International Journal for Research in Engineering Application & Management (IJREAM)
ISSN : 2454-9150 Vol-10, Issue-02, May 2024

Review Of PEG-400 as a Self-Curing Agent in Self-Curing Concrete

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Abstract— The process of curing concrete involves maintaining the moisture level in freshly prepared concrete to ensure it hardens properly and achieves the desired strength and durability. Proper curing helps to keep the surface of the concrete moist and reduce shrinkage. It's important to start the curing process as soon as the concrete has hardened enough so that it doesn't crack or break when exposed to pressure. Concrete gains its strength through hydration, so curing is a crucial step in achieving the desired strength of the concrete. The curing process of concrete is essential to achieve the desired durability and strength. Typically, it takes 7 to 28 days for the concrete to harden and gain strength. This process requires a significant amount of water, which cannot be wasted. In today's world, water scarcity is a major problem and hence alternatives are needed to be found wherever possible. In the construction field, ample water supply is required. Therefore, alternative methods are needed, such as self-curing concrete. This method involves the use of self-curing agents that facilitate the curing process without the need for external water. Self-curing agents such as SAP (Super Absorbent Polymer), PEG-400 (Polyethylene Glycol-400), Lightweight aggregates, etc are used for the self-curing mechanism. The advancements in the construction and chemical industry have paved the way for the development of new curing techniques and construction materials.

Keywords — Curing, hydration, Lightweight aggregates, PEG-400(Polyethylene Glycol-400), Self-Curing, SAP(Super Absorbent Polymer).

I. INTRODUCTION

- Curing of Concrete

Concrete is a construction material composed of cement, sand, and water mixed in specific proportions. The cement and water undergo a chemical reaction, which binds the aggregate together. The stage at which concrete loses its plasticity and hardens completely is known as the final setting time. Curing is a process of keeping the freshly prepared concrete moist to prevent it from losing the necessary moisture content required for the hydration process.[18]

When water is added to the mixture of cement, sand, and aggregate, an exothermic reaction called hydration occurs. This reaction helps the concrete to harden, but it is not an instant process and takes time. To ensure that the concrete is properly hydrated, a larger volume of water is needed during the processing stage. It is essential to keep the concrete moist until the hydration reaction is completed. If the curing process is neglected in the early stages, the quality of the concrete may be compromised. If the curing is not done correctly, the resulting concrete may not achieve the desired strength.

The objectives of curing concrete are as follows:

- It increases the hydration process of the concrete, which helps to achieve the desired strength.
- It improves the durability of the concrete by minimizing cracks.
- Improving the curing process of concrete can enhance its serviceability by increasing its resistance to abrasion.
- It enhances the concrete microstructure by improving the formation of stronger hydrate gels and solid mass.[18]

- Purpose of Curing of Concrete.

Hydration is the chemical process that occurs between cement and water. The reaction is exothermic (the reaction which releases heat).

The process of hydrating concrete starts when water is added to the mixture. This causes the concrete to dry out

 DOI : 10.35291/2454-9150.2024.0140

quickly due to an exothermic reaction that generates heat. To achieve maximum strength as soon as possible, the concrete needs to be kept damp during the hydration process.[18] This is why curing concrete is so important, as it helps the concrete gain its strength by ensuring proper hydration.

- Self-Curing Concrete

Self-curing concrete can harden without external water by using self-curing admixtures.[20]. Utilizing self-curing concrete, instead of traditional curing methods, is beneficial in regions with limited water resources [24].

II. CURING METHODS

Water addition is considered the best method for curing concrete, as it satisfies all the requirements of curing. This includes the absorption of heat from hydration, the promotion of hydration, and the elimination of shrinkage. Water curing is carried out by adding water to the surface of the concrete to ensure that it is continuously moist. However, the water used for this purpose should not be more than 5°C cooler than the concrete surface as spraying warm concrete with cold water may cause thermal shock, leading to cracking.

Water curing can be done in the following ways:

- Spraying Of Water

This method is well-suited for a variety of construction projects and can be used in most conditions. It involves spraying water to cure vertical reclining walls, plastered surfaces, concrete columns, and other similar structures. House pipes are connected to the main water supply lines to aid in the spraying process. However, when working on tall structures, spraying water at higher levels may cause difficulties for workers on lower floors.[19]

- Ponding Of Water

Ponding is a cost-effective and efficient way of curing concrete, provided that there is a sufficient supply of good 'dam' material such as clay soil and water, and that it doesn't interfere with later building operations. This method involves submerging pavement slabs, roof slabs, and other horizontal surfaces under shallow ponds of water, which are created by constructing temporary barriers. These ponds, which should not be more than 5 cm deep, are kept filled with water for several days. Ponding is particularly useful in hot weather as it helps maintain a consistent temperature on the surface of the slab.[19]

