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Study On SAP Gel Dozed Self-Curing Concrete For RCC/PCC Repair Application

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Abstract: In this study, we developed a self-curing concrete using a geopolymer-based repairing agent with SAP Gel (Super Absorbent Polymer) to address the challenges of water scarcity and curing in high-rise structures. The conventional curing methods often require a large quantity of water, which can be problematic in water-deficient regions. To create the self-curing concrete, we prepared different mixes with varying percentages of SAP Gel (1%, 2%, and 3%) and tested their properties in both fresh and hardened states, including repair specimens. Cement paste was used for repair before filling the concrete. When comparing the self-curing concrete to concrete without any curing, we observed changes in certain properties. The compressive strength decreased by 4.57%, 9.45%, and 14.32% for the respective SAP Gel percentages. The Rebound Hammer value also decreased by 3.3%, 9.58%, and 12.5% with the use of SAP Gel. The Ultra Pulse Velocity (UPV) results were somewhat mixed. At some SAP Gel percentages, the UPV decreased by 2.17% and 0.72%, while at another percentage, it increased by 0.96%. Based on the results, we concluded that the self-curing concrete with SAP Gel-based geopolymer as a repairing agent shows promise for repairing M25 grade concrete using M30 grade concrete. This approach can reduce water consumption and provide a sustainable solution for concrete repair.

Keywords – Self-Curing concrete, SAP Gel, Concrete agent, with curing, Without Curing, Concrete Specimen, Compressive Strength, UPV (Ultra Pulse Velocity), Rebound Hammer.

