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Design and Application of Concrete Curing Blankets with Infused Water Super Absorbent Polymers (SAPs)

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***Abstract* -** This research presents a recently developed product for concrete curing using superabsorbent polymer (SAP) infusion. A curing blanket has been developed, consisting of layers of polyethylene (PE), nonwoven geotextile fabric (GT), and embedded sodium polyacrylate (SAP) particles. Each layer is carefully optimized to enhance its performance. Spectrometer tests have revealed the transmittance characteristics of PE sheets, crucial for effective water supply during curing. Advanced imaging techniques and standardized testing protocols have been used to analyse the morphology and water absorption capacity of various SAP variants. Conventional burlap and non-woven geotextile fabrics have been assessed for compatibility and water absorptivity. The results highlight the potential of SAP-infused blankets to improve compressive strength, reduce surface cracks, and enhance visual appeal compared to traditional methods. The optimal combination of specific SAP powder into geotextile fabric (GT-200), laminated with specific PE sheet (S7), shows superior moisture retention and surface finish. This study offers insights into reshaping concrete curing practices, emphasizing water-saving benefits and improved structural integrity in hot climates.

***Keywords*:** Concrete Curing; Superabsorbent Polymers; Curing Blanket; Nonwoven Fabric.

1. Introduction

Concrete curing often faces challenges, including plastic shrinkage cracking and excessive water consumption [1]. Concrete is widely used worldwide for its versatility, durability, and affordability [2]. Concrete technology employs various curing methods to ensure optimal hydration and strength development. Traditional methods, like water curing, involve maintaining moisture through continuous immersion or intermittent wetting, valued for its simplicity [3,4]. Chemical curing involves using chemicals to initiate and accelerate the hydration process, leading to rapid strength development [5,6]. Steam curing involves exposing concrete to high-temperature steam to accelerate hydration and promote early strength gain [7–11]. Thermal curing involves maintaining high temperatures for concrete, which accelerates hydration and the chemical reactions between cement and water. Moreover, it increased strength growth and overall structural integrity [12,13]. Carbonation curing places concrete in a carbon dioxide-rich environment, leading to the formation of calcium carbonate and strengthening of the concrete over time [14–17]. These methods have limitations: water curing is labor- and water-intensive; chemical curing is costly and environmentally harmful; steam and thermal curing require high energy; and carbonation curing is limited by CO2 supply [18]. Superabsorbent polymers (SAPs) enhance concrete curing by improving hydration and durability while reducing water usage [2,19]. SAPs support both internal and external curing, with studies showing they can boost strength, reduce shrinkage, and aid self-healing [20–27]. However, internal curing may increase cracking and limit efficiency [27,28]. External methods, such as water curing with SAP blankets, effectively maintain moisture and reduce plastic shrinkage [24,29].

Previous research on SAP-infused curing blankets shows that SAPs absorb water, reduce evaporation, and minimize plastic shrinkage cracking. These methods improve compressive strength and surface finish compared to traditional curing methods. Snoeck et al. [30] investigated ways to reduce plastic shrinkage in concrete by comparing external and internal curing methods using superabsorbent polymers (SAPs). Their study tested plastic shrinkage cracking in fresh concrete and monitored factors like capillary pressure, setting time, bleeding, strength, and microstructure. They found that external curing with calcium alginate significantly reduced plastic shrinkage cracking, proving its effectiveness in concrete construction. Meyer et al. [31] explored using superabsorbent polymers (SAPs) to induce plastic shrinkage cracks in concrete. By applying different SAP quantities and types to simulate evaporation conditions, they found that higher SAP amounts and fasterabsorbing varieties increased plastic shrinkage and crack size. This method effectively induced cracks, providing a valuable approach for systematic concrete testing.

This research introduces a multi-layer curing blanket with Superabsorbent Polymers (SAPs), featuring a polyethylene top and SAP-infused non-woven fabric. It enhances curing efficiency, reduces water usage, minimizes environmental impact, and supports sustainable construction by maintaining moisture, improving strength, and cutting costs.

