Properties of Self-curing Concrete: A Comparative Review of Various Curing Agents

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Abstract – *Concrete is widely recognized as an indispensable material in the contemporary era due to the advancements in global infrastructure. Accommodation is considered a fundamental necessity for individuals. Presently, there is a surge in the construction of structures due to the population surpassing the limit. Conversely, the presence of inadequate supervision is resulting in a decline in the structure's overall quality. The project engineers prioritize the expeditious achievement of the objective and financial gain. Numerous construction sites lack adequate quality control measures, with several of them failing to meet the standards specified by Indian codal provisions. Given that the construction industry predominantly employs inexperienced nontechnical labourers who are tasked with performing high-risk activities, they possess the capability to successfully accomplish allotted work within the designated timeframe. They carry out their tasks without understanding the requisite methodology. As a result, the structures' current lifespan is decreasing as a result of substandard work execution by the labor force and the site supervisor. The primary challenges pertaining to the implementation of concrete construction involve inadequate curing and compaction. The fundamental error that occurs during execution will ultimately have an impact on the structure's durability. Consequently, research has been conducted into the development of self-curing concrete containing compacting agents. The investigation's findings validate the effectiveness of the curing agents incorporated into the concrete.*

Key words: *self-curing agents, durability, compaction,and e autogenous shrinkage.*

1. INTRODUCTION

Concrete is the most widely used construction material globally, but it is susceptible to various issues such as drying shrinkage, cracking, and reduced durability. Traditional curing methods, such as water curing and curing compounds, are effective but labor-intensive and often impractical in certain environments. Self-curing concrete, on the other hand, utilizes internal mechanisms to maintain adequate moisture content, thus mitigating these issues. Self-curing agents play a pivotal role in enabling this process by providing water or moisture-retaining compounds. This review delves into the recent advancements in self-curing agents, their modes of action, and their impact on concrete performance.

Mechanisms of Self-Curing Agents:

Self-curing agents operate through different mechanisms to maintain the required moisture levels within the concrete matrix. These mechanisms include water reservoirs, superabsorbent polymers (SAPs), internal curing agents, and chemical admixtures. Water reservoirs release moisture gradually into the concrete, while SAPs absorb and retain water, gradually releasing it as needed. Internal curing agents, such as lightweight aggregates, provide internal water reservoirs within the concrete matrix. Chemical admixtures modify the properties of water to enhance its retention capacity, thereby facilitating self-curing.

Applications and Benefits: Self-curing concrete offers several advantages over traditional curing methods. It reduces the risk of drying shrinkage and cracking, leading to improved durability and structural integrity. Additionally, self-curing agents can enhance the early-age strength development of concrete, resulting in faster construction cycles. Moreover, the reduced reliance on external curing methods minimizes labor costs and environmental impact, making self-curing concrete a sustainable choice for construction projects.

Impact on Concrete Properties: Research studies have demonstrated the positive impact of self-curing agents on various concrete properties. These include reduced shrinkage, improved compressive and flexural strength, enhanced durability, and better resistance to cracking. Additionally, self-curing agents can improve the workability and rheological properties of concrete, leading to better finishability and surface quality.

Future Directions and Conclusion: Despite the significant advancements in self-curing agents, further research is needed to optimize their performance and address practical challenges. Future studies should focus on developing cost-effective and environmentally friendly self-curing agents, as well as exploring their compatibility with different concrete mixtures and construction practices. Overall, self-curing concrete has immense potential to revolutionize the construction industry by offering a sustainable and effective solution to curing-related challenges

In past decades, a notable deal of interest has been shown in the study of making concrete better by the process of incorporating specifically engineered ingredients and simulating the techniques for batching and mixing. Compared to traditional concrete, modern types of concrete are highly advantageous in as much as they provide good workability in the fresh state, possess high strength and low permeability. However, these types of concrete shown to be more sensitive to initial age cracking than conventional concrete. High performance concrete, *falling into the category so-called modern concrete, is essentially characterized by a cement matrix with low water/cement ratio (w/c), often including mineral additions like silica fume and the use of admixtures as super plasticizers. One of the major problems with these mixtures is their tendency to undergo early age cracking. While this cracking may or may not compromise the compressive strengths of these concretes, it likely does balance their long term durability.*