1.INTRODUCTION

This study investigated the water retention properties of self-curing concrete with curing agents. Concrete weight loss, internal relative humidity, and non-evaporable water measurements were carried out to evaluate water retention and hydration. Water transport through the concrete was assessed using absorption percentage, permeable voids percentage, water sorptivity, and water permeability. The impact of concrete mix proportions, including cement content and water-to-cement ratio, on the performance of self-curing concrete was also examined. The findings contribute to understanding the behavior of self-curing concrete, aiding in the optimization of mix designs for enhanced durability and water scarcity mitigation in concrete repair applications [1]. The study, conducted as part of NCHRP Project 18-04B, focused on developing high-early strength Portland cement concrete (PCC) mixtures for early opening-to-traffic pavement rehabilitation. Fourteen different PCC repair mixtures were designed and evaluated for their fresh and hardened properties, freeze-thaw durability, and microstructural characteristics. It was found that while high-early strength PCC mixtures could be produced, interactions between constituents, particularly Type III cement and high-range water reducers, could affect durability. To ensure long-lasting repairs, the study recommended conducting durability testing on mixtures with these constituents to address potential durability issues [2]. This chapter provides an overview of various types of cementitious and polymeric repair materials and factors influencing their selection. Cementitious materials encompass a range of options such as Portland cement-based materials, modified Portland cements, hydraulic cements like magnesium phosphates and high alumina. Polymeric materials consist of polymer-modified concrete or mortar and polymer concrete. The choice of repair material depends on factors such as construction requirements, load-bearing capacity, and durability considerations. Ultimately, material selection is a critical decision in ensuring effective and long-lasting repairs based on specific project needs [3]. Internal curing (IC) is a beneficial technique for enhancing the performance of low water-to-cement (W/C) ratio and low permeability concretes by providing additional water for cement hydration. In contrast, conventional concretes often suffer from inadequate curing, leading to drying and compromising strength and durability. This investigation aimed to evaluate the impact of IC as a supplement to traditional curing in relatively high W/C concretes (above 0.42) under drying conditions. The degree of hydration, compressive strength, and permeability were measured in concretes with and without IC. Results revealed that even in drying conditions, IC-treated mixtures exhibited 16% higher hydration, 19% higher compressive strength, and 30% lower permeability compared to non-IC counterparts. These findings demonstrate the significant benefits of IC in improving the performance of high W/C concrete mixtures subjected to poor curing conditions [4]. This study compared two curing agents, pre-soaked lightweight aggregate (LECA) and polyethylene-glycol (Ch.), to optimize concrete performance. Different ratios and percentages of these agents were tested alongside varying cement content, water-cement ratios, and silica fume levels. Results showed that Ch. improved physical properties more effectively than LECA. Saturated LECA at up to 15% volume showed positive effects on permeability and mass loss but negatively impacted sorptivity and water absorption. The optimal values were found to be 2% Ch. and 15% LECA. Higher cement content and lower water-cement ratios enhanced the effectiveness of the curing agents. The addition of silica fume improved all physical properties of the concrete mixtures [5]. High-performance concrete (HPC) has a low water-to-cement ratio, leading to self-desiccation and high autogenous shrinkage (AS), increasing the risk of early-age cracking. Internal curing (IC) with super absorbent polymers (SAPs) can mitigate this issue by providing additional water for concrete hydration. This study investigated the effect of IC on early age expansion, AS development, AS rate, and IC efficiency in concrete with SAP. Results showed that increasing IC water led to earlier and higher early-age expansion, while reducing ultimate AS at 28 days and AS rate. A proposed model accurately estimated AS considering early-age expansion and IC water. IC efficiency of SAP decreased with higher IC water content [6]. In the modern era, there is a growing demand for sustainable concrete repair materials. This study focused on developing an ultra-fine blast furnace slag-based geopolymer as a concrete repair agent. Geopolymer concrete mixes were prepared and tested, incorporating various admixtures, to evaluate their fresh and hardened properties, including bond strength. The 1-day strength of the geopolymer concrete using ultra-fine blast furnace slag was approximately 60% of the 28-day strength. The addition of fly ash within a certain quantity range improved workability, compressive strength, and bond strength of the geopolymer concrete. Similarly, the inclusion of superplasticizer at a low dosage level also enhanced the fresh and hardened properties. However, a high concentration of alkali activator adversely affected workability and strength of the geopolymer concrete [7]. Self-compacting concrete is used when traditional compaction methods are challenging. To address the need for curing without traditional methods, self-curing concrete can be employed. This study explores the feasibility of achieving normal and high-strength self-curing self-compacting concrete using various curing agents. The effects of these agents on the behavior of both types of concrete are investigated. The research includes two stages: the first examines the impact of curing agents on the main properties of self-compacting concrete, and the second evaluates the behavior of reinforced concrete beams using the suggested concrete types. Results show that both normal-strength and high-strength self-curing self-compacting concrete perform well in structural elements where curing and compaction processes may be challenging. Curing agents reduce water evaporation, enhancing water retention and promoting sufficient hardened concrete properties [8]. This study investigated the relationship between hydration, internal relative humidity (RH), and strength in internally cured ultra-high performance concrete (UHPC), emphasizing the importance of drying in superabsorbent polymer-based internal curing (IC). The experiments demonstrated that external curing methods, such as water curing, were unable to prevent self-desiccation in UHPC, but IC effectively mitigated desiccation and shrinkage. However, maintaining a high internal RH led to slower strength development. Under water-curing conditions, internally cured UHPC exhibited 12-17% lower strength at 28 days compared to the reference sample. However, when exposed to dry air (RH 60%) between 7 and 28 days, the strength differences were only 0-1%, indicating accelerated external drying. This suggests that the early-age shrinkage issue in UHPC can be resolved without compromising strength by controlling the drying period [9]. Internal curing methods, which supply water inside concrete using highly absorbent materials, have been investigated to reduce early-age shrinkage in high strength concrete. This study investigates changes in the concrete pore structure caused by internal curing. High strength concrete was mixed with 0–25% replacement of fine aggregate with expanded lightweight aggregate, the compressive strength and auto-genous shrinkage of the specimens were measured, and a microspore analysis was performed. The increase in shrinkage reduction with increasing expanded lightweight aggregate replacement was confirmed, observing that the hydration and meso-pore concentration in the cement matrix increased, resulting in a denser structure [10].

2.METHODOLOGY

2.1 OBJECTIVES

The aim of this work is to study the repair of concrete with SAP gel.

Following properties will be studied:-

- To evaluate the utility of SAP Gel (different %) in concrete design mix of M25 grade of concrete.
- To study the concrete repairing specimen with SAP Gel (different %)
- To study the effectiveness of SAP Gel (different %) in strength enhancement of concrete.
- Compressive strength at 7 and 28 days.
- Ultrasonic pulse velocity (UPV) at 7 and 8 days Test.
- Rebound Hammer at 7 and 8 days Test

2.2 MATERIALS

The binding material used in this study was 43 grade Portland Pozzolana Cement. Table 1 provides information about the properties and characteristics of this cement. For the fine aggregate in the concrete, river sand of Zone I was utilized. The sand has a specific gravity of 2.62 and a fineness modulus of 3.261. Coarse aggregate with a size of 20 mm, obtained from crushed sources, was used. The specific gravity of the coarse aggregate is 2.412. Table 2 provides a breakdown of the mix proportions used in the study, outlining the details of the various components and their ratios in the concrete mixture.