2. Materials and Methods

A new concrete curing method using superabsorbent polymer (SAP) infused blankets is investigated in this study. Different polyethylene sheets, sodium polyacrylate SAPs powders (different sources), and non-woven geotextile sheets were evaluated for compatibility. The optimal combination was tested on fresh concrete, with moisture retention and surface finish compared to traditional burlap curing. Figure 1 shows the study methodology during both development and testing phases.

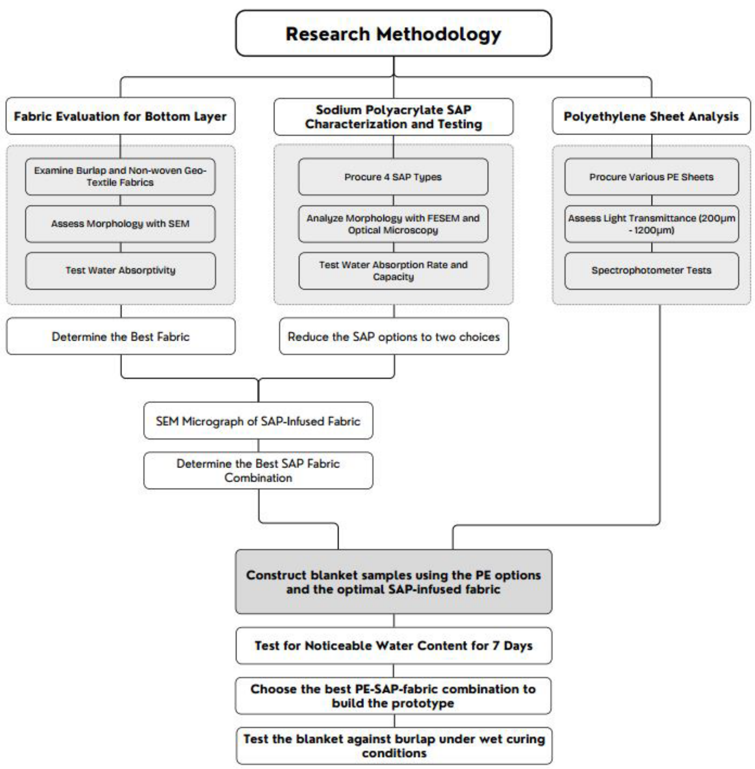


Fig. 1 Flowchart for Developing and Testing SAP-Infused Concrete Curing Blankets.

2.1. Polyethylene Sheet Analysis

In the optimization of the concrete curing process, the pivotal role of light transmission was recognized as essential for dissociating polymeric layers needed for effective water supply. Various polyethylene (PE) sheets were evaluated from different sources for their suitability in transmitting light across the sunlight spectrum ($200\mu m$ to $1200\mu m$), including Infrared (IR), visible, and Ultraviolet (UV) ranges. The characteristics of the sheets, such as thickness and transmittance percentages, are detailed in Fig. 2. As illustrated the variety of materials analyzed, laying the groundwork for further testing and optimization. Polyethylene (PE) sheets were analysed for light-transmitting properties using spectrophotometer tests, revealing their interaction with light and role in water supply during concrete curing. Laminated with different bottom layers, their light transmissibility was further evaluated for its effect on wetting duration, critical to to curing efficiency.