SELF-CURING CONCRETE

ACI-308 Code states that "Self-curing or Internal curing refers to the condition by which the cement hydration occurs because of the availability of additional interior water that is not part of the mixing water". In normal, curing of concrete means creating situations such that water is not lost from the surface of the concrete through the internal reservoirs (in the form of saturated or pre-soaked Light Weight fine Aggregates, Super Absorbent Polymers (SAP), or saturated wood fibers) created. Self-curing refers to the time-dependent relationship in improvement of concrete strength due to the gradual release of water which was absorbed before mixing to the cement particles to allow continued hydration. Concrete with internal curing may also have evolved from the concept of self-curing concrete, which is based on the introduction of a chemical admixture that is able to reduce water evaporation by a retaining function. The addition of a self-cure chemical based on a water-soluble polymeric glycol lead to improved durability of concrete cured in air, which was pointed out by Dhir et al. (1995). However, the performance of such admixture does not attain the efficiency of the water film curing as discussed by Hewlett (1998). The use of water retaining agents should not be seen as internal curing, since it is conceptually based in the internal sealing rather than internal curing.

Self-curing concrete is a revolutionary advancement in construction technology, offering numerous benefits that significantly enhance the durability, sustainability, and efficiency of concrete structures. Traditionally, curing concrete involves external methods such as wet curing or membrane curing, which are labor-intensive, time-consuming, and prone to issues like cracking and surface defects. However, self-curing concrete addresses these challenges by incorporating water-retaining agents or internal curing agents directly into the concrete mix.

2. REVIEW OF LIERATURE

Harris et al. (2015) have studied the free water and bound water in cement pastes. Quasi-elastic neutron scattering technique has been used to study the bonding of water to the cement pastes to enhance better hydration.

Gettu & Roncero (2015) have investigated the effect of glycol based shrinkage reducing admixture in concrete over a period of year. They have maintained the temperature and relative humidity and observed the significant reduction of drying shrinkage to 22% by the volume of concrete. In respect to the strength point of view, they stated the better behaviour of concrete with SRA than concrete under moist curing.

Subramaniaii et al. (2015) have made an attempt to reduce the autogenous shrinkage in low w/c concrete by the use of various shrinkage reducing admixtures. Fly ash, Metakaolin, GGBS and micro silica were the four supplementary materials taken as the partial replacement to the cement. They concluded that concrete with individual fly ash and metakaolin replacement to cement under ethyl propyl polyoxy ethylene ether at a dosage of 0.025% reduces the shrinkage by 40%.

The internal curing concrete with water soluble polymers was investigated by El-Dieb et al. (2012) in cement mixes. Poly-Ethylene Glycol (PEG) and Polyacrylamide (PAM) have been used as self-curing agents individually and in combined form. Silica fume was used as a partial replacement to cement to have a better hydration effect. Various mixes were prepared and results such as water retention, moisture transport, mass loss etc., were compared with and without mineral and self-curing admixture. Test results proved that mix with combination of PEG and PAM with 8% of silica fume provides better property than conventional mix.

Dhir et al. (1998) have presented self-cure concrete contains a chemical agent that reduces the evaporation of water from its surface, primarily by reducing the vapour pressure at the concrete pore solution surface. The self-curing agent developed at the concrete technology unit, University of Dundee, also produces an alteration in cement hydration product micro structure, and it was considered that this may also contribute to the improved water retention properties. To investigate this weight loss tests are conducted on both self cure and ordinary pastes exposed to controlled ambient conditions, whilst thermo gravimetric analysis was carried out on identical specimens. It was found that, whilst the evolution of heat of hydration renders the early stages of drying very complex, it was possible to examine the diffusion dependent stage of drying.