- Wet Coverings

To keep the concrete wet during the curing process, wet coverings such as wet gunny bags, jute matting, and straws are wrapped around vertical surfaces. For horizontal surfaces, sawdust, earth, or sand can be used as wet coverings to maintain a damp condition for a longer period. After the formwork is removed, another method suitable for flat, columnar, and vertical surfaces is to cover them with straw, burlap, hessian, or jute soaked in water. These materials are kept moist for the entire curing period. Fabrics are particularly useful on vertical surfaces as they help distribute water evenly over the surface, preventing surface evaporation from within the concrete and supplying the additional water required for hydration.[19]

- Immersion

The precast concrete items are usually immersed in curing tanks for a specific duration.

- Water Retention by curing compounds(Membrane method)

The chemical method of curing concrete involves spraying suitable chemical compounds dissolved in solvents onto the fresh concrete to be cured. This creates a thin film of the chemical compound on the concrete surface, which prevents evaporation and allows the concrete to set and harden properly without requiring additional water. These curing compounds are typically made of different types of resins. However, a key disadvantage of this method is that it is not possible to continuously add new layers of concrete on top of the cured surface without first completely removing the chemical film. The thick film of the chemical compound will eventually start peeling off after 2-4 weeks, leaving behind properly cured concrete.

- Temperature Control Method

The strength of concrete development is a function of time and temperature. Higher temperatures accelerate the hydration process, leading to faster strength development.

The exposure of concrete to higher temperatures is done in the following manners:

- Steam curing at ordinary temperature:

Steam curing is mostly used for prefabricated concrete elements. The concrete is placed in a chamber and steam is applied to accelerate hydration. It attains its 28-day strength in about 3 days. However, exposing concrete to high temperatures during the early period of hydration may reduce its strength later on. Therefore, it is recommended to delay subjecting fresh concrete to high temperatures after casting.

- Steam curing at high temperatures and pressure:

This method of curing concrete involves using super-heated steam at high temperature and pressure in a closed chamber, also known as autoclaving. Unlike normal steam curing, this process can develop the strength of the concrete in just one day instead of the usual 28 days, without any loss in strength at a later stage.

- Electrical curing:

Electricity is sometimes used to cure concrete in very cold climates, but it is not economically feasible in ordinary temperatures.

 DOI : 10.35291/2454-9150.2024.0140

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III. SELF-CURING CONCRETE

Self-curing concrete is a type of concrete that can cure and harden itself without requiring external water. Self-curing admixtures are added to facilitate this process. Self-curing concrete is particularly useful in areas where water is scarce or external curing is not feasible. These admixtures increase the internal moisture content of the concrete, thereby enhancing its self-curing properties.[20] Internal curing agents lead to autogenous shrinkage and improvement in the mechanical and durability behavior of concrete.[25]

Self-Curing Admixtures.

Self-curing technology, also known as internal curing, has gained popularity in the concrete research field. The concept is to reduce water evaporation from concrete and improve its water retention capacity. To achieve this, internal curing agents, acting as water reservoirs, are added to the concrete mixture. These agents gradually release water during the hydration and evaporation process, leading to better quality and durability of the concrete.

- Prewetted lightweight aggregates.

Prewetted Lightweight aggregates are often used as internal reservoirs in cement paste. During hydration, a system of capillary pores is formed, and as the relative humidity decreases due to hydration and drying, a humidity gradient develops.[6] The pores in the cement paste are smaller than those in the LWA, and so the pores of the cement paste absorb water from the LWA through capillary suction due to a difference in vapor pressure. The water is then transported to the drier cement paste, where it reacts with the un-hydrated cement. The un-hydrated cement particles then hydrate to form hydration products, which reduce the size of the pores in the cement paste and enable them to continue absorbing water from the LWA. This process continues until all the water from the LWA has been transported to the cement paste, creating a self-curing mechanism.[20]

Among the various features found in LWA, it has been shown to have high porosity and absorption capacity with the added benefit of supplying curing water internally.

- Superabsorbent Polymer (SAP).