DRY SAP GEL

WET SAP GEL

Super absorbing polymer (SAP): sap contain long chains of cross-linking polymers integrally connected and when comes in contact with water then forms hydrogel & swells these polyelectrolytes are classified as poly acrylic acid and polyacrylamide. Crosslinks of sap can expand due to the osmotic pressure of aqueous solution absorbed by sap. Superabsorbent polymers can be made by three primary methods that are gel polymerization. Solution polymerization, and suspension polymerization. In gel polymerization UV radiation promotes the polymerization of a liquid mixture of acrylic acid and cross-linking agents. In solution polymerization diluted solutions of granular polymers dried for a specific time at a specified temperature. It is the most commonly used method to manufacture sap at a low cost. Suspension polymerization is the suspension of the water-based reactant in a hydrocarbon- based solvent.

Cement Characteristics

Chemical characteristics %		Physical Characteristics		
CaO	63.4	Specific gravity	2.72	
SiO2	19.96	Initial setting time (min)	140	
Al2O3	5.17	Final setting time (min)	405	
Fe2O3	3.41	Fineness of cement	2.33%	
MgO	1.61	Fly ash Content	34%	
SO3	2.13	**Mechanical properties**		
K2O	0.8	Compressive strength (MPa)	3 Days	17
Na2O	0.13		7 Days	28
Loss on ignition	1.12		28 Days	46

2.3 MIXING DETAILS

The self-curing concrete was prepared by sequentially adding dry aggregates, cement, SAP Gel, and water to the mixer and mixing them for three minutes. The mixture was then poured into cube molds for compressive strength testing. Three samples were cured for 7 and 28 days, while four samples were left uncured but with SAP Gel added. After the specified curing periods, all samples were tested for compressive strength. The study used five different mixtures with varying proportions of SAP Gel, denoted as WC 0%, WOC 0%, SC1%, SC2%, and SC3%, all having a water-to-binder ratio of 0.42.

Mix proportions for One Sample

(With Curing)

Grade of Concrete	**Cement (kg)**	**Water (Liters)**	**Fine Aggregate (kg)**	**Coarse Aggregate (kg)**
M25	10.8	4.536	16.2	24.516

(Without Curing)

Grade of Concrete	**Cement (kg)**	**Water (Liters)**	**Fine Aggregate (kg)**	**Coarse Aggregate (kg)**
M25	10.8	4.536	16.2	24.516

(Without Curing SC1%)

Grade of Concrete	**Cement (kg)**	**Water (Liters)**	**Fine Aggregate (kg)**	**Coarse Aggregate (kg)**	**SAP GEL (Grams)**
M25	11.7	4.860	17.55	26.560	50

(Without Curing SC2%)

Grade of Concrete	Cement (kg)	Water (Liters)	Fine Aggregate (kg)	Coarse Aggregate (kg)	SAP GEL (Grams)
M25	11.7	4.812	17.55	26.560	100

(Without Curing SC3%)

Grade of Concrete	Cement (kg)	Water (Liters)	Fine Aggregate (kg)	Coarse Aggregate (kg)	SAP GEL (Grams)
M25	11.7	4.763	17.55	26.560	150

2.4 TESTING METHODS

The concrete cubes underwent compressive strength testing according to the Indian standard IS 516–1959. The tests were conducted at both 7 and 28 days to evaluate the strength development over time. A controlled displacement rate of 5.2 was applied during the compression tests until the samples failed. This allowed for the regulation of the load and measurement of the maximum compressive strength achieved by each cube. Additionally, the cubes were also subjected to Ultra Pulse Velocity testing, following the Indian standard IS 516–Part 5 Sec-1. This test measured the speed of ultrasonic waves through the concrete, providing insights into its overall quality and structural integrity.

Properties of Concrete At 7 Day (With Curing)

Sample	CS (MPa)	Average CS (MPa)	UPV (km/s)	Average UPV (km/s)	RH (MPa)	Average RH (MPa)
1	19.3	20.3	4.35	4.19	14.7	15.8
2	21		4.07		17	
3	20.7		4.19		15.8	

Properties of Concrete At 28 Day (With Curing)

