Comparative Experimental Investigation on Internal Curing Agents for Concrete Under Limited External Curing

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Abstract — Water scarcity is a critical challenge for the global construction industry, which accounts for approximately 15% of global freshwater consumption, with a substantial share attributed to concrete curing alone. Studies report that 1 m³ of concrete requires up to 3 m³ of water solely for curing. This study investigates the performance of five pre-soaked internal curing agents — Sodium Polyacrylate, Lightweight Expanded Clay Aggregate (LECA), Cotton fibers, Sawdust, and Perlite — combined with a water-sprinkling curing method on M25 grade concrete. Compressive strength of cube specimens was evaluated at 7, 14, and 28 days. Sodium Polyacrylate yielded the highest 28-day compressive strength of 28.83 MPa, exceeding the control mix (26.56 MPa), while LECA followed closely at 27.57 MPa. The findings demonstrate that selecting internal curing agents can reduce external water demand while maintaining or enhancing structural performance, offering a sustainable and scalable curing solution for water-stressed construction environments.

Keywords: LECA, Perlite, Sodium Polyacrylate, Saw Dust

I. Introduction

Concrete is one of the most extensively used construction materials worldwide due to its versatility, strength, and durability. However, its production and curing processes consume a significant number of natural resources, particularly water. The construction industry is responsible for nearly 15% of global freshwater consumption, contributing to the ongoing depletion of this critical resource. With only 2.5% of the Earth's total water being fresh and less than 1% accessible for human use, the increasing demand for construction has intensified the problem of global water scarcity. According to the United Nations, around 2.2 billion people currently lack access to safe drinking water, and by 2030, the global water demand is expected to exceed available supply by nearly 40%. In conventional concrete curing, large volumes of water are used to maintain sufficient moisture for the hydration of cement. However, a substantial portion of this water approximately 30–50% is lost through evaporation, runoff, or inefficient application methods. This wastage not only increases the overall construction cost but also adds stress to already scarce freshwater sources, especially in arid and semi-arid regions. Therefore, there is a growing interest in developing curing methods that are both efficient and environmentally responsible.

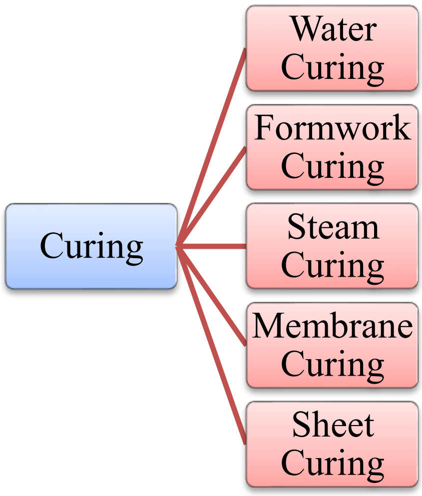

Fig. 1: Types Of Curing

This technique involves incorporating materials that can absorb and retain water, gradually releasing it during the hydration process to ensure proper curing from within. In the present study, a hybrid curing method is introduced that combines internal curing with controlled external sprinkling of water. This dual approach aims to achieve the required hydration and strength while significantly reducing total water usage. The internal curing materials used in this research include Light Expanded Clay Aggregate (LECA) – 10%, Perlite – 3%, Cotton fiber – 0.5%, Sawdust – 1.25% and Sodium Polyacrylate – 0.5% (by weight of cement or aggregates). The amount of material was selected by performing repeated experiments so that best of the best amount can be selected. The water absorption capacities are approximately LECA (15–20%), Perlite (28–30%), Cotton fiber (50–60%), Sawdust (70–80%), and Sodium Polyacrylate (300–400 times its own weight). Together, they form internal water reservoirs within the concrete matrix, providing sustained hydration and minimizing the dependency on external water.

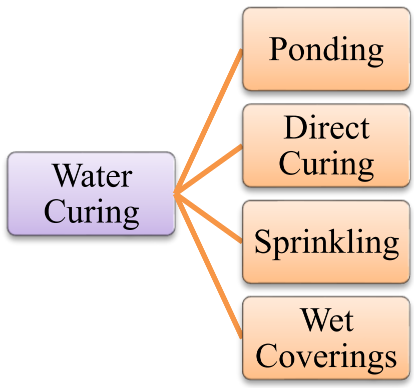

Fig. 2: Types Of Water Curing

II. LITERATURE RIVIEW

Curing is a critical process in concrete construction that ensures adequate moisture and temperature conditions for continued cement hydration. Inadequate curing leads to reduced strength, increased porosity, and poor durability. Over the past two decades, researchers have extensively investigated internal curing as a sustainable alternative to conventional external water curing methods. The following review summarizes key findings relevant to the materials investigated in the present study. Internal Curing — General Background Studies have reported that 1 m³ of concrete requires up to 3 m³ of water solely for the curing process, highlighting the urgency of developing water-efficient curing strategies. Internal curing addresses this by incorporating pre-soaked porous materials that act as internal water reservoirs, releasing moisture gradually to sustain hydration from within the concrete matrix. Superabsorbent polymers and pre-soaked lightweight aggregates improve internal curing by absorbing excess water during mixing and releasing it gradually, thereby reducing autogenous shrinkage and improving cement hydration.

