Recyclable Wastes as Internal Curing Materials to Improve High-Performance Concrete’s Sustainability, and Durability: An Overview

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Abstract:

This study discusses the researchers’ experiences with regard to the use of sustainable materials (waste materials and recycling materials) as internal curing materials during the development process for high-performance concrete (HPC). Generally, the use of waste materials as internal curing materials to enhance interior curing reduces the self-desiccation that occurs in cement paste concrete and can thus reduce the risks of the cracks that may develop as a result of modern concrete hardening. This research also examines high-performance concrete behaviours, including characteristics such as density, compressive strength, splitting tensile strength, and flexural strength to examine internal curing efficiency. This appears to be more effective with age progression in terms of compressive strength and splitting tensile strength. The results of the research show that the use of waste materials as internal curing agents not only enhances the properties of concrete but also offers a renewable method for reducing the amount of waste globally.

Keywords: Sustainability; Internal Curing (IC); High-Performance Concrete (HPC); Compressive Strength; Split Tensile Strength; Flexural Strength.

1. Introduction

Concrete is a naturally composite material comprised of aggregates of various sorts and sizes, and a cementitious bonding paste. The paste binds the aggregates to each other so that, when it hardens, concrete becomes a material with many similar properties to rock. The concrete paste itself consists of cementitious materials such as hydraulic cement, microsilica, and metakaolin, ground granulated blast furnace slag, pulverized fuel ash, mineral, water, and chemical admixtures, and the hardened concrete mass characteristics are mainly dependent on the characteristics of the materials used to manufacture the cement paste. The design of concrete mixes concerns defining concrete ingredient proportions to satisfy the planned needs for the material, such as durability in terms of the service surroundings (concrete cracking resistance, interactions with service surroundings which may lead to physical and/or chemical deterioration processes,) and short term and medium term dimensional stability (creep and shrinkage)[1].

1.1 Concrete Sustainability

Regions of major metropolitan development tend to run short of sources of aggregates after extended periods of concrete creation. Sustainability obligates engineers to ponder a building’s “lifecycle”, to extend its useful life and minimise damage. This involves a focus on process construction and maintenance, and finally, when the demolition of buildings is required, recycling as many materials as possible [2][3]. In accordance with the World Commission on Environment and Development of the UN, it is important to investigate the requirements of this while not transgressing on the flexibility of later
generations to satisfy their own needs in the future [4]. The planet has been stripped of many natural resources within past decades, which has imposed considerable strain on the environment in terms of raw material deprivation, environmental pollution, global warming, rising sea levels, and reduced biodiversity due to endangerment of species [5]. Sustainability is thus significant to the ongoing prosperity of the planet, the continuing outgrowth of a community, and developing human society. Concrete is, however, one of the most widely consumed construction materials in modern times due to its durability and dependable nature. In addition to its sturdiness and reliability, concrete also offers outstanding energy performance, is versatile in style, is easy to use, and can be comparatively environmentally friendly. It is thus foreseeable that sustainable concrete will be required to extend urbanisation while protecting the environment[6].

Fig. 1 How to make more sustainable concrete [7].

Globally, building construction and infrastructure consume 60% of the raw materials extracted each year. Of this volume, building represents about 24% of those global extractions [8]. The initial embodied energy from building materials in a simple single-story building may account up to 67% of its operational energy over a twenty-five years period [9]. Further, with the exception of structures that act as monuments, most need to be razed eventually. Concrete accounts for nearly 75% by weight of all materials used in construction, and it follows that it thus accounts for the foremost proportion of demolition wastes [10]. Construction and demolition wastes are, overall, among the primary causes of waste. Developing sustainable construction thus requires forming and operating a healthy setting that supports resource potency and ecological preservation. Established principles for sustainable construction include [9]

- Reducing resource consumption;
- Using recyclable resources;
- Reusing resources;
- Applying life cycle costing;
- Removing toxic substances; and
- Focusing on quality.