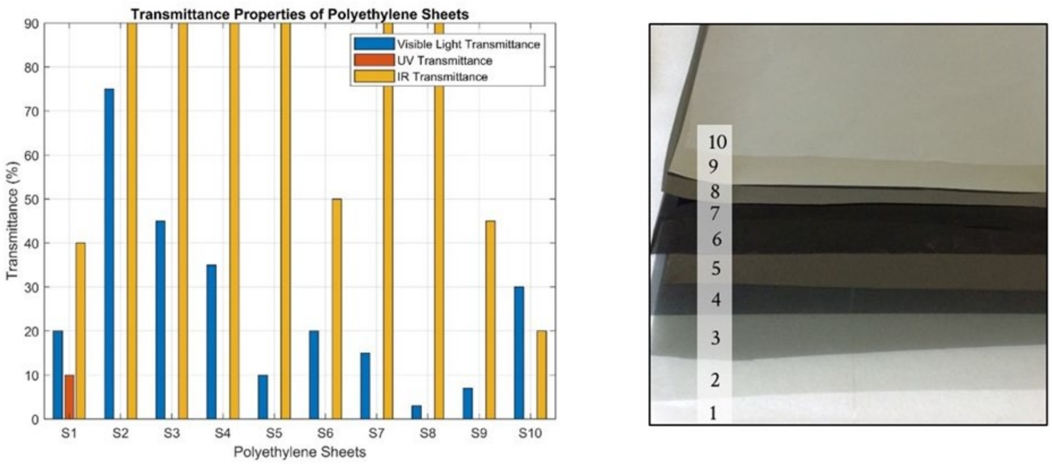


Fig. 2 Transmittance properties of polyethylene sheets, including VLT, UV, and IR, analyzed through spectrophotometer testing and wetting duration measurements.

2.2. Sodium Polyacrylate SAP Characterization and Testing

Building on the previous step, four types of Sodium Polyacrylate (SAP) were procured and analyzed for shape, average diameter, and water absorption. CSP and NSP were sourced from Tansee Co. [32], while JSP was obtained from Nippon Shokubai Co. [33]. In the study of Sodium Polyacrylate (SAP) variants, FESEM and Optical Microscopy were used to examine morphology and porosity, while Dynamic Light Scattering (DLS) assessed particle size. Water absorption rate and capacity were tested by adding 25mL of tap water to 0.25g of SAP in Petri dishes Fig. 3. Measurements were taken at intervals, and excess water was removed to compare dry and wet weights.

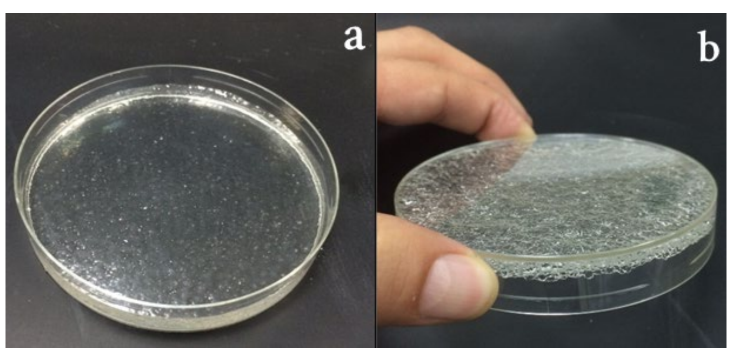


Fig. 3 Water Absorption Rate and Capacity Testing for SAP Variants. (a) Initial. (b) Final.

2.3. Fabric Evaluation for Bottom Layer

In this investigation, conventional burlap and non-woven Geo-Textile fabrics (GT-80, GT-100, GT-200) from Alyaf Co. [34] were examined for morphology, water absorptivity, and SAP powder retention. SEM was used to analyze porosity and diameter. Water absorptivity was measured for fabric sheets, and SAP stability analysed via SEM microscopy. The optimal

JSP powder and GT-200 combination were used in prototypes, monitoring slab water content over 7 days as shown in Fig. 4.

Fig. 4 Samples made with JSP, GT-200, and various PE selections.

2.4. Large-Scale Prototype

A large-scale prototype using JSP, GT-200, and S7 was deployed on fresh concrete for 7 days, compared to the burlap wet curing method, where water was applied three times daily. Three core samples from both methods were tested for compressive strength following ASTM C 42/C 42M – 99 guidelines. Fig. 5 shows the stages of blanket preparation, curing, and core drilling.

Fig. 5 Preparation of the blanket, curing process, and core drilling.

3. Results and Discussion

3.1. Polyethylene Sheet Characteristics

Spectrometer tests of the polyethylene (PE) sheets showed that most effectively blocked UV light, reducing SAP degradation. However, the sheets exhibited varying transmittance levels for visible and infrared (IR) light. The impact of visible or IR light transmission on SAP chain formation and deformation was assessed. Fig. 6 illustrates the transmittance of electromagnetic waves through polymeric sheets S1-S5 and S6-S10. As [35] highlights, PE sheets block UV light, reduce SAP degradation, and ensure long-term reliability with minimal aging effects.