A. Sodium Polyacrylate (Superabsorbent Polymer)

Sodium Polyacrylate, a superabsorbent polymer (SAP), has been widely studied as an internal curing agent. Sodium polyacrylate, also known as water-lock, is a sodium salt of polyacrylic acid . In water, it swells to a rubbery gel capable of absorbing up to 99% water by weight. Studies on SAP-based internal curing have reported that the best compressive strength results are obtained at 0.5% SAP by weight of cement, which directly aligns with the optimum dosage adopted in the present study. Additionally, experiments conducted on M25 grade concrete with different ratios and it was found that o.5% is the best percentage of sodium polyacrylate.

B. Lightweight Expanded Clay Aggregate (LECA)

LECA is one of the most widely researched lightweight aggregates used for internal curing. A study M25 grade on self-curing concrete found that compressive strength increased gradually from 10% to 15% LECA replacement, with a maximum compressive strength of 33.89 N/mm² obtained at 10% LECA. At 28 days, concrete with 10% LECA replacement showed approximately 10% higher compressive strength compared to conventional concrete, confirming the internal curing effectiveness of pre-saturated LECA particles through continued hydration and reduced porosity. The present study adopted 10% LECA replacement, consistent with these findings.

C. Perlite

Perlite is a naturally occurring volcanic material that, when expanded, exhibits high porosity and excellent water absorption capacity, making it effective as an internal curing agent. Research indicates that higher perlite replacement levels significantly reduce compressive strength, making lower dosages more appropriate for structural concrete. Through preliminary trials, 3% was identified as the optimum dosage that maximized moisture retention while minimizing strength reduction in M25 grade concrete.

D. Sawdust

Sawdust is an agricultural as well as industrial by-product that has been explored as a sustainable internal curing material due to its porous structure and moisture retention capacity. Experimental studies on sawdust-modified cement composites have focused on evaluating mechanical properties and durability under both water-saturated and non-water-saturated curing conditions. While sawdust offers eco-friendly advantages, its organic nature can interfere with cement hydration at higher replacement levels, making low dosages such as the 1.25% adopted in the present study more appropriate.

E. Cotton Fibers

Cotton fibers have been investigated for their ability to retain moisture within the concrete matrix and simultaneously provide microcrack resistance. Studies on cotton waste fibers in high-strength concrete reported that peak flexural toughness improved, confirming the structural benefits of incorporating cotton fibers in concrete. At low dosages such as 0.5%, cotton fibers serve primarily as moisture-retaining micro-reservoirs without significantly reducing workability.

F. Research Gap

Previous studies have primarily focused on evaluating individual internal curing agents such as lightweight aggregates, superabsorbent polymers, and other porous materials as alternatives to conventional curing methods. While these studies have demonstrated improvements in hydration, shrinkage control, and durability, most investigations have examined a single internal curing material in isolation. In addition, many studies have treated internal curing as a complete replacement for conventional curing. However, the potential benefits of combining internal curing with controlled external water sprinkling have received comparatively less attention. Such a combined approach may enhance cement hydration, improve compressive strength development, and reduce the quantity of water required for conventional curing, thereby contributing to more sustainable construction practices.

III. MATERIALS & METHODOLOGY

A. Cement

Ordinary Portland Cement (OPC) conforming to the requirements of IS 12269 was used throughout the study. The cement was fresh, free from lumps, and stored under dry conditions prior to use. OPC was selected due to its widespread use in structural concrete and its suitability for M25 grade concrete production.

B. Fine Aggregate

Natural river sand conforming to Zone II grading requirements as specified in IS 383 was used as fine aggregate. The sand was clean, free from organic impurities, and oven-dried before mixing. Fine aggregate plays an important role in improving the workability and packing density of concrete.

C. Coarse Aggregate

Crushed stone aggregate of nominal maximum size 20 mm conforming to IS 383 was used in the concrete mixes. The aggregates were clean, durable, and free from deleterious materials. Coarse aggregates provide the primary load-carrying skeleton of concrete and significantly influence its mechanical properties.

D. Water

Potable water free from harmful salts, oils, acids, and organic matter was used for both concrete mixing and curing purposes. The water satisfied the requirements of IS 456 for concrete production.

E. Internal Curing Materials

Five different pre-soaked materials were selected and evaluated as internal curing agents in this study.

F. Lightweight Expanded Clay Aggregate (LECA)

LECA is a lightweight porous aggregate produced by heating clay at high temperatures. Due to its highly porous structure and high-water absorption capacity, LECA can store a considerable amount of water and gradually release it during cement hydration, making it an effective internal curing material.

Fig. 3: LECA

G. Sodium Polyacrylate (SAP)

Sodium polyacrylate is a superabsorbent polymer capable of absorbing several hundred times its own weight in water. After absorbing water, the polymer forms a gel-like structure that acts as an internal water reservoir and releases moisture as hydration progresses.