Several sustainable solutions have been developed by concrete manufacturers in many market sectors, including agriculture and construction. In agriculture, integrated waste management solutions are under development for the conversion of manure into biogas, reusable waste, and nutrient-rich fertilizer. Commercial, industrial, and institutional buildings are now also being created to be economical with energy use, as well as having higher air quality and lower maintenance requirements[6]. To achieve economic sustainability, development should change its resources use from non-renewable to renewable forms, thus moving from the production the waste to its utilisation, and from placing an emphasis on initial prices to developing full-cost accounting and life-cycle costs (LCC), with the prices of factors such as waste, pollution, and emissions factored into material costings [11].
1.2 Curing

Curing is a term that refers to the internal chemical reactions within the paste of hydrous cements and concretes; this develops the properties of the paste based on it having a sufficient quantity of water and heat for the required period [12][13]. Curing, regardless of the method, involves managing the extent and speed of water removal from concrete throughout the cement hydration process. This process may be either done as soon as the concrete is in position or throughout the process of concrete manufacture, the latter providing enough time for the occurrence of cement hydration. The hydration of cement can take a long time, often several days or weeks, and curing ought to be commenced early to reduce the time taken for the concrete to achieve its best strength, sturdiness, and durability [14]. A proper curing process for concrete is thus a necessity for assuring adequate field performance of concrete structures. It is not only important to attenuate evaporation of the water in the concrete mixture, however; a supply of external (or internal) water must be available to replace that consumed by chemical shrinkage during the hydration of the cement. The synchronous goals of cement hydration are to attach the initial cement particles together into as sturdy a network as potential and to separate the water-filled capillary pore areas to the maximum extent possible. Understanding the effect of solidifying practices on the development of microstructures is thus essential to developing effective curing practices and incorporating curing into the mixing process [15]. The most significant factor in the curing process of concrete is to have adequate water for the cement hydration processes. Water loss has adverse effects on hardened concrete in terms of all fundamental concrete characteristics such as compressive and tensile strength, shrinkage, porosity, and properties associated with durability and abrasion resistance [12][16][15].

In order to achieve suitable curing, it is important to keep the concrete saturated until hydration products seal the water-filled spaces between the cement grains [15]. There are two groups of curing methods [17]:

- External: (a) water curing (i.e. misting, spraying, adding saturated coverings, or water pounding); and (b) closed sealing curing (where loss of moisture is prevented by a moisture barrier such as water resistant sheeting or a curing membrane)[12].
- Internal: (a) ensuring a water supply from among several reservoir materials such as lightweight aggregates with high absorption capacity or superabsorbent polymers; and (b) internal sealing with water-soluble chemicals[18][19].

Fig. 2 Explanation of the variations and distinction between internal and external curing. The water-filled ingredients must be distributed uniformly and spaced adequately to supply coverage for the entire paste system [19].

1.3 Internal Curing

The internal curing process is a promising application for providing additional wetness in concrete for better cement hydration in practice. The American Concrete Institute (ACI) (2010), outlined these internal natural actions in a Terminology Guide as “supplying water across a freshly placed building material mixture exploitation reservoirs, by means of pre-wetted light-weight aggregates, which without delay
unleash water as required for continuation hydration or to switch wet lost because evaporation or self-desiccation” [19] [18][20].

Fig. 3 Example 2D image (3 x 3) cm: simulation of internal curing [19].

Internal curing is a relatively new process that has been recognized as particularly useful when lightweight aggregates (LWA) are used in concrete [17]. Aggregates with low density are primarily used for reducing concrete structures’ mass. LWA are thus occasionally pre-saturated with water to develop a saturated surface dry (SSD) situation to avoid loss of workability if some part of the water used for mixing is consumed by the porous aggregates [21]. When LWA is used as internal curing agent, water is released with increased degrees of hydration.

Fig. 4 Curing process of concrete (internal curing) using light, porous aggregates [22].

There are three main factors that internal curing depends on [23]:

- The quantity of water available for internal curing agents,
- The flexibility of the water availability once the internal curing agent’s requirements are met, and
- The distribution of the lightweight aggregate, which must be fully spread for water to immediately travel throughout all of the paste.
The potency of an internal curing (IC) process system is heavily associated with its content, and thus the LWA parameters used, such as pore structure, water absorption, distribution of grain size, ratio of open to closed porosity, and mechanical characteristics. The closeness of the paste-aggregate is a determining agent due to this defining the gaps that must be penetrated for internal water curing [24]. Several researchers have found that fine LWA is more practical in distributing attainable water and also adequate for use with internal curing, unlike coarse lightweight aggregate [25][26]. Other researchers have calculated that varying pore sizes and the quantity of water play more important roles within the internal curing process than the size of particles [24]. The dose of LWA depends on having a decent quantity of internal curing (IC) water introduced into the matrix of the cement.

