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INTERNAL CURING AGENTS IN CONCRETE

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Abstract - *This paper summaries the current knowledge about the curing, internal curing, and mainly deals with the various internal curing agents used in concrete. The effect of various internal curing agents on the properties of concrete is been discussed. Initially the definitions of internal curing is discussed. Followed by that different articles on various internal curing agents and the effects of various internal curing agents on properties of concrete are reviewed.*

Key Words*:* Curing, Internal Curing, Internal Curing Agent, Super Absorbent Polymer, Lightweight Expanded Clay Aggregate, Pumice, Perlite, Wood Fibre, Concrete.

1. INTRODUCTION

Curing in concrete is defined as the process of maintaining adequate amount of moisture in the concrete within a proper temperature range inorder to help cement hydration at early ages. Curing plays an important role on development of strength and durability of concrete. Concrete curing is traditionally done externally. External / traditional curing methods include tactics to supply additional moisture to replace moisture lost to hydration and evaporation, sealing in the mix water, and applying moisture and heat to accelerate hydration. Fogging, sprinkling, and application of wet coverings, plastic sheeting, and membrane compounds are commonly utilized methods of external curing.[1]

Later an approach has been established known as Internal curing (IC), that utilizes a material to deliver moisture internally to concrete, facilitating hydration throughout the concrete even after conventional curing methods are discontinued. Internal curing can be accomplished by placing reservoirs of water within the interior of the concrete that are able to provide moisture in addition to that provided by the batch water to the cement particles as the chemical reaction of hydration occurs. ACI also be defines internal curing as "the use of absorptive materials in the mixture that supplement the standard curing practices by supplying moisture via internal reservoirs to the interior of the concrete".[2]

A variety of materials possess the characteristics necessary to support internal curing, including prewetted lightweight aggregate (LWA), prewetted crushed returned concretefines, superabsorbent polymers, or prewetted wood fibers and absorbent limestone aggregates. These materials, when fully saturated, may provide enough moisture to fully hydrate the cement paste and potentially diminish or eliminate the shrinkage associated with the hydration process. If this shrinkage can be reduced, the potential for early-age cracking can be reduced as well.

Internal curing of concrete can be ensured mainly by two ways. One is by using light weight aggregate (LWA) and other by adding chemical curing admixtures. Internal curing using expanded shale, clay or slate lightweight aggregates is a simple and practical way of supplying additional curing water throughout the concrete mixture. This is done by replacing some of the conventional aggregate in the mixture with an equal volume of prewetted lightweight aggregates. In case of chemical curing agents in internal curing super absorbent polymer and shrinkage reducing admixtures like polyethylene glycol were applicable. These are incorporated into the concrete as an admixture hence known as internal curing compounds. They inhibit moisture loss and thereby improve long term strength and reduce drying shrinkage. Internal curing compounds are relatively new, and care should be taken when utilized.[3]

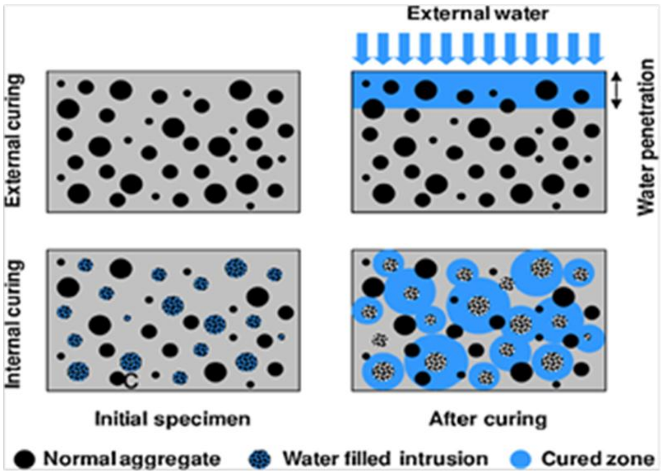

Fig-1: Conceptual diagram of external and internal curing

2. INTERNAL CURING AGENTS

A curing agent is added into the concrete to provide an internal water reservoir that gradually releases its water during hydration. Now a variety of curing agents are readily available.

2.1Super Absorbent Polymer(SAP)

Fig-2: Sodium Polyacrylate

The introduction of SAP as a new additive for the production of concrete materials presents a number of new possibilities in respect of water control, i.e., the purposeful water absorption and/or water release in either fresh or hardened concrete. Proper curing of concrete structures is important to ensure they meet their intended performance and durability requirements. [4,5]Superabsorbent polymer (also called slush powder) can absorb and retain extremely large amounts of a liquid relative to their own mass. Water-absorbing polymers, which are classified as hydrogels when cross-linked absorb aqueous solutions through hydrogen bonding with water molecules. A SAP's ability to absorb water depends on the ionic concentration of the aqueous solution. In deionized and distilled water, a SAP may absorb 300 times its weight and can become up to 99.9% liquid, but when put into a 0.9% saline solution, the absorbency drops to approximately 50 times its weight. The presence of valence cations in the solution impedes the polymer's ability to bond with the water molecule. The total absorbency and swelling capacity are controlled by the type and degree of cross-linkers used to make the gel. Low-density cross-linked SAPs generally have a higher absorbent capacity and swell to a larger degree. These types of SAPs also have a softer and stickier gel formation. High cross-link density polymers exhibit lower absorbent capacity and swell, but the gel strength is firmer and can maintain particle shape even under modest pressure. SAPs have found a widespread use as a high-tech material e.g. for contact lenses, breast implants, fire fighting, drug delivery, in baby diapers and as soil conditioners. [6].