The diffusion coefficients observed for water vapour passing through the dry region of self-cure paste surface were much lower than those observed for the control. This has been attributed in two mechanisms: the lower vapour pressure above the pore solution leading to a smaller difference across the dried portion of the paste and lower relative humidities in the cement pores, and the change in microstructure which reduces permeability. When viewed through the scanning electron microscope, self-cure cement pastes display numerous, extremely thin crystals of calcium hydroxide. It is portable that the presence of these crystals refines the pore structure of the paste, since these modifications appear to strongly influence concrete permeability.

The use of shrinkage reducing admixture of molecular weight 400 as an internal curing agent was studied by Jagannadha Kumar et al. (2012). The application of such admixture of molecular weight 400 in concrete helps in self-curing and enhances better hydration and strength. In this study, the effect of admixture on compressive strength, split tensile and modulus of rupture by varying the percentage of dosage by weight of cement from 0% to2% were studied for M20 and M40mixes. It was found that the admixture could help in self-curing by giving strength on par with conventional curing.

Roland & Robert (2002) have carried work on internal curing composition for concrete which includes a glycol and a wax. The invention provides for the first time an internal curing composition which, when added to concrete or other cementitious mixes meets the required standards of curing as per Australian Standard AS 3799.

Dhir et al. (1995) has described the durability of self cured concrete. The significant long term tests such as initial surface absorption, chloride ingress, carbonation, corrosion potential and freeze / thaw resistance characteristics were studied for air cured self-cure concrete and it was compared with plain air cured concrete. The test result shows that the specimen under air cured self-cure concrete behaves better than plain air cured concrete. Also the test results prove that the film controlled concrete gives superior behaviour than air cured self-cure concrete, but the enhancement of air cured self-cure specimen could be achieved by varying the dosage of self-cure chemical (or) by use of different self-cure agent.

Jun Zhang et al. (2015) have studied the effect of autogenous shrinkage in high strength sulfoaluminate cement concrete incorporated with pre-soaked light weight aggregate. The concrete was studied and compared with conventional concrete. Here the induced curing water to the cement ratios was varied from 0% to 0.12% at an interval of 0.03%. The authors made various trial and computed that autogenous shrinkage was decreased to a certain limit and decrease of relative humidity was reduced by increasing the ratio of wIC / C upto a certain limit.

Henkensiefken et al. (2011) have investigated the water movement in internal curing concrete with saturated light weight aggregate under lower w/c ratios. X-Ray absorption technique has been used to monitor the water movement to enhance the hydration of the cement paste. The authors concluded that the efficiency of water movement entirely depends on position of aggregate inside the matrix.

Javier Castro et al. (2011) have made a research work on expanded shale, clay and slate as a fine light weight aggregate to produce internal cured concrete. They have tested the significant properties of absorption and desorption under controlled temperature as a function of time. They have made several trial samples with and without light weight aggregates and finally concluded that specimen with internal curing aggregate possess less absorption capacity than concrete without light weight aggregates.

Liu & Zhang (2010) have used pre-soaked light weight aggregates as an internal curing agent to study the permeability behaviour of high performance concrete. They have compared the target based concrete with control concrete and concrete incorporated with shrinkage reducing admixture. From all the cases of analysis, they concluded that fine particles of LWA gives better performance in terms of water retention, strength and long term behaviour than particle with higher order.

Geetha (2012) has made an investigation on self-curing concrete using Spinacia Oleracea as a natural internal curing agent. She has used the curing agent in her research at a dosage of 0.05%, 0.1%, 0.15% upto 0.45% with a constant interval of 0.05% based on weight of cement. She has studied workability, mechanical and durability properties of the concrete with curing agent for various dosages and compared the results obtained with conventional concrete involve full curing. She concluded that the better performance of concrete has achieved for 0.3% of self-curing agent which shows superior behavior than conventional cured concrete.