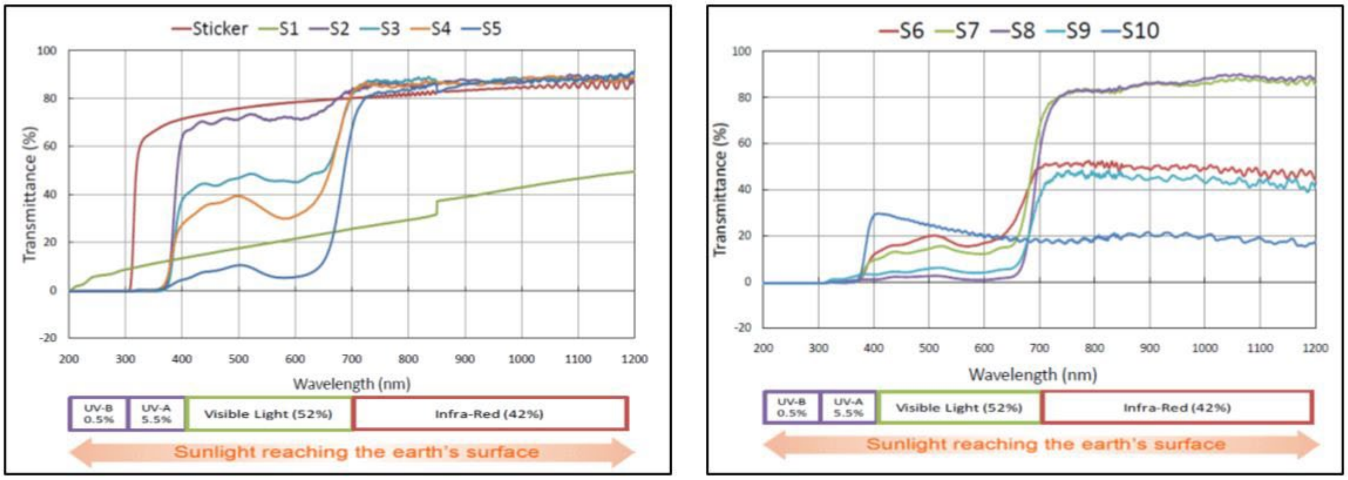


Fig. 6 Electromagnetic transmittance: S1-S5 (left), S6-S10 (right).

3.2. SAP Particle Analysis and Fabric Evaluation

Field Emission Scanning Electron Microscopy FESEM and optical microscopy were used to examine SAP particle morphology. Micrographs revealed irregular shapes with randomly distributed open and semi-open pores, enhancing particle entanglement with bottom fabrics. This structure increases surface area, improving interaction with fabric fibers and aiding water absorption and retention. Fig. 7 shows detailed SEM micrographs of SAP powders and their average particle sizes, with a $500\mu m$ scale bar, alongside optical micrographs at various scales.

Dynamic Light Scattering (DLS) was conducted to evaluate the particle size distribution of Sodium Polyacrylate (SAP) particles using Microtrac software. Fig. 8 shows the average particle size distribution, revealing that JSP had the smallest particle size and CSP the largest. This variation influences SAP’s absorption capacity and effectiveness in concrete curing. The analysis aligns with [36], highlighting SAP's role in enhancing water absorption and retention. DLS revealed critical morphological details that impact absorption rates.

