# Sustainable Development Through Use of Self-Curing Concrete

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Concrete requires sufficient curing to attain the desired strength as well as durability properties. If the concrete is not cured adequately, cement will not undergo full hydration. It is a well-known fact that more fraction of cement particles attaining hydration leads to formation of desirable compounds in the concrete. Moreover, it results in an improved performance of the concrete on site. The sufficient cement hydration ensures that the concrete porosity is decreased to such an extent that the required strength and durability are achieved; moreover, volume changes in the concrete due to shrinkages are also reduced [1].

Initial drying shrinkage is because of quick drying of concrete. It results in the formation of powdery surfaces with low resistance against abrasion. An improper curing increases concrete absorptivity as well as permeability. These two vital factors are a function of concrete porosity. The durability depends upon whether the pores and capillaries are interconnected or discrete. The size and quantity of pores and capillaries prevailing in the cement paste are a function of water curing and water-cement ratio. The capillaries and pores are partly or fully filled by the hydration products. Hence, proper curing is very essential for concrete to attain the desired properties [1, 2 and 3].

It is a well-known fact that the water-cement ratio of at least 0.38 is desired for concrete, of which 0.23 is needed for hydrating all the cement particles and 0.15 for filling the voids in the gel pores. However, practically, water-cement ratio of 0.5 is necessary for full hydration in a sealed container for attaining the required relative humidity (RH) level. However, in the field it's entirely a different story. Even though higher water-cement ratio is used, concrete is open to atmosphere leading to evaporation and insufficient hydration.

## Need for Self-Curing (Internal Curing) of Concrete

Lack of sufficient moisture conditions results in virtually slowing down the rate of cement hydration. Hydration process practically stops when the RH within the pores falls below 80% and it becomes negligible when the internal RH drops to 30% [4]. The conventional curing is done by external application of water to the hardened concrete. Self-Curing or internal curing is a mechanism of preserving sufficient moisture in concrete for an effective cement hydration and reduction of self-desiccation [5]. Self-desiccation is a localized drying because of decreasing RH which may be due to cement demanding additional water for hydration. It is the reduction in the internal RH of a sealed system when empty pores are formed.

Initial period evaporation leads to plastic shrinkage cracking and during final setting; it results in to drying shrinkage cracking. Therefore, curing time and temperature are vital factors that govern the rate of strength development [6]. At high temperatures, ordinary concrete loses its strength due to formation of cracks between two thermally incompatible ingredients, i.e., cement paste and aggregates. Continuous evaporation of moisture occurs from an exposed concrete surface due to difference in chemical potentials between vapor and liquid phases.

Self-Curing facilitates in preserving water inside the concrete mass so that no additional water is required for an external curing. As a thumb rule, 1 $m^3$ of

# Contracts for Infrastructure Works

*15th October 2022, 9am to 6pm*
*at Vivanta by Taj President, Cuffe Parade, Mumbai*

## OBJECTIVE OF THE SEMINAR

*The pace is now right* to analyse and examine the changes that the two years and more of the pandemic thrust upon the judicial thinking, processes and procedures for contracts especially those related to the extensive Infrastructure development in the country.

The term 'Infrastructure' is used here to imply all sectors - Roads & Highways, Railways & Metros, Shipping & Water transport, Airports, Water, Wastewater & Solid Waste, Power, Irrigation & Flood Control, Townships, Smart Cities, Buildings, Hospitals & HealthCare, Industrial, etc.

The Consulting Engineers Association of India, based on similar successful interactions and the feedbacks received, brings yet another opportunity for discussion on current topical issues in the legal eco-system.

**Chief Guest:** **Vice Admiral Rajaram Swaminathan, AVSM, NM**
Director General Naval Projects (Mumbai)

**Distinguished Guest:** **Dr. Ramnath Sonawane,** Secretary,
Maharashtra Water Resource Regulatory Authority

## Topics & Faculty

1. **Current Judicial trend and issues in Limitation of Interest clauses in Contracts - Mr. Rajat Taimni & Mr. Aditya Gupte, Tuli & Co**
2. **What the Future outlook would be vis-à-vis Operation and Interpretation of Force Majeure clauses in Covid-19 – Mr. Ashutosh M Kulkarni, Advocate**
3. **Recent Judicial Pronouncements on Liquidated Damages – Mr. Suwigya Awasthy, PSL Advocates & Solicitors**
4. **Right to Claim variations and acceleration/ damages and time extension in Contract Execution – Mr. Vikas Kumar Sinha, IRAS, DFCCIL**
5. **Design Liability in Design and Build contracts- Mr. Kirindeep Singh, Dentons Rodyk & Davidson LLP**
6. **Final & Binding- Engineers Determination Clause- With reference to Indian Contract- How can this be Challenged? - Mr. Sachin Mishra, TATA Consulting Engineers Limited**

**Panellists – Dr. Vandana Bhatt, Mr. Uttam Sengupta, Mr. Chetan Kavdia, and Dr. Milind Wankhede**

**Two sessions for interaction with the attendees.**

People from the legal sector, construction and engineering who have their finger on the pulse will share their views, experience and the recent pronouncements on legal matters and their impact on the Works. They will be **eminent persons from their fields to break bread together and exchange experiences, notes and views** with Corporate Legal Heads, VP/ GM Contracts, Commercial Managers, Project Managers, Engineers & Quantity Surveyors, Construction Professionals, Consultants, Lawyers & Arbitrators, Insurance Professionals and Others who have a professional interest in the handling of contracts and the resolution of divergent views that arise on the Works.