Madduru et al. (2016) investigated the use of paraffin wax as a internal curing agent in the preparation of self - compacting concrete. Here the fresh, hardened and microstructural properties have been studied with and without paraffin wax. The authors have concluded that the water loss from the concrete was minimum at the age of 90 days and the optimum dosage of the curing agent under lower and heavy molecular weight was found to be 0.1% and 1% based on weight of cement. In addition to that the strength remains more or less same for the concrete under both curing regimes as per their notice.

One of the critical factors influencing the properties and performance of concrete is the curing process, which involves maintaining adequate moisture and temperature conditions to facilitate hydration and development of strength (Neville, 2011). Traditional curing methods, such as ponding, wet covering, or membrane curing, are labor-intensive, time-consuming, and often prone to deficiencies such as inadequate moisture retention and surface drying (Ganesh et al., 2019).

To address these challenges, self-curing agents have emerged as an innovative solution to enhance the curing process and improve the properties of concrete. Self-curing agents are chemical admixtures or additives that are incorporated into the concrete mix to promote internal curing by reducing moisture loss and enhancing hydration (Wang et al., 2020). By mitigating the need for external curing methods and improving moisture distribution within the concrete matrix, self-curing agents offer several potential benefits, including improved strength development, reduced shrinkage, and enhanced durability (Kheder et al., 2018).

In this review article, we provide a comprehensive analysis of self-curing agents and their role in enhancing the sustainability and durability of concrete structures. The following sections will discuss the types of self-curing agents, their mechanisms of action, effects on concrete properties, sustainability benefits, practical applications, and future research directions.

2.1 Types of Self-Curing Agents

Self-curing agents can be classified into various categories based on their chemical composition and mode of action. Common types of self-curing agents include internal curing agents, superabsorbent polymers (SAPs), and crystalline admixtures.

2.2 Internal Curing Agents

Internal curing agents, also known as pre-wetted lightweight aggregates or saturated lightweight aggregates, are porous materials added to the concrete mix to provide a reservoir of water for internal curing (Bentz et al., 2011). These aggregates absorb water during mixing and release it gradually during hydration, ensuring continuous moisture supply to the cementitious matrix (Bentz and Weiss, 2018). Internal curing agents are typically lightweight materials such as expanded shale, clay, or perlite, which have high porosity and capillary suction properties (Garcia et al., 2017). Fig. 1depicts the self-curing mechanism in concrete.

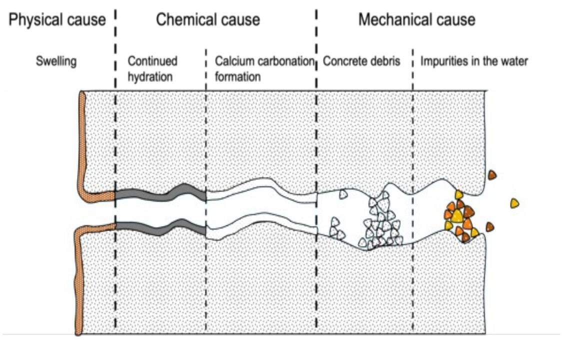

Fig1 Self healing (sorce:https://en.wikipedia.org/wiki/ Selfhealing_concrete#:~:text=Autogenous%20self%2Dhealing %20mechanism)

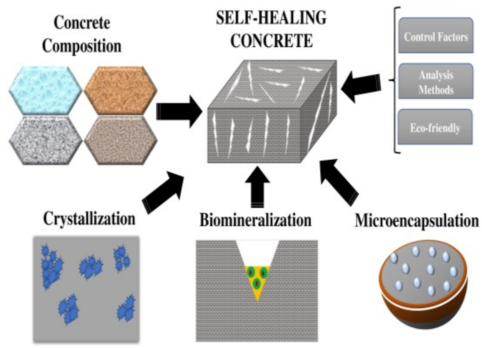

Fig2 self-curing mechanism (Roque et al. 2003)