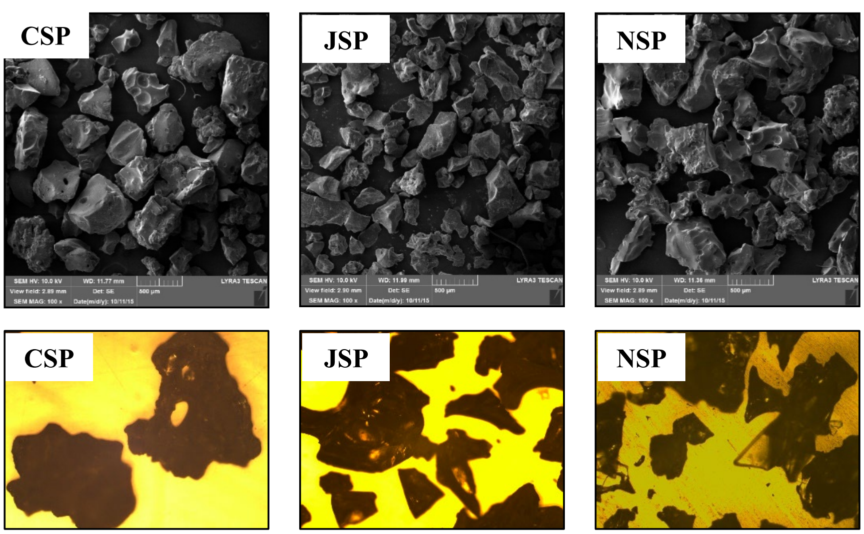


Fig. 7 SEM and optical micrographs of SAP powders: average particle sizes (top), various scales (bottom), $500\mu m$ scale bar.

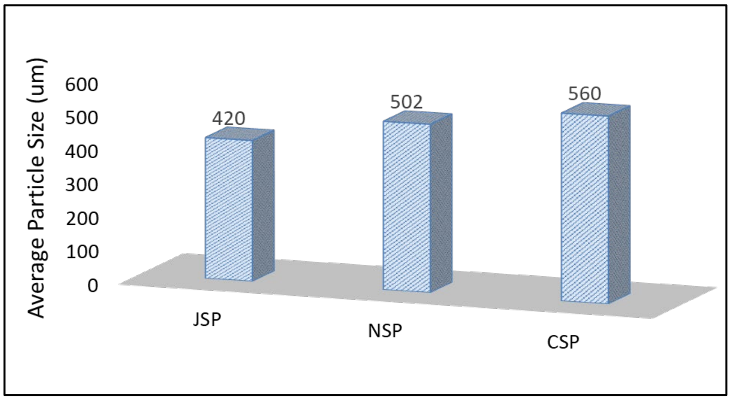
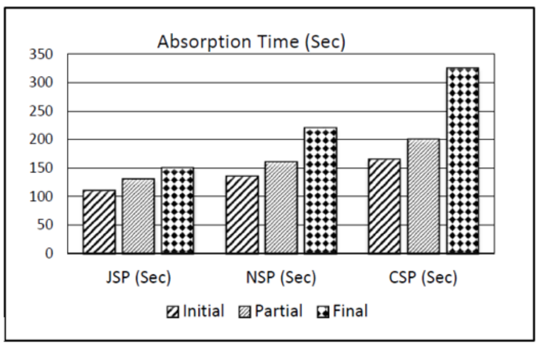


Fig. 8 Visualization of average particle size distribution in SAP powders.



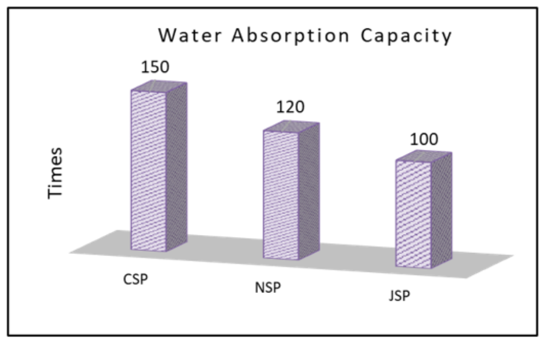


Fig. 9 Absorption time at different stages (left) and total capacity (right) for various SAP