Alnasra[7] studied the effect of adding sodium polyacrylate (SAP) to concrete mortar as an internal curing agent on the strength, after conducted a sundry experiments and select the optimum quantity to enhance concrete strength. The researcher found that 0.11% of SAP to cement mass (without extra water) it was the optimum quantity that leads to improved concrete strength. Hareendran et.al [8] tested the compressive strength of six different mortar samples with different quantity of superabsorbent polymer 0%, 0.2%, 0.25%, 0.3%, 0.35% and 0.4% to cement mass with some extra water. After 28 days, the addition 0.35% of SAP gave the highest value in the compressive test even higher than the reference mixture.

Waleed A. Abbas et.al[9] focus on the effect of SAP on workability,compressive strength and tensile strength of the mortar concrete. At 0.4% SAP the best compressive strength and tensile strength is obtained. Ravindra.D.Warkhade et.al[10] studied the effect of various replacement of cement by SAP by 0.1%,0.3%,0.5%,0.7% for M20 Grade. Here mechanical properties of concrete found for varying percentage of SAP without water curing.

Jirawan siramanont[11] reported that internal curing using SAP is nearly depends on the method of polymerisation. SAP from bulk polymerisation has demonstrated superior performances to water. Concrete with bulk polymerised SAP shows greater strength gain when introduced to an external water sources. It also found that, Sap's affinity for water will affect rheological behaviour of concrete. Therefore SAP with properly matched swelling behaviour, as internal curing agents, should constituently lead to strength gain. Since volume of the swollen SAP's should be partially or not fully replaced by hydration products during hydration at later ages.

2.2Light weight Expanded Clay Aggregates(LECA)

Fig-3: Light weight Expanded Clay Aggregate

Lightweight Expanded Clay Aggregate (LECA) is a manufactured and artificial lightweight aggregate which were produced by using clay, coal, perlite, and bottom ash after heating at 1200°C in a rotary kiln, the clay expanded to about four to five times its original size and took the shape of pellets. This process was originally employed to produce lightweight cubes in Scandinavia in 1930.

Expanded clays are clays which may expand up to 5–6 folds by volume as a result of gas release when they are treated with heat. A hard sintered crust is formed on the outer surface, while quite light and highly durable aggregate with a porous clinker-like structure may be produced inside it.The honeycombed structure of LECA has a high crushing resistance, favourable fire resistance, and excellent thermal and sound insulation properties[12]

Water absorption of LECA is significantly more than for normal weight aggregates. When LECA are used in concrete in a pre-saturated condition, the water inside the lightweight aggregate is additional internal water, which is not part of the mixing water. This water can penetrate from the lightweight aggregate into the surrounding matrix to a distance of up to several millimeters during the first seven days of hydration measured water transport from saturated pumice lightweight aggregate to hardening cement paste. [13]

One of the benefits of internal curing is increased hydration and strength development. Apart from the compensation for moisture loss, the existence of this absorbed water plays a role in 'internal curing' of the concrete also. Expanded clay aggregates are used in many different industries due to its technical features and numerous advantages when compared to many other industrial raw materials. expanded clay aggregates have high compressive strength among lightweight aggregates. This gives it a significant position in the construction industry. 20% may be saved in reinforcing steel while up to 50% may be saved in heating–cooling expenses in buildings containing Light Weight Expanded Clay Aggregate (LECA). Due to lightweight property, light weight aggregate concrete is a favorable material for the precast industry also. This will reduce the cost of transportation and handling.[14]

JoAnn Browning et.al[15] study focused on use of light weight aggregates as internal curing agent in concrete. Here partial replacement of normal weight aggregate with prewetted vacuum saturated light weight aggregate used. From this study demonstrates the positive impact of extended curing on concrete.
D.cusson [16] research focused on case studies of using internal curing in concrete. A large number of case studies have been conducted, especially in the past 50 years on light weight concrete structures, including bridges, buildings, and offshore platforms. In the wellington stadium, New Zealand, this stadium is New Zealand‟s first major structures built with lightweight aggregates concrete. They used pre-soaked expanded shale coarse aggregate.it found that it has superior durability performance similar to light weight concrete structures. Fifa World Cup Pavilion, Germany is another example for use of internal curing agents. here Super absorbent polymers were used to entrain internal curing water in concrete mixtures containing normal density aggregates.it found that the early age autogenous shrinkage was greatly reduced by internal curing, however total shrinkage was only found to decrease slightly at older age and 28 day strength compression, direct tension, bending of SAP cured concrete were approximately lower than those of reference concrete made without SAP. This reduction in strength due to porosity which can be regarded as additional macro pores.