Fig. 4: SAP

H. Perlite

Perlite is a naturally occurring volcanic glass that expands when heated. The resulting lightweight porous particles possess significant water absorption capacity and can serve as internal reservoirs for curing water within the concrete matrix.

Fig. 5: Perlite

I. Cotton

Cotton fibers exhibit high water absorption characteristics due to their cellulose-based structure. Pre-soaked cotton was investigated as a natural and readily available internal curing material capable of retaining and gradually releasing water during concrete hydration.

J. Sawdust

Sawdust is a by-product of the wood processing industry and possesses a porous structure capable of absorbing and retaining water. Its utilization as an internal curing material offers both sustainability and waste utilization benefits while potentially contributing to internal moisture supply.

Fig. 6: Sawdust

K. Preparation of Internal Curing Materials

Prior to concrete mixing, LECA, sodium polyacrylate, perlite, cotton, and sawdust were soaked in water for a predetermined period to achieve maximum water absorption. Excess surface water was removed before incorporation into the concrete mix. The pre-soaked materials acted as internal water reservoirs and supplied moisture to the concrete during the hydration process.

IV. METHODOLOGY

The internal curing materials were incorporated into the concrete to provide additional moisture from within the matrix during hydration. Along with internal curing, controlled external water sprinkling was carried out throughout the curing period. The performance of the concrete mixes was evaluated by conducting compressive strength tests at 7, 14, and 28 days, and the results were compared to assess the effectiveness of the different internal curing agents. A control mix without any internal curing material was also cast for comparison.

Fig. 7: Filling of concrete in mould

Fig. 8: Casted Blocks

V. RESULT AND DISCUSSION

Admixture	7 Days	14 Days	28 Days
Common Concrete	19.24 MPA	23.97 MPA	26.56 MPA
Leca	17.55 MPA	24.92 MPA	27.57 MPA
Perlite	18.42 MPA	22.94 MPA	25.26 MPA
Sodium Polyacrylate	20.22 MPA	26.23 MPA	28.23 MPA
Saw Dust	15.42 MPA	21.96 MPA	24.12 MPA
Cotton	16.63 MPA	23.72 MPA	25.41 MPA

Table I: Compressive Strength of Concrete Blocks

The compressive strength of all mixes was evaluated at 7, 14, and 28 days and compared against the M25 target strength of 25 MPa, as presented in Table I. Sodium Polyacrylate achieved the highest 28-day strength of 28.83 MPa, exceeding the control (26.56 MPa) by 8.5%, attributed to its gradual water release mechanism ensuring continuous hydration. LECA followed at 27.57 MPa, demonstrating effective internal water reservation despite lower early strength. Cotton (25.41 MPa) and Perlite (25.26 MPa) marginally met the M25 criterion, confirming limited but acceptable performance at the tested dosages. Sawdust (24.12 MPa) failed to meet the 25 MPa threshold, likely due to organic interference with cement hydration. All mixes showed consistent strength gain from 7 to 28 days. Sodium Polyacrylate exhibited the most progressive and uniform gain across all ages, while LECA showed slower early strength but significant later development, indicating delayed internal curing action.

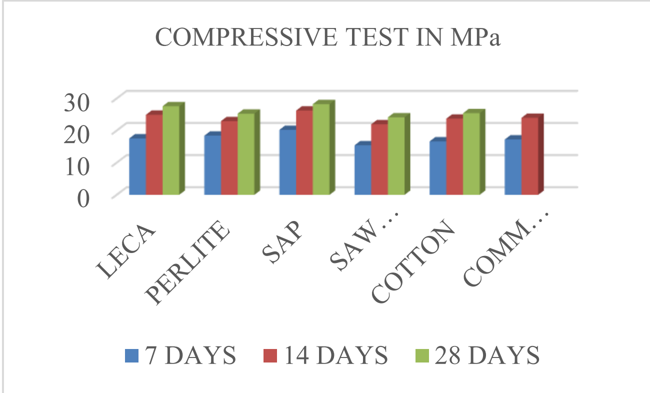

Fig. 9: Bar chart showing compressive strength

VI. CONCLUSION

1) Sodium Polyacrylate (0.5%) emerged as the most effective internal curing agent, achieving 28-day compressive strength of 28.83 MPa, surpassing the M25 target by 15.3%, while significantly reducing external water demand.
2) LECA (10%) proved to be the best lightweight aggregate-based internal curing agent with 27.57 MPa, offering a sustainable and structurally reliable alternative to conventional curing.
3) Cotton and Perlite marginally satisfied the M25 strength criterion, confirming their viability as supplementary internal curing agents at low dosages.
4) Sawdust failed to meet the M25 target strength, and its use as a sole internal curing agent is not recommended without further optimization or chemical treatment.
5) The combination of internal curing with water sprinkling presents a dual advantage, it dramatically reduces external water consumption during curing while simultaneously ensuring superior hydration from within, producing high quality, durable concrete.
6) Internal curing using pre-soaked materials represents a cost-effective, eco-friendly, and practically viable strategy for sustainable construction, particularly in water-scarce regions where conventional ponding or membrane curing is difficult to implement.

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