Superabsorbent polymers (SAP) are hydrogels that have a three-dimensional cross-link network structure. They are capable of absorbing a large amount of liquid compared to their weight due to osmotic pressure, and they can expand to form an insoluble gel. SAPs have been widely used in various fields including forestry, agriculture, and health supplies, as they can serve as a water reservoir and retain water. Additionally, SAPs have been used with cementitious materials in concrete to mitigate shrinkage, such as autogenous and drying shrinkage, by self-curing and enhancing durability against freeze and thaw deterioration. When SAP is exposed to an aqueous solution, a chemical reaction occurs, leading to shrinkage or swelling of the SAP. The presence of osmotic pressure originates from a concentration gradient of moveable ions between the gel and solution. The swollen SAPs then act as water reservoirs in the concrete. However, as the humidity in the concrete decreases, the absorbed water is pulled back into the cement paste capillary pores. This leads to the SAPs gradually releasing the absorbed water and leaving the voids.[20] Juntao Dang et al., conducted a study on the impact of superabsorbent polymer (SAP) on the shrinkage and crack resistance of concrete at an early age. The research revealed that the pre-absorbed SAP had a lesser effect on concrete shrinkage when internal curing (IC) water was subtracted from the mixing water. As the volume of unabsorbed SAP gradually increased, there was a decrease in concrete shrinkage.[17]

- Polyethylene-glycol 400.

Polyethylene glycol is a polymer made up of ethylene oxide and water with the formula H(OCH2CH2)Noh , where n is the average number of repeated ethylene oxide groups, usually between 4 and 180. According to Raoult's Law, when the vapor pressure of a solute in its pure state is less than the vapor pressure of the solvent in its pure state, adding additives can theoretically decrease the vapor pressure of water and thus reduce the rate of evaporation above a concrete surface.[4] Therefore, the use of water-soluble polymers such as PEG as self-curing agents in concrete is effective in retaining water and enhancing the hydration process. Moreover, hydrophilic units in the polymeric chains form hydrogen bonds with water molecules. Hydrogen bonds are weak bonds formed between hydrogen atoms and strongly electronegative atoms in other molecules. The positively charged hydrogen atom is attracted to the electronegative atom electrostatically, as shown in Figure. Water-soluble polymers containing either hydroxyl (-OH-) or ether (-O-) functional groups have been used to minimize the impact of self-desiccation in concrete.[1]

Properties of PEG 400 as a self-curing agent in concrete[21]

Sr. No.	Property	Value
1	Appearance	Clear Liquid
2	Odor	Nil
3	Specific Gravity	1.09
4	pH Value	5-7
5	Molecular Weight	400
6	Density	1.128 g/cm3

Benefits Of PEG-400 as a self-curing agent in concrete:

- Faster Construction Rate
- Reduced labour cost
- Improved Strength and Durability
- Enhanced workability

 DOI : 10.35291/2454-9150.2024.0140

- Reduced Cracking and Shrinkage

PEG 400 added in the mix mainly forms hydrogen bonds with water molecules and reduces the chemical potential of the molecules which in turn reduces the vapor pressure, thus reducing the rate of evaporation from the surface.[4] PEG 400 increases the slump value.[26]

Shikha Tyagi conducted an experiment using PEG-400, in concrete. The experiment aimed to determine the ideal dosage of PEG400 that would result in maximum strength for M25 and M40 grade concrete. The findings showed that the optimal dosage for M25 is 1%, while for M40, it is 0.5%. In addition, the study also looked into the impact of PEG400 on workability, using slump cone and compaction factor tests. The dosage of PEG400 was varied from 0% to 2% for both M25 and M40. The results indicated that the self-curing agent helps in self-curing and provides better strength compared to conventional curing techniques. It also enhances workability. Based on the results, it was concluded that PEG-400 is an effective self-curing agent for concrete[15]. A study conducted by Azhagarsamy et al., investigated the strength and durability properties of M20-grade concrete using water-soluble polyethylene glycol (PEG 400) at a concentration of 0.5% as a self-curing agent. The compressive strength of the concrete was measured after 3, 7, and 28 days under both normal curing and self-curing conditions. The results showed that the use of 0.5% PEG 400 led to an average increase in compressive strength of 12.73% and split tensile strength of 13.31%. This demonstrates that self-curing concrete outperforms conventional concrete in terms of strength and durability[16].

IV. CONCLUSION

The study examines the various literature regarding the different curing methods and various self-curing agents that can be used in self-curing concrete. From the study, it can be stated that PEG-400 can be used in self-curing concrete as a self-curing agent. PEG 400 primarily forms hydrogen bonds with water molecules, reducing their chemical potential and vapor pressure, thus decreasing the evaporation rate from the surface. Better formation of C-S-H gel, which gains more strength. PEG-400 dosage can vary from 0 %to 4 % by the weight of cement. Using self-curing concrete instead of conventional curing is helpful in areas with low water availability.

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 DOI : 10.35291/2454-9150.2024.0140