specimens. This improvement is due to the enhanced hydration process enabled by internal curing.

Products such as MK and RHA can exhibit financial, ecological, and technological advantages by reusing waste materials, creating cost-effective mortar and concrete for affordable building, and reducing carbon emissions. Concrete combinations containing SAP have higher water retention capacity compared to standard mixes, with the optimum dosage being 0.3%.

G. L. Abishek conducted research on self-curing concrete and found that the addition of PEG can enhance compressive strength by a maximum of 10%. Utilizing this self-curing chemical in concrete aids in diminishing water usage during construction. The ideal proportion of PEG for obtaining the appropriate compressive strength, split tensile strength, and elastic modulus in grade M50 high-strength concrete experiments is 1.5%.

B. Summary

Self-curing concrete is an effective and sustainable technique that utilizes novel mechanisms to gradually hold and release moisture, facilitating appropriate cement hydration and minimizing the likelihood of surface fractures and low durability. It provides increased strength, durability, and fracture resistance, while minimizing the requirement for hand curing and saving time and labour expenses. Self-curing concrete helps in sustainability by saving water resources and decreasing energy usage during curing, therefore lowering the environmental impact of construction projects. It is especially advantageous in areas with limited water availability or severe weather conditions. Self-curing concrete is suitable for a wide range of building projects, especially in areas facing water shortages or severe weather conditions. Compressive strength of self-curing and conventional concretes increased slowly over time during air curing, necessitating water curing to avoid negative characteristics. Self-curing concrete mixtures have superior water retention compared to standard concrete mixes.

IV. METHODOLOGY

A. Problem Formulation

We often utilize PEG400 as a self-curing agent due to its excellent compatibility, but it can be expensive and not readily available everywhere. An alternative agent, such as Sodium Polyacrylate, which is commonly used in agriculture for its absorbent properties, can be used instead.

B. Materials used

These are all materials that were used for these experiments:

- Concrete: M35 Grade
- Self-Curing Concrete: Sodium Polyacrylate as admixture
- AR Glass Polymer Fiber

C. Material 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 evaluating strength. Additional tests comprise the evaluation of cement soundness using the Le-Chatelier method, Loss on Ignition (LOI), chemical composition analysis, and setting time determination by the Gillmore Needle Test. These tests verify that the cement complies with the prescribed criteria and guarantee correct handling and curing.

Table I. Physical properties

Sr No.	*Particulars*	*Test Results*	*IS CODES*
1	Fineness Modulus	293 m^2/kg	IS:4031 PART-1-1988
2	Standard Consistency	28.4 (%)	IS 4031
3	Setting Time: Initial Final	181 min 251 min	IS 8142:1976
4	Soundness: Le-Chat Expansion Autoclave Expansion	1.05 mm 0.065 mm	IS 5514
5	Compressive Strength: 72 +/- 1hr. (3days) 168 +/- 2hr. (7days) 672 +/- 4hr. (28days)	39.0 MPa 51.0 MPa 72.0 MPa	IS 4031 PART-6

Table II. Chemical properties

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

Sr No.	*Particulars*	*Test Results*
6	Total Loss on Ignition (% by mass)	1.88
7	Total Chlorides (% by mass)	0.008

2) *Properties of Aggregates:* Testing the properties of aggregates is essential for ensuring quality control in the construction sector. 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. Petrographic examination identifies mineralogical and textural properties, whereas soundness tests assess the resilience of aggregates to disintegration caused by freeze-thaw cycles. Organic impurity tests detect the existence of organic substances in aggregates, which might diminish concrete strength if present in high amounts.