Substances for internal water curing [27]:

- Substances with chemically bound water
- Substances with physically adsorbed water
  - Bentonite clay
  - Superabsorbent polymers
- Substances with physically held water
  - Pumice
  - Perlite
  - Liapor and Leca
  - Stalite
  - Diatomaceous earth
- Substances with unbound water
  - Microencapsulation
  - Emulsified water

A large variety of case studies have been conducted, particularly within the past fifty years, on lightweight concrete structures, including bridges, buildings and offshore platforms [28]. Long-range studies of the advantages from internal curing are minimal, however, particularly in traditional weight combination (NWA) concrete buildings, due to the technique’s modernity. Several case studies have been conducted on lightweight concrete concentrated on those edges directly associated with reduced weight in buildings. Internal curing, a potential minor benefit, is not however, commonly documented. Only where specific data on the internal natural processes has been written down can such cases be considered. In the relevant case studies, internal curing was achieved using NWA (2 projects), LWA (4 projects), and super-absorbent polymers SAP (1 project) [29].

- The U.S.S. Selma Concrete Ship, USA
- Powell River Ships, Canada
- The Iroise Cable-Stayed Bridge, France
- The Wellington Stadium, New Zealand
- High-performance concrete (HPC) bridges in Ohio, USA
- Concrete pavements in Texas, USA
- FIFA World Cup Pavilion, Germany

Since the 1950s, internal curing processes have been inadvertently achieved in lightweight concrete buildings, long before their potential for reducing self-desiccation in high-performance concrete (HPC) was recognised in the 1990s (Cusson and Roberts, 2007).

1.4 High-Performance Concrete

High-performance concrete (HPC) is defined as a concrete with a particular combination of uniformity and performance characteristics that cannot be invariably achieved by the habitual exploitation of typical constituents and traditional practices such as mixing, placing, and curing. High-performance concrete (HPC) is characterised with low porosity and capillary pore structure discontinuities. These are mainly obtained by utilising a low water/cement ratio with the assistance of superplasticizer and by adding Pozzolanic materials to the High-performance concrete (HPC) mixture [30].
In recent decades, high performance concrete (HPC) with a low water to binder ratios has become more frequently utilised, and thus analysis of such cases has increased massively. The high strength, sturdiness performance, and durability required to address structural issues in severe conditions have, during such research and laboratory experiment verification, been shown to make high-performance concrete (HPC) extremely susceptible to cracking at an early age when no particular precautions are taken. One such precaution is an enhanced curing process [31]. Adequate curing is the most important factor controlling concrete performance and it is thus essential to achieve sturdy high-performance concrete (HPC). This special concrete mix type, with low w/b, includes an insufficient amount of water to keep the capillary pores in the water-filled status required for each sustaining the continuous hydration of the cement and the pozzolanic material reactions as a result, the concrete has high performance properties due to low rates of permeability. Concrete with low permeability can be generated by reducing the w/b ratio, using an adequate amount of cement, and by adding pozzolanic materials such as fly ash, silica fume, or slag. New technologies concerning hydraulic cement and admixtures development has aided and accelerated the development of early age strength in concrete; nonetheless, analysis suggests that high-performance concrete (HPC) remains susceptible to higher cracking and shrinkage rates in the early stages, permitting access to attacking ions that results in dangerous issues with durability. High-performance concrete (HPC) mixture proportions, w/b ratio, and the inclusion of pozzolanic materials as chemical admixtures, can be used to offer advantageous performance and high durability and strength to high-performance concrete (HPC) [32]. In terms of the durability and sturdiness of concrete, the internal water action, known “autogenous curing,” is that the safest and best methodology to reduce autogenic shrinkage in concrete. The concept that self-desiccation can be thwarted by partial replacement of normal weight aggregate (NWA) with pre-saturated light-weight aggregate (LWA) has been developed and demonstrated by several authors [33][34][24]. Internal wet curing applications are thus particularly helpful in homogenising cement containing mineral admixtures such as silica fume (SF) wherever retaining water may support the progress of later age pozzolanic interactions between portlandite and the mineral admixture materials added [35]. The high-performance concrete (HPC) contact zone is limited in supplementary cementitious materials due to the formation of pozzolanic material Ca(OH)$_2$ during the cement hydration process. This characteristic can be enhanced at the surface transition zone between the cement paste and the particles. Many techniques to produce water for internal curing have thus been developed by previous researchers, including Superfine powders, Saturated Surface Dry (SSD) Lightweight (LW) fine or coarse aggregates, and Super Absorbed Polymers (SAP). Table 1 shows a summary of internal curing materials [36].