Calcium Carbonate Formation*: When water enters the cracks in concrete, it reacts with unhydrated cement particles to form calcium hydroxide. This calcium hydroxide then reacts with carbon dioxide in the air to form calcium carbonate, a mineral that fills the cracks and seals them.*

Use of Supplementary Cementitious Materials (SCMs)*: Concrete mixtures often contain supplementary cementitious materials such as fly ash, silica fume, or slag. These materials contribute to self-healing by reacting with water and producing additional calcium silicate hydrate (C-S-H) gel, which can help fill in small cracks.*

Bacterial Healing*: In some advanced concrete formulations, bacteria are embedded within the concrete mix. When cracks form and water enters, these bacteria become activated and produce calcium carbonate, helping to close the cracks.*

Pozzolanic Reactions*: Some types of concrete contain pozzolanic materials, such as volcanic ash or calcined clay. When mixed with calcium hydroxide in the presence of water, these materials form additional C-S-H gel, which can contribute to self-healing.*

3. CONCLUSION

Internal curing agents play a crucial role in enhancing the performance of self-curing concrete. This innovative approach involves incorporating water-absorbing materials within the concrete mix to mitigate the need for external curing. The literature on internal curing agents highlights their significant impact on reducing shrinkage, improving durability, and enhancing overall mechanical properties of the concrete.One key aspect discussed in the literature is the selection of suitable internal curing agents, such as lightweight aggregates, superabsorbent polymers, or pre-soaked fine aggregates.

These materials efficiently absorb and release water during the hydration process, ensuring a continuous moisture supply within the concrete matrix. This internal curing mechanism contributes to reduced autogenous shrinkage, cracking, and improved long-term performance.The literature also explores the influence of *internal curing on various concrete properties, including strength development, permeability, and resistance to external environmental factors. Studies demonstrate that incorporating internal curing agents positively affects the mechanical properties of the concrete, leading to increased compressive and flexural strength. Moreover, the use of internal curing agents is found to be particularly advantageous in challenging environmental conditions, such as hot and dry climates, where external curing methods may be less effective. The research emphasizes the potential for sustainability benefits, as self-curing concrete reduces the need for additional water resources and labor-intensive curing procedures. In summary, the literature on internal curing agents in self-curing concrete underscores their role in addressing common challenges associated with traditional curing methods. The incorporation of water-absorbing materials within the concrete mix enhances overall performance, durability, and sustainability, making self-curing concrete a promising solution for the construction industry.*

In conclusion, the self-healing process in concrete represents a promising advancement in construction technology, offering significant potential for extending the service life and durability of concrete structures. Through the integration of innovative materials and techniques, such as the use of encapsulated healing agents or bacteria-based systems, concrete is capable of autonomously repairing cracks and mitigating damage caused by external factors such as weathering or mechanical stress.

The effectiveness of self-healing mechanisms in concrete has been demonstrated through various laboratory experiments and field trials, showcasing impressive healing efficiencies and improved mechanical properties. Furthermore, the environmentally-friendly nature of many self-healing systems aligns with the growing demand for sustainable construction practices, contributing to reduced maintenance requirements and lifecycle costs over the long term.

However, while the concept of self-healing concrete holds immense promise, several challenges and limitations remain to be addressed. These include issues related to scalability, compatibility with existing construction practices, and the long-term durability of healing mechanisms under real-world conditions. Additionally, the economic feasibility of implementing self-healing technologies on a large scale requires further evaluation, particularly in comparison to traditional repair methods.

Despite these challenges, ongoing research and development efforts continue to advance the field of self-healing concrete, with the potential to revolutionize the way we design, construct, and maintain infrastructure in the future. By addressing key technical and economic considerations, and leveraging emerging technologies, self-healing concrete has the potential to become a mainstream solution for enhancing the sustainability and resilience of our built environment.

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