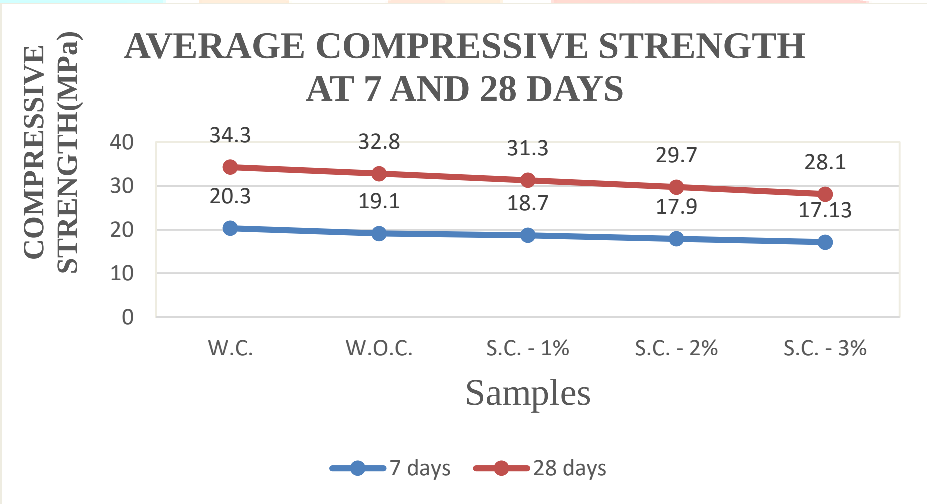
Sample	CS (MPa)	Average CS (MPa)	UPV (km/s)	Average UPV (km/s)	RH (MPa)	Average RH (MPa)
1	35.1	34.36	4.34	4.31	28	25.5
2	33.6		4.37		23.1	
3	34.4		4.22		25.6	

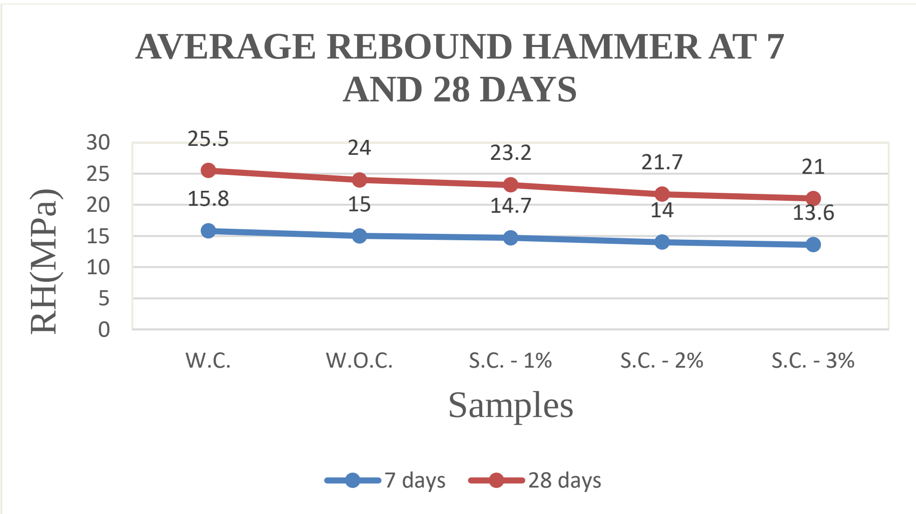
Properties of Concrete At 7 Day (Without Curing)

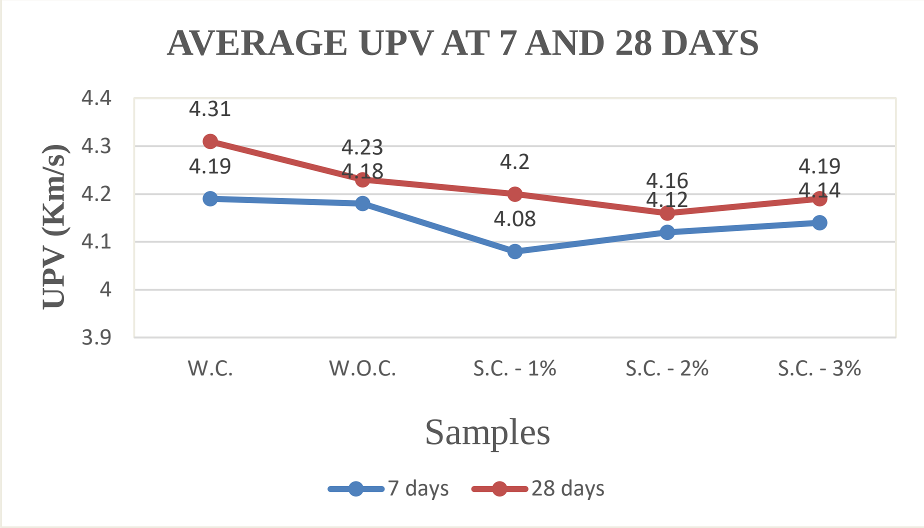
Sample	CS (MPa)	Average CS (MPa)	UPV (km/s)	Average UPV (km/s)	RH (MPa)	Average RH (MPa)
Convectional	18.1	19.2	4.14	4.18	13	15
	19.4		4.17		15.6	
	20		4.16		16.5	
SAP Gel 1%	20	18.7	4.13	4.08	15.6	14.7
	17		4.03		13.7	
	18.5		4.08		14.8	
SAP Gel 2%	18	17.9	4.09	4.12	14	14
	16.8		4.18		12.7	
	18.9		4.1		15	
SAP Gel 3%	18.1	17.13	4.18	4.14	15.8	13.6
	17		4.07		13	
	16.3		4.17		12	