The analysis of SAP water absorption rate and capacity revealed patterns, as shown in JSP exhibited the shortest final absorption time, indicating rapid water absorption, while CSP demonstrated the highest absorption capacity among the tested variants. This inverse relationship between particle size and absorption rate, contrasted with the proportional relationship between particle size and absorption capacity, highlights important design considerations for blankets. An ideal blanket must balance sufficient water-holding capacity with swift absorption to prevent runoff, especially in hot climates like the MENA region, where rapid curing is essential. [35] explores how SAP particle size affects the rheological properties of cement-based materials, noting that larger particles absorb more water and take longer to saturate, influencing strength and viscosity. This aligns with our findings, where different SAP types, such as CSP and JSP, show distinct absorption behaviors vital for effective curing blanket design. The morphology of fibre layers differs between burlap and non-woven geotextile, as shown in Fig. 10. Burlap fibers have random diameters with compact spacing and small pore sizes, which limit SAP particle entanglement. In contrast, non-woven geotextile variants have a uniform average fiber diameter of $20\mu m$ and pore size of $40\mu m$. The primary variation relates to fiber density per square area, indicated by the mass in grams per square meter (e.g., GT-80 weighs 80 g/m²). Higher fiber density may enhance SAP particle entanglement, while lower density could result in particle dispersion.

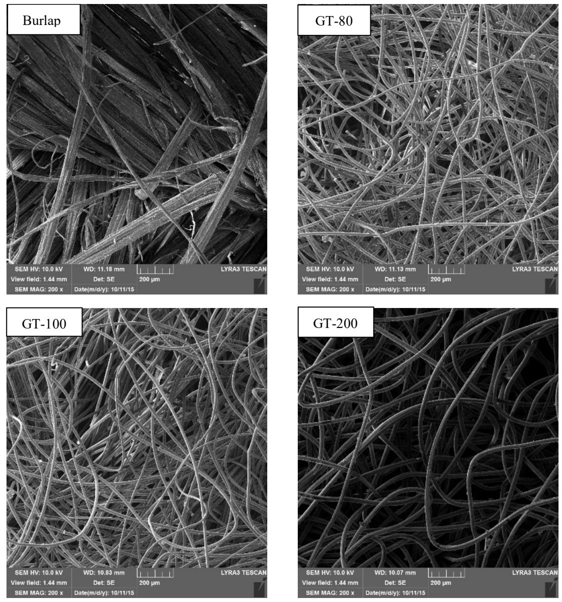


Fig. 10 SEM micrographs depict various fiber types, with a scale bar of $200\mu m$.

The water absorptivity of fabrics reveals notable findings, as shown in Fig. 11. Burlap absorbs its weight in water, while non-woven fabrics display superior absorption capabilities. Specifically, GT-80 can absorb up to 16 times its weight. Fiber density also influences water capacity, with higher densities correlating to lower absorption capacities. GT-200 fabric is particularly effective, absorbing ten times its weight, resulting in 2000 mL of water compared to 1280 mL for GT-80. Thus, GT-200 demonstrates high efficiency in water absorption, indicating its suitability for practical applications.

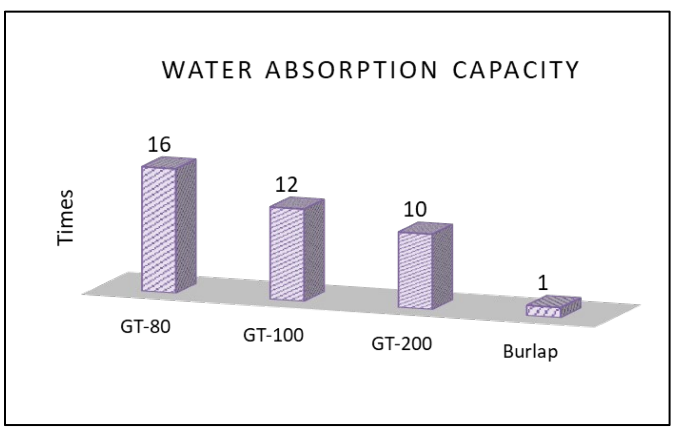


Fig. 11 Water absorption capacity of various fabrics relative to their weight.