## WHO SHOULD ATTEND?

- Corporate Legal Heads
- VP/ GM Contracts
- Commercial Managers
- Project Managers
- Engineers & Quantity Surveyors
- Construction Professionals/ Consultants
- Lawyers & Arbitrators
- Insurance Professionals
- Others who have a professional interest in the handling of contracts

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finished concrete needs about 3 $m^3$ of water, most of which goes into curing [7]. Making water available for external curing has certain limitations such as non-availability of potable water, lack of accessibility of the structure, and low water-cement ratio of High Performance Concrete. In Indian construction industry, external curing techniques are tedious, labor intensive and unsustainable. On the contrary, sometimes, there may be lot of water wastage through evaporation and run-off. To cope up with these issues, Self-Curing is a sustainable solution.

## Mechanism of Internal Curing

Concrete curing methods can be broadly categorized in to water adding method and water retaining method. Self-Curing is a water retaining method. There are two major ways of internal curing of concrete. The first method utilizes the prewetted porous lightweight aggregates (LWAs) to provide an internal water source in order to replenish the water consumed by chemical shrinkage during cement hydration. The second approach uses hydrophilic additives to reduce water evaporation from concrete surface and bring about water retention. These additives reduce the water loss and create an affinity for the moisture from the atmosphere, as well. This leads to an uninterrupted concrete curing. In recent years, the idea of Self-Curing concrete has been proving its worth and is gradually making impact in the field applications from the laboratory studies.

As per ACI 308 committee [8], "Internal curing is a mechanism by virtue of which cement hydration takes place due to additional water available which is not the part of mixing water". The driving mechanism for internal curing is chemical shrinkage. Chemical shrinkage is a process in which the products of a reaction occupy a smaller volume than the reactants [9, 10]. It refers to decrease in volume which occurs during hydration due to chemical reaction. Before setting of concrete mass, this volume change is not a problem, because as chemical shrinkage occurs, concrete is still in fluid form and particles have an ability to re-adjust themselves to fill the voids created by chemical shrinkage. However, once the concrete sets, rigid nature of concrete does not allow the particles to re-adjust which leads to formation of vapor-filled voids in concrete [11].

Self-Curing is particularly beneficial in concretes with low water-cement ratio because of the chemical shrinkage which is associated with Portland cement hydration and low permeability of these materials. As the water incorporated into and absorbed by the cement hydration products has a specific volume less than that of bulk water, a hydrating cement paste will imbibe water, about 0.07 g water/g cement, from the available sources [12]. In greater water-cement ratio concretes, this water is supplied by surface curing. However, in low water-cement concretes, concrete permeability becomes too low in first 2 to 3 days and hence does not allow an efficient transfer of water from external surface to the interior of concrete [13]. If additional water can be distributed somewhat uniformly throughout the concrete through internal curing, it will be readily available to migrate to the nearby cement paste and participate in hydration process.

Self-Curing is an efficient way to decrease self-desiccation and autogenous shrinkage [11, 14]. Autogenous shrinkage is a volume change in concrete taking place without moisture transfer from the environment into concrete. It is because of internal chemical and structural reactions of the concrete. It is significant in High Performance Concretes because of low quantity of water and increased amount of various binders used. During initial few hours, before concrete becomes a hardened skeleton, autogenous shrinkage is often due to only chemical shrinkage. However, after one day, it can also result from self-desiccation since the hardened skeleton resists the chemical shrinkage. Along with thermal strains, it can be a considerable contributor to early-age cracking.

Apart from reducing shrinkage, Self-Curing facilitates in reducing shrinkage cracking [15], plastic shrinkage cracking [16] and water absorption [17]. The basic difference between the conventional curing and internal curing is shown in fig. 1 [18]. In external curing, water is applied on the surface. The water penetration depth is affected by the factors such as quality of concrete and age. The advantage of Self-Curing is that the water gets distributed throughout the concrete mix.

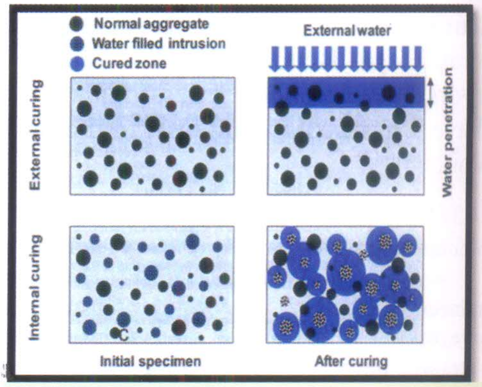


Figure 1: Difference between External Curing and Internal Curing [18]

Figure 2(a): Super Absorbent Polymer [4]

Figure 2 (b): Microscopic View of SAP [4]

Super Absorbent Polymer (SAP) is a hydrophilic material. It is added in to concrete by mass of cement. It can absorb and retain extremely large amounts of a liquid relative to its own mass. Fig. 2(a) and (b) [4] show SAP and its microscopic view.