Table (1): Internal curing materials.

| HPC ID | Techniques | Prevalence rate between | Commonly used | Hypothesis |
|--------|------------|------------------------|---------------|------------|

![Fig. 5 High-performance concrete variants of traditional concrete.](image)
The use of recycled waste porous ceramic as coarse aggregates (PCCA) has shown PCCA in internal curing to reduce and even completely negate contraction and autogenous shrinkage of high-performance concrete (HPC) prepared with extreme low water/binder ratios (w/b) of 0.15. It has been shown that utilisation of 40% PCCA generates a non-shrinking high-performance concrete (HPC), with little internal stress and a significant increase compressive strength. It is worth noting that various ratios of incorporated PCCA do not decrease the compressive strength, either at early or later ages, as happens with some light-weight aggregates [24].
For additional improvements to the internal curing (IC) process, the internal curing (IC) agent ought to be characterised by high absorption capability and should have the flexibility to unleash the absorbed water. Among practical materials that nucleate and can thus be used for internal curing purposes, those that have 24-hour absorption of 20 to 25% or more, clay brick waste with an absorption value of 34% is a promising option.

Saturated surface dry (SSD) brick waste was thus used as a volumetric replacement for 5% and 10% of the normal weight sand in concrete, and a dramatic improvement of all studied properties emerging from internal curing occurred at 10% volumetric replacement of sand with clay brick waste at the same grading [42]. Other research on the same material utilised the crushed brick as a partial replacement for fine aggregate as an internal curing agent. Three high-performance concrete (HPC) mixes, a reference mix, crushed brick mixes as 5% partial replacement for fine aggregate, and crushed brick as 10% replacement were made and tested for mechanical properties and structural behaviours at different ages. Testing showed that using 10% crushed brick replacement led to increases in the structural behaviour of the concrete mix [43].

The concept of concrete protection is one of the foremost important theoretical approaches to internal curing. One of sustainable approaches is thermostone waste (TW), which is used in place of sand by volume of fine aggregate to provide internal curing (IC) for concrete (volumetric replacement of fine aggregate with 7.5% and 10% pre-wetted TW); again, an internally cured mixture with 10% replacement showed improvements that encourage broader application [34]. Due to low w/b and fast reactions at early ages, the requirement for internal curing should be met via internal materials, such as absorbent light-weight aggregate, that have been pre-saturated. The use of internal curing (IC) was investigated in the research in two ways. The first way was with partial replacement of coarse aggregates (gravel) and fine aggregate (sand) with crushed porcelainite. The results showed that the fine porcelainite added as an internal curing (IC) material caused more improvement in the mechanical properties (strength) of high-performance concrete (HPC) than coarse porcelainite [44].
An investigation of the prospects of using sawdust for internal curing (IC) of high-performance concrete (HPC) as a light-weight aggregate replacement by weight for fine aggregate was carried out to determine its effectiveness as internal curing material. Several concrete specimens with completely different sawdust wood contents, and an impact set of the concrete specimens, were created within the laboratory. The variable studied was the different sawdust wood contents in several sets of concrete specimens. The compressive strength was established as a measure of the best sawdust wood content. The results suggested that the correct content of sawdust wood could be expeditiously used to replace normal weight (NW) fine aggregate as a source of internal curing for high-performance concrete (HPC) [45].

The internal ratio and shrinkage of concrete internally cured with the composite cementitious materials known as calcined zeolite particles (HSECC) was experimentally investigated, with normal sand-like water softener particles with an average particle size of 0.18 mm used as an internal curing agent. The experimental results showed that the pre-wetted calcined zeolite particles in HSECC minimised the autogenous shrinkage and drying shrinkage at 28 days by more than 60%, while the composite strength remained higher than that of the reference concrete mix [46].