SEM micrography of GT-80 infused with SAP provides insights into particle entanglement within the fabric matrix. The images show that CSP particles exhibit limited entanglement, even in GT-80, the fabric with the lowest density. In contrast, JSP particles, with diameters less than $500\mu m$, integrate well with the fabric structure, indicating enhanced infusion and potential for improved performance. This observation highlights the significance of particle size and fabric density in optimizing SAP integration, affecting the efficacy of the final composite material for concrete curing applications. Fig. 12 presents SEM micrographs of CSP (left) and JSP (right) infused in GT-80, with a scale bar of 1 mm. [36] emphasizes that fabrics with excellent water absorption can minimize wetness on the skin and enhance comfort under extreme conditions.

Our findings support this by showing that fabric characteristics, like fiber density and particle size, are critical for optimizing water absorption.

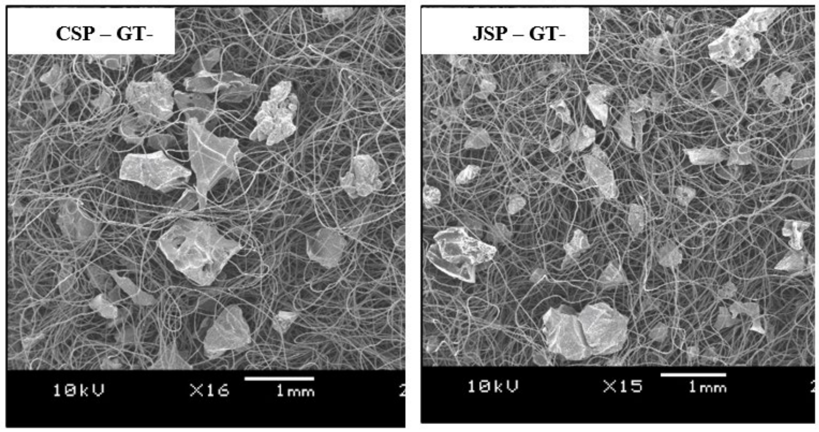


Fig. 12 SEM micrographs depict CSP (left) and JSP (right) infused GT-80 non-woven fabric, with a scale bar of 1 mm for reference.

3.3. SAP-Infused Blanket Performance on Concrete

The primary objective of this research is to establish a methodology for the stable integration of SAP powder within the fabric matrix. By leveraging the quick absorption rate of JSP, the project aims to enhance concrete curing efficacy. Final prototype specimens are created by laminating ten polyethylene (PE) samples with JSP-infused GT-200 non-woven fabric, promoting efficient moisture retention. The investigation also analyses the apparent water content levels of concrete slabs under the ten sample blankets over seven days. Significant observations begin on Day 5, revealing variations in moisture retention capabilities among the configurations. Specifically, as shown Fig. 13, the sample with the S1 PE sheet has completely dried by Day 5, leading to its exclusion from the final selection. On Day 6, as shown in Fig. 13, further observations revealed that samples S2, S4, S9, and S10 exhibited a similar level of dryness as sample S1. Notably, these samples, along with S1, showed no observable changes or moisture retention in subsequent inspections. By Day 7, as indicated in Fig. 13, a significant moisture retention discrepancy was noted, with only slab S7 achieving full saturation. This underscored the importance of PE sheet composition and fabric interaction. The S7 PE sheet laminated to JSP-infused GT-200 fabric was finalized as the most effective prototype for optimal moisture retention and concrete curing.