Table III. Physical properties of aggregates

Sr No.	*Particulars*	*Test Results*	*IS CODES*
1	Fineness Modulus: Coarse Aggregate(10mm) Coarse Aggregate(20mm) Fine Aggregate (Sand)	3.10 3.07 2.78	IS 383
2	Elongation and Flakiness Index: 20 mm 10 mm	10.76/9.67 13.74/11.93	IS 2386 part-1 1963
3	Bulk Density: 20 mm 10mm Sand	1.65 1.68 1.67	IS 2386(Part-III)-1963
4	Specific Gravity: 20 mm 10 mm Sand	2.83 2.84 2.65	IS 2386
5	Water Absorption: 20 mm 10 mm Sand	1.35 1.37 2.54	IS 2386

3) *Properties of Sodium Polyacrylates and AR Glass Fibers:*

Table IV. Ar glass fibers

Sr No.	*Particulars*	*Density*	*Specific Gravity*	*Young's Modulus*
1	AR Glass Fiber	2.86 gm/cm^3	2.6 – 2.8	71.7 – 80 GPa

Table V. Sodium polyacrylates

Sr No.	*Particulars*	*Absorption Speed*	*Particle Size*	*pH Range*
1	*SPA-3*	*<=80*	*230-100 mesh*	*5.6-6.5*

4) *Fresh Concrete Test:* It is essential to test fresh concrete to ensure it meets the stipulated quality and performance standards before placement. The slump test evaluates the viscosity and manoeuvrability of concrete. The

slump test involves filling a slump cone with freshly mixed concrete and then lifting it to assess the amount of slump. The data can be utilized to adjust the mix design, placement procedures, or curing operations to achieve the desired performance. The IS: 1199-1959 Slump Concrete Test was performed to analyse concrete samples treated with different quantities of curing agents and reinforcing materials.

5) *Hardened Concrete Test:* Testing is performed on hardened concrete to assess its strength, durability, and other characteristics. Common tests frequently include the compressive strength test, which measures the maximum load a concrete sample can bear before breaking. Cylindrical or cube-shaped specimens are produced and then tested under compression until they reach failure. The results are often presented in megapascals (MPa) or pounds per square inch (psi).

Tensile strength tests, such as splitting tensile test or flexural strength test, assess the concrete's resistance to being pulled apart or bent. Universal testing equipment is used to analyse cylindrical specimens with dimensions of 150mm x 150mm x 300mm. The split tensile strength is determined by putting a load along the generatrix element on the vertical diameter of a cylinder under horizontal tension. Flexural strength tests evaluate the capacity of a beam or slab to withstand failure under bending forces. Beam specimens of 100mm by 100mm by 700mm are examined using a compression testing device. The modulus of rupture is measured in N/mm².

V. RESULTS

A. Compressive Strength:

Table VI. Compressive Strength (N/mm^2)

Sr No.	***Mix***	***7th Day***	***28th day***
1	N0	24.17	38.35
2	P0.25	24.10	38.36
3	P0.50	24.38	38.06
4	P0.75	24.29	38.45
5	P1.00	24.17	38.35
6	P1.25	24.93	38.78
7	P1.50	25.20	39.22
8	P1.75	25.66	39.54
9	P2.00	24.79	38.48
10	P2.25	24.46	38.36
11	P2.50	24.18	38.45
12	P2.75	24.12	38.22
13	P3.00	23.98	37.7
14	P3.25	23.81	37.86
15	P3.50	23.50	37.48
16	P3.75	23.25	37.26
17	P4.00	23.16	37.10
18	P4.25	22.72	36.78
19	P4.50	22.68	34.07
20	P4.75	21.43	33.77
21	P5.00	21.13	33.93

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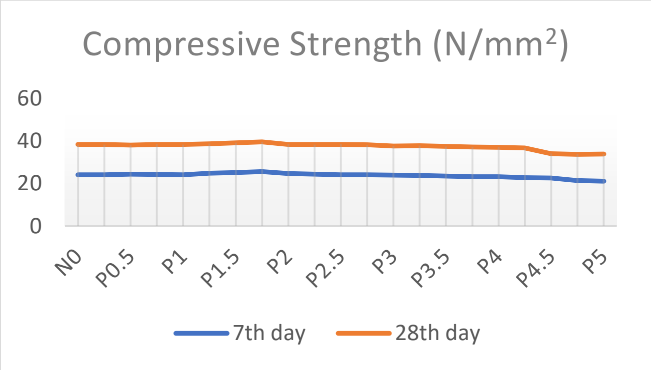

Fig. 3. Graphical repesentation of Compressive Strength

B. Split tensile Strength:

Table VII. Split tensile strength (n/mm^2)