Raj Prakash et.al[17] studies the effect of partial replacement of coarse aggregate by LECA by 0%, 20%, 40%, 60%, 80%, 100%. Here it compares the weight of concrete and strength properties of LECA concrete against conventional concrete. In this study the researcher found that workability of LECA concrete increases with increase in partial replacement of coarse aggregate. The results states that as the percentage replacement of the LECA increases strength decreases. Shivashankar et.al[18] investigates the effect of partial replacement of coarse aggregate by LECA by 0%, 25%,50% .In this study the researcher aims to find the fresh and hardened properties of LECA concrete. The results states that as the percentage replacement of the LECA increases strength decreases.

2.3Pumice

Fig-4: Pumice stone

Pumice is a porous volcanic rock which resembles a sponge. The porous structure is formed by dissolved gases which are precipitated during the process of cooling as the lava hurtles through the air. All types of magma may form pumice. The connectivity of the pore structure may range from completely closed to completely open. A representative value for the absorption of pumice is 0.27 kg/kg [19]. Burcu Akcay et al [20] experimentally investigate the Effects of distribution of lightweight aggregates (LWA) on internal curing of concrete. Different sizes and amounts of natural pumice LWAs were used as water reservoirs to provide internal curing in mitigating autogenous deformation. Seven concretes were prepared using constant water to binder ratio of 0.28 and the light weight aggregate of three different volume fractions such as 10%, 20%, and 30% of the total aggregate volume of concrete added. Experimental results have shown that the use of pre-soaked LWAs as water reservoirs effectively mitigates the autogenous shrinkage of concrete.

2.4Perlite

Fig-5: Perlite

Perlite is an amorphous volcanic glass that has relatively high water content. It occurs naturally and has the property of highly expanding when heated sufficiently. When quickly heated to above 900°C, the crude rock expands 4-20 times its original volume as the combined water vaporizes and creates countless tiny bubbles. This results in a bulk density in the range 30-400 kg/m^3, and a water absorption of 200-600%. Perlite expansion is due to the presence of two to six percent combined water in the crude Perlite rock. When the crude oil is quickly heated to above 870^{0}C, the product pops in a similar manner to popcorn[21].

Perlite has found multiple uses such as for filtration, as an abrasive and within horticulture to provide aeration and moisture retention. However, perlite is primarily used within the construction area for example as concrete aggregate and as a cavity-filling insulation. Disintegration of perlite particles has been observed during mixing due to their high porosity and consequently low strength [18]. This may have adverse effects on the concrete. Fully saturated, the water content of perlite may be 4.5 kg/kg [18].

Dhanalakshmi et al[21] conducted a study on various percentage replacement of sand by perlite and found that the optimum replacement percentage of sand by Perlite is 10%. The compressive, split tensile and flexural strength were reduced if the replacement percentage of Perlite will be increased.

2.5Wood-derived powders and fiber

Fig-6: Sawdust

Kraft and thermomechanical pulp fibers as well as cellulose and wood powders which varies in their size and morphology have been investigated for use as internal water curing agents in cement-based materials. A water absorption of 1-3.3 kg/kg for these wood-derived powders and fibers has been reported.[22].

Iftikhar Azim et al [23] investigates the use of presaturated sawdust for producing high performance concrete. Pre-saturated sawdust is used as a source of internal curing by partially replacing sand. Pre-saturated sawdust is used to replace fine aggregate at three replacement levels of 5, 10 and 15% by mass respectively. These samples are subjected to different curing conditions. Compressive strength tests are conducted and comparison with control mix and unit weight analysis is also carried out. The compressive strengths of the samples without external curing for 5% replacement level are improved by 81.92%, 51.16%, 4.01% and 7.64% at 3,7,14 and 28 days respectively. While the compressive strengths of specimens with external curing for 5% replacement level are improved by 8.55%, 27.57%, 50.35 and 6.26% at 3,7,14 and 28 days respectively. The unit weight is decreased by 5.52%, 10.71% and 17.49% for 5, 10 and 15% replacement levels of sawdust, respectively.

3. CONCLUSIONS

There is a need to cure adequately inorder to prevent the two primary negative consequences. Firstly, limiting strength development and producing a more permeable final product. Secondly, the loss of water causes concrete to shrink and, if restrained, the concrete develops stresses that may lead to cracking. Inorder to overcome the problems of inadequate curing two main strategies are adopted. They are one by the Use of light weight aggregate(LWA) and the other by the use of super absorbent polymer(SAP).By the use of various internal curing agents, we can increase strength to an extent and reduce cracking in concrete and thereby improve the durability of concrete.

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