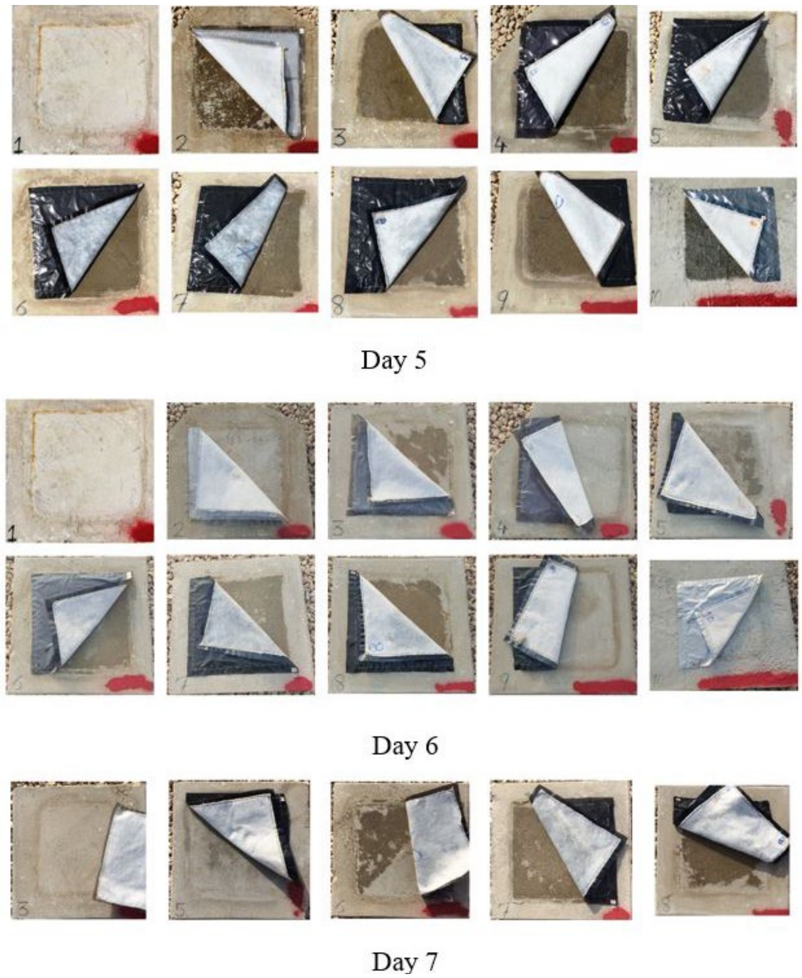


Fig. 13 Water content observations of the sample blankets on Day 5,6 and 7.

3.4 Comparison with Conventional Curing Methods

The surface finish analysis highlights significant advantages of the SAP-infused blanket over traditional burlap wet-curing methods. Fig. 14 shows a reduction in surface cracks on concrete treated with the blanket, enhancing aesthetic appeal and structural integrity. Additionally, the lack of discoloration suggests better maintenance of visual quality over time. These findings underscore the effectiveness of the novel curing method for achieving superior surface finishes in concrete applications. [37] assesses the effects of various curing methods on concrete properties, focusing on wet burlap. It notes that while wet burlap is common, alternative methods, like curing compounds, can enhance compressive strength and durability, especially in hot conditions. This aligns with our findings, which show the SAP-infused blanket reducing surface cracks and preserving visual quality compared to traditional burlap. Compressive strength results, detailed in Table 1, indicate that concrete cured with the SAP-infused blanket outperforms burlap-covered concrete, despite the latter being wetted three times daily for seven days. Insights from [30] on external curing with superabsorbent polymer layers further support our study on compressive strength, surface finish, and water conservation. [30] highlights calcium alginate's role in preventing shrinkage, aligning with our SAP blanket results, which enhance strength and conserve water, crucial for sustainability in water-scarce MENA regions.

Fig. 14 Surface finish comparison: burlap-cured concrete (left) vs. innovative blanket (right).

Table 1 Compressive strength in MPa comparison of sample drilled cores between burlap-covered and blanket-covered concrete.

Slab	Core 1	Core 2	Core 3	Average
SAP-infused Blanket Covered	37	36	35	36.0 MPa
Burlap Covered	35	34	36	35.0 MPa

4. Conclusion

A new method for concrete curing using superabsorbent polymer (SAP) infused blankets is explored in this study. The examination of polyethylene (PE) sheets, various sodium polyacrylate SAP variants, and fabric options aims to optimize curing, enhance compressive strength, and improve surface finish. Key findings include:

(1) Development of SAP-infused blankets as an innovative curing method, improving concrete strength and surface quality.

(2) Optimization of PE sheets and SAP combinations, identifying JSP SAP powder with GT-200 fabric and S7 PE sheet as the most effective.

(3) Demonstrated benefits include significant water savings, fewer cracks, and enhanced structural integrity, particularly in hot climates.

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