Sr No.	*Mix*	*7th Day*	*28th day*
1	N0	3.14	3.81
2	P0.25	3.13	3.76
3	P0.50	3.15	3.82
4	P0.75	3.21	3.83
5	P1.00	3.33	4.02
6	P1.25	3.53	4.09
7	P1.50	3.64	4.34
8	P1.75	3.74	4.44
9	P2.00	3.56	4.18
10	P2.25	3.40	4.01
11	P2.50	3.46	4.07
12	P2.75	3.37	3.97
13	P3.00	3.31	3.91
14	P3.25	3.28	3.87
15	P3.50	3.26	3.81
16	P3.75	3.10	3.79
17	P4.00	2.96	3.71
18	P4.25	2.69	3.63
19	P4.50	2.63	3.39
20	P4.75	2.61	3.33
21	P5.00	2.52	3.23

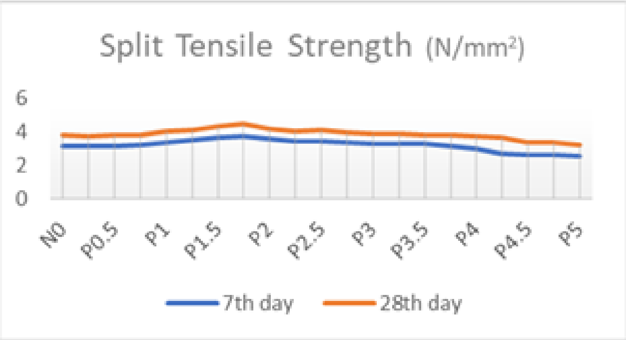

Fig. 4. Graphical representation of Split Tensile Strength

C. Flexural Strength:

Table VIII. flexural strength (n/mm^2)

Sr No.	*Mix*	*7th Day*	*28th day*
1	N0	4.32	5.44
2	P0.25	4.29	5.43
3	P0.50	4.27	5.41
4	P0.75	4.35	5.55
5	P1.00	4.43	5.74
6	P1.25	4.55	5.85
7	P1.50	4.66	5.94
8	P1.75	4.75	5.98
9	P2.00	4.92	6.10
10	P2.25	4.88	6.01
11	P2.50	4.74	5.91
12	P2.75	4.70	5.85
13	P3.00	4.63	5.79
14	P3.25	4.56	5.73
15	P3.50	4.50	5.70
16	P3.75	4.42	5.64
17	P4.00	4.39	5.58
18	P4.25	4.31	5.41
19	P4.50	4.07	5.18
20	P4.75	4.02	5.11
21	P5.00	3.90	5.03

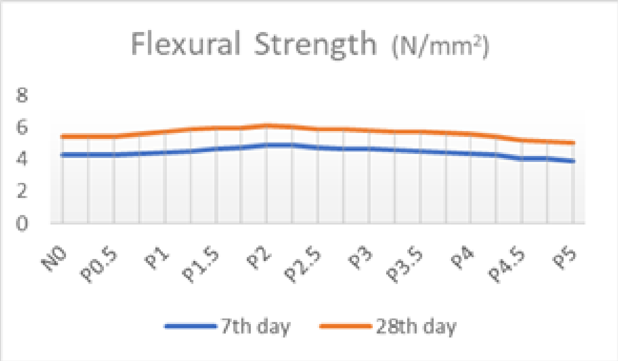

Fig. 5. Graphical representation of Flexural Strength

VI. CONCLUSION

- An increase in the content of sodium polyacrylate leads to a higher slump value in self-cured concrete, indicating improved workability.
- The tests which were conducted and its results were taken on the 7th and 28th day,
- The compressive, split tensile, and flexural strengths of the material were determined by varying concentrations of sodium polyacrylate from 0% to 5%, and the corresponding data were documented. It was found at the initial stage of adding sodium polyacrylate that the test results were the same as ordinary concrete in all experiments.
- As the concentrations increased, it showed an increase in its value. The compressive strength peaked at 1.75 percent, while the split tensile and flexural strength reached their maximum at 1.75 percent and 2 percent, respectively, as the concentrations increased.

Throughout the testing, it was seen that the value declined as the concentrations were markedly increased.

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