These water absorbing polymers, classified as hydro gels, when cross-linked, absorb aqueous solutions through hydrogen bonding with water molecules. The other hydrophilic materials acting as Self-Curing agents are Shrinkage Reducing Admixtures (SRA) such as polyethylene glycol, propylene glycol, polyvinyl alcohol, paraffin wax, acrylic acid, etc. These agents are added by mass of cement to reduce the surface tension of the mixing water. These chemical polymers added into concrete mix have a tendency of forming hydrogen bonds with water molecules and reduce chemical potential of water molecules. This reduces the vapor pressure, thereby decreasing the evaporation rate from the concrete surface and enhancing cement hydration.

Rate of hydration increases quantity of solid phase of the paste owing to the fact that water is consumed by chemical reactions of hydration. In addition, water adsorbed onto the surfaces of the solids in the hydration products keeps them saturated, maintaining the RH in the paste to evade the phenomenon of self-desiccation.

The various LWAs used in prewetted condition for the internal curing are expanded shale, expanded clay, pumice, perlite, sintered fly ash aggregates, etc. These are added as partial replacement of fine aggregates or coarse aggregates by volume. Part replacement of fine aggregates with fine LWAs is preferred due to their uniform distribution throughout the concrete mass. Efficiency of LWA as an internal curing additive primarily depends on amount of absorbed water which it can hold, it's particle size and distribution and it's pore structure. The optimum quantity of LWA used to attain Self-Curing is a function of type of LWAs, their size, degree of their moisture preconditioning, water-cement ratio of mix and type and amount of binders used in the concrete mix. LWAs should hold sufficient water until needed and should not affect water-cement ratio. They should give up water at high RH, through good desorption behaviour. The water leaves pores of LWAs provided that enough suction pressure exists. However, this favorable desorption behaviour is not characteristic of all LWAs [19]. The distance of water travelled from the surfaces of internal reservoirs was estimated by Bentz et. al. [20] in terms of hydration age. Early age (< 1 day): 20 mm, middle age (1day to 3 days): 5 mm, late (3 to 7 days): 1mm, worst case (> 28 days): 0.25 mm.

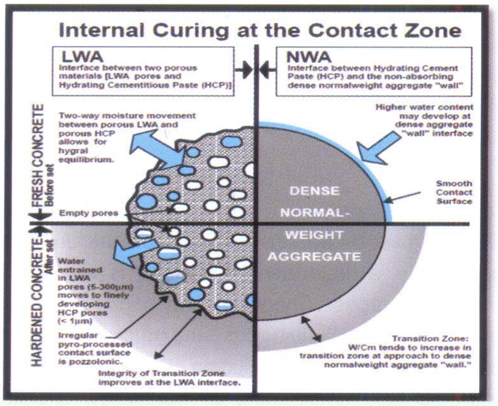


Figure 3: Difference in moisture movement between Porous LWAs and NWAs [20]

The microstructure of Interfacial Transition Zones (ITZ) around LWAs and normal weight aggregates (NWAs) are different (Fig. 3). In NWAs, a wall effect exists because of inherent size differences between cement particles and aggregates. There is a deficiency of cement particles and a surplus of water (porosity) near the aggregate surface; so, a higher water-cement ratio within the ITZ.

## Field Applications of Internally Cured Concrete

There are many cases of practical use of Self-Curing concrete on construction sites, especially for highway projects in advanced countries. Prewetted LWAs were utilized as internal curing additives. Photographs of two such cases are shown in Figure 4 and 5.

Figure 4: Internally Cured Concrete being Cast at Bartell Road in New York (Wolfe, 2010)

Figure 5: Internally Cured Concrete Bridge Deck being Cast Near Bloomington, IN (Di Bella, Schlitter, & Weiss, 2010)

## Scope for Internally Cured Concrete for Sustainable Development in India

After agricultural sector, construction industry sector is second largest contributor to Indian economy. So, it needs to be taken on priority basis in terms of providing world class infrastructure as well as delivering time-bound projects. Success of Indian construction sector largely depends upon the availability of raw materials, skilled manpower, construction equipment and state of the art technologies.

Availability of required quality as well as quantity of water is an issue. The unskilled workers don't realize the importance of sufficient curing, thereby producing a low-quality concrete. On the contrary, sometimes, a huge amount of water is wasted for the curing purpose. There is a dire need of producing the concrete with judicious and optimum use of constituent materials, including water, to cope up with the field requirement of workability, strength and durability. India has a complex physical diversity in the form of temperatures and humidities. These factors are important for concrete performance in its life cycle. If internal curing is practiced in India, it would lead to a sustainable development.

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