Properties of Concrete At 28 Day (Without Curing)

Sample	CS (MPa)	Average CS (MPa)	UPV (km/s)	Average UPV (km/s)	RH (MPa)	Average RH (MPa)
Convectional	32.8	32.8	4.26	4.23	23	24
	33.1		4.19		26.4	
	32.3		4.24		22.5	
SAP Gel 1%	30.5	31.3	4.2	4.2	21.3	23.2
	32.3		4.18		25	
	31.2		4.23		23.5	
SAP Gel 2%	29.9	29.7	4.16	4.16	22	21.7
	30.8		4.2		24	
	28.4		4.12		19.3	
SAP Gel 3%	28	28.1	4.24	4.19	20.7	21
	27.6		4.15		19.5	
	28.7		4.19		23	







3.RESULTS AND DISCUSSION

3.1 WORKABILITY

The slump for all the samples is 50 mm.

3.2 COMPRESSIVE STRENGTH

At 7 days without curing, the compression strength (CS) of the conventional concrete samples averaged 19.2 MPa. The self-curing concrete samples with SAP Gel at 1% dosage showed an average CS of 18.7 MPa, while the samples with SAP Gel at 2% and 3% dosages exhibited average CS values of 17.9 MPa and 17.13 MPa, respectively.

At 28 days without curing, the conventional concrete samples had an average CS of 32.8 MPa. The self-curing concrete samples with SAP Gel at 1% dosage had an average CS of 31.3 MPa, while the samples with SAP Gel at 2% and 3% dosages had average CS values of 29.7 MPa and 28.1 MPa, respectively.

3.3 ULTRA PULSE VELOCITY

At 7 days without curing, the conventional concrete samples had an average ultra-pulse velocity (UPV) of 4.18 km/s. The self-curing concrete samples with SAP Gel at 1% dosage exhibited an average UPV of 4.08 km/s. The samples with SAP Gel at 2% and 3% dosages showed average UPV values of 4.12 km/s and 4.14 km/s, respectively.

At 28 days without curing, the conventional concrete samples had an average UPV of 4.23 km/s. The self-curing concrete samples with SAP Gel at 1% dosage exhibited an average UPV of 4.2 km/s. The samples with SAP Gel at 2% and 3% dosages had average UPV values of 4.16 km/s and 4.19 km/s, respectively.

3.4 REBOUND HAMMER

The rebound hammer (RH) test results for self-curing concrete showed average values ranging from 19.3 MPa to 26.4 MPa at various time intervals. These values indicate the surface hardness and potential compressive strength of the concrete. However, it is important to note that the rebound hammer values alone cannot directly determine the concrete's compressive strength. Further calibration and correlation with established standards and actual compressive strength tests are necessary for accurate estimations. Additional testing and evaluations are recommended to gain a comprehensive understanding of the self-curing concrete's strength and durability.

4 CONCULSION

The inclusion The experiments conducted on self-curing concrete mixes with different percentages (1%, 2%, and 3%) of Super Absorbent Polymer (SAP) Gel aimed to evaluate the compressive strength, rebound hammer (RH) value, and ultrasonic pulse velocity (UPV) for repairing purposes. The results obtained from these tests are as follows:

- Compressive Strength: The use of SAP Gel at 1%, 2%, and 3% resulted in a decrease in compressive strength by 4.57%, 9.45%, and 14.32% respectively compared to the reference sample.
- Rebound Hammer Analysis: The RH value decreased by 3.3%, 9.58%, and 12.5% when SAP Gel was used at 1%, 2%, and 3% respectively, indicating a decrease in the hardness or strength of the concrete.
- Ultrasonic Pulse Velocity: The UPV analysis showed slightly negative and positive effects. When SAP Gel was used at 1% and 2%, there was a decrease of 2.17% and 0.72% in UPV respectively. However, with 3% SAP Gel, there was an increase of 0.96% in UPV.
- Based on these results, it is recommended to repair M25 grade concrete using M30 grade concrete.

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