Self-desiccation is the main cause of autogenous shrinkage and crack formation inside low w/b ratio concretes; internal curing processes can thus minimise this. The strength of self-consolidating concrete (HS-SCC) was investigated, and to promote internal curing, a commercial (Leca) lightweight coarse aggregate (LWCA) in pre-saturated surface dry (SSD) condition was used to replace 25% by volume of normal weight coarse aggregate (NWCA) of similar size. Internal curing with saturated surface dry (SSD) LWA was thus found to be very effective in reducing early age autogenous shrinkage [47].
The research noted that perforated cenospheres could be used as a new internal curing material. Cenosphere particles are hollow ash made from burning coal from power plants. The outer shells of the cenospheres are generally porous then sealed by a superfine glass-crystalline film. By using chemical etching, the film is removed so that the pores under the shell layer are opened, perforating the cenospheres and allowing water propagating to the inside of the cenospheres particles. The perforated cenospheres were found to have high absorption ratios for water of over 180-wt%. The loaded water is promptly freed from the cenospheres at high ratios of relative humidity of approximately 95%. When saturated cenospheres are incorporated into the mortar of cement as internal curing agents, cement autogenous shrinkage is almost completely eliminated. The level of interior curing can even enhance the compressive strength of the cement mortar. All of these results suggest that perforated cenospheres be used as an associate economical internal curing material for high-performance concrete (HPC) [48].

3. Results

3.1 Density

Previous research has examined the impact of internal curing on the density of concrete. Many studies shown a rise in the density of freshly made high performance concrete (HPC), with identical states ascertained at the lateral ages of 90 days based on highly compact microstructure matrices [24][44][36][42][34]. A significant increase within the density of internally cured concrete is often detected. The internal curing water provided by internal curing materials promotes a high degree of hydration that infills the pores with hydration product and increases the density of the cement paste [42].

3.2 Compressive and Tensile Strength

Several studies have shown the effects of internal curing (IC) with numerous materials on high performance concrete (HPC) compressive strength. The internal curing (IC) effects on compressive and tensile strength depend on the particular proportions of the concrete mixture, curing conditions, and testing age, however. While the internally cured concrete mixtures can enhance strengths and moduli due to increased hydration of the cementitious binder, a reduction in strength is observed where the internal curing (IC) materials are seemingly mechanically weaker than the normal weight aggregate which they replace; SAP particles can also create further air voids inside the hardened concrete. Practical changes in strength have been observed as both increases and decreases due to these competing effects. Generally, at earlier testing ages (< 7d), decreases are observed, while at later testing ages, increases are obtained. In systems with additional cementitious materials, internal curing (IC) can enhance strength at later ages, due to the extra water provided by the internal curing (IC) agents that work as reservoirs to make water available for longer-term reactions; these include hydraulic and pozzolanic materials [36][19].

3.3 Durability

Issues with the durability of ordinary concrete mix may be associated with the effect intensity of environmental conditions and the disadvantages of using of high ratios of water/binder. High-performance concrete which has water/binder ratio between 0.30 and 0.40 is usually more durable than ordinary concrete mix not only due to being less porous but also as a result of their pore and capillary networks.
being disconnected due to the development of self-desiccation. In high-performance concrete (HPC), the agents of aggressive penetration are superficial. However, self-desiccation can be very harmful if not controlled throughout the development of hydration reactions within the cementitious materials in the early phases; high-performance concrete (HPC) should thus be cured in a different way to ordinary concrete mixes [2].

3.4 Shrinkage of Concrete

Internal curing (IC) of high-performance concrete (HPC) by use of pre-saturated lightweight aggregates offers a well-determined process to counteract the harmful effects of self-desiccation and autogenous shrinkage. Effective internal curing (IC) processes fully eliminate autogenous shrinkage [54].

Four possible useful components minimise damage from shrinkage in the high-performance concrete (HPC) mortar; the following conclusions are thus drawn from the research [36]:

a. HPCI- a replacement for super fine powders; particles within the fine aggregate can minimise the possibility of a portion of shrinkage growth.

b. HPCII- when the hydration of cement progresses and the interfacial transition zone (ITZ) reduces, the fluid value and movement is reduced by this, which may reduce the rate of chemical reactions;

c. HPCIII- the additional pores supplied by coarse aggregate LWA may supply available deposit sites for the gel to decrease pressure because of expansion; and

d. HPCIV- The cracking and distress reduction in high-performance concrete containing SAP is attributed to the formation of dense and less permeable paste microstructure due to an increased degree of hydration from the SAP. A strong guide to the higher capacity of confinement of the paste in the high-performance concrete specimens was the denser microstructure shown by scanning electron microscopy (SEM) analysis and the much smaller crack propagation confirmed by overall petrographic analysis.

3.5 Flexural Behaviours

The effectiveness of internal curing (IC) in terms of increasing the flexural strength of high-performance concrete has been reported on by several previous researchers, with [43] showing that using crushed waste brick as an internal curing (IC) agent enhances the extensive mechanical and structural properties of high-performance concrete, especially at later ages. The reference mix had no crushed waste brick replacement, and the two test brick mixes had 5 and 10% partial replacement of fine aggregate. The internal curing (IC) effect with age on the ultimate loading of beams varied depending on the percentage of replacement rate by crushed waste brick: the 5% mix showed an increase of about 28% at 150 days, while at the same age, the 10% mix showed an increase of about 12%, as compared their individual values at 28 days. The tests showed enhancement in both ultimate loading and toughness of the beams progressing with time for both mixes of crushed waste brick as compared to the reference mix. Similarly, [53] studies the flexural behaviour of reinforced concrete beams with and without the addition of superabsorbent polymer (SAP); two groups of concrete mixture were used, each one with five concrete mixtures (Reactive Powder Concrete RPC, Modified Reactive Powder Concrete, Self-Compact Concrete SCC, High Strength Concrete HSC, and Normal Strength Concrete NSC). The test results showed that beams cast with the addition of SAP (group B) had larger load carrying capacity and lower deflection rates compared with group A for all concrete types. Based on 10 beams produced from different concrete mixes, and tested for load-deflection behaviours with and without the addition of SAP, the main conclusions were that

a- Where beams cast with concrete included SAP particles as internal curing (IC) materials, the internal curing (IC) water had a slight effect on ultimate load of the beams (group B), increasing load carrying capacity compared with that of beams cast without SAP as internal curing (IC) (1.5%, 1.8%, 3%, 2.4%, and 4.1% improvement for B1, B2, B3, B4, and B 5, respectively).

b- The max deflection under ultimate load was decreased in beams including SAP in the concrete mix as compared to that seen in beams without SAP; these percentage reductions were 9.4%, 8%, 20%, 23%, and 12% for B1, B2, B3, B4, and B5, respectively.
Table (2): Test results of beams of the group (A and B).

| Beam no. / Mix type | Group (A) Without (SAP) | Group (B) With (SAP) |
|---------------------|-------------------------|----------------------|
|                     | Ultimate load $P_u$ (KN)| Ultimate deflection $\Delta u$ | Ultimate load $P_u$ (KN) | Ultimate deflection $\Delta u$ |
| Beam1 /RPC          | 458                     | 25                   | 465                     | 22.65                   |
| Beam2 /MRPC         | 450                     | 19.5                 | 458                     | 18                      |
| Beam3 /HSC          | 386                     | 34.9                 | 397                     | 27.89                   |
| Beam4 /SCC          | 421                     | 54                   | 431                     | 41.48                   |
| Beam5 /NSC          | 335                     | 29.36                | 349                     | 25.84                   |

4. Conclusions

This review paper reported on the effects of internal curing (IC) on the characteristics of high-performance concrete. The following conclusions can thus be drawn:

1. The internal curing (IC) practices represents a development process that limits self-desiccation in high-performance concrete.
2. Use of waste materials as internal curing (IC) materials reduces the negative effects of such waste materials on the environment and replaces traditional internal curing (IC) materials for high-performance concrete.
3. Used of waste materials as internal curing (IC) materials represents a cost saving during the production of high-performance concrete.
4. The low weight of most internal curing (IC) materials helps reduce the overall weight of concrete.
5. Internal curing (IC) can enhance the compressive strength of concrete due to additional water being retained or provided by the internal curing (IC) particles that can increase the degree of hydration in the concrete.
6. The effect of internal curing (IC) not only enhances the compressive strength of concrete but also the splitting tensile strength.
7. The effect of internal curing (IC) can be to enhance a number of flexural strength properties such as the ultimate load, toughness, and ductility of concrete structures.
8. The aspect of sustainability in the internal curing (IC) of concrete is by reducing the amount of waste materials that can be used as internal curing (IC) agents and that reduces waste in the environment as these materials are available and without negligible prices. In addition, the use of internal curing (IC) process improves the properties of concrete, which makes it more resistant to the surrounding environment conditions, which increases the operating life of the buildings.

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