Comparative review on mechanical properties of concrete with replacing curing water by self-curing compounds

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Abstract. The curing of concrete requires large amount of water. Self-curing concrete is one kind of concrete, which fix itself by holding water (dampness content) in it. A body of literature on the different self-curing compounds is uses for curing purpose without externally curing the concrete is currently available, but a systematic review is lacking. Therefore, this paper reviews the published literature on the use of different self-curing compounds in concrete and past work analysis on self-curing concrete. Various chemicals were uses to attain this curing. It was found out that various chemical admixtures like Poly ethylene glycol, Sodium lignosulphonate, Polyn vinyl alcohol, Super absorbent polymer and normally accessible and regularly utilizes materials like Light weight aggregates, Wood powder and Light expanded clay aggregate were uses to fabricate self-curing concrete. This paper summarizes the collected literatures on replacement of curing water with self-curing compounds and how these affects the fresh properties and hardened (solidified) properties of concrete, furthermore, we expected that this work may advise further examination regarding the utilization of curing compounds to upgrade the properties of cement and concrete items.

Keywords: Light weight aggregates, Poly Ethylene Glycol, Polyvinyl alcohol, Sodium Lignosulphonate, Self-curing compounds.

1. Introduction
Self-curing concrete (SCC) is generally called internal curing concrete. " self-curing might be characterized as the procedure by which the hydration of concrete happens in view of the accessibility of extra inner water that isn't a piece of the blending Water [1]. The Characteristics of concrete is majorly considered in strength and durability point of view. Optimum strength depends on major parameter Curing. Therefore, it is important to cure for good hydration for at least 14-28 days and to meet the target intensity. Curing of concrete is the process for the preservation of moisture and temperature conditions for the normal hydration reaction is to be defined as the process for the concrete to develop durable properties over time [2]. Improper curing will quickly have an effect on concrete efficiency and longevity. Coming to High-performance concrete falling into the so called modern concrete category. One of the key issues with such high intensity concrete formulations is their propensity to crack at an early age [3]. Concrete with a high cement content and low water to cement ratio can result, not only in delayed strength production and reduced longevity but also in autogenous shrinkage and cracking, in an internal drying of concrete by consuming water through hydration, called self- desiccation [4]. The continued availability of inner humidity to maintain hydration reactions at moderate temperatures and when external forces are not available at an early age are essential to a proper curing [5], this is achieved
with external curing after mixing, placing and finishing in conventional curing. Water is the most widely used construction material and because of regular use of water supplies in modern world, water shortage zones are gradually increased. Furthermore continuous cure is also very difficult with work done at heights, vertical components, sloped towers and floors [6].

Internal cure technique (IC) provides extra concrete moisture for better cement hydration and decreased self-desiccation; this is an extremely promising technique [7]. Conventional application eliminates water leakage from the concrete’s surface even when internal treatment produces inner storage tanks to fulfill the hydration needs of the whole concrete structure and thus assume a stronger result [8]. The self-curing process is based on a chemical admixture / curing agent which can reduce water evaporation through a retaining function [9]. Many admixtures are used to achieve efficient curing outcomes for self-curing concrete such as polyethylene glycol (PEG), lightweight aggregates, poly vinyl acryl (PVA), sodium lignosulphonate (SL) and poly acryl amide (PAM), light expanded clay aggregate, wood powder and coco pith [1]. The writers have collected much of the available literature and are quickly explored in the context of descriptions of various properties. A review had been embraced to know the impact of using different self-curing agents in producing concrete equivalent to the conventionally cured concrete and presented. Besides, this paper at long last gives a viewpoint that may be useful for the further examination.

2. Types of Curing

Potential materials used in self curing concrete:

Self-curing can be done by two types of admixtures 1) Chemical admixtures, 2) Natural admixtures.

Natural admixtures:
   a) Wood powder
   b) Light weight aggregates
   c) Spinacea pleracea
   d) Calatropis gigantean

Chemical admixtures:
   a) Poly ethylene glycol (PEG)
   b) Poly vinyl alcohol (PVA)
   c) Poly acryl amide (PAM)
   d) Sodium Lignosulphonate (SL)
   e) Poly acrylic acid (PAA)
Table 1. Specifications of PAA [6]

| properties                | value                      |
|---------------------------|----------------------------|
| Average Molecular Weight  | 5000000 g/mole             |
| Stability                 | Stable                     |
| Water Solubility          | Soluble                    |
| Density at 25ºC           | 1.189 g/ml                 |
| Shape and appearance      | Powder                     |
| Colour                    | White                      |

Table 2. Specifications of LECA [2]

| Properties          | Values obtained |
|---------------------|-----------------|
| Type                | Crushed         |
| Specific gravity    | 1.29            |
| Fineness modulus    | 2.62            |
| Bulk density (kg/m³)| 669             |
| Water absorption    | 16%             |

Table 3. Specifications of PEG-400 [21]

| Properties                  | Values                                  |
|-----------------------------|-----------------------------------------|
| Specific gravity            | 1.12 at 27ºC                            |
| pH                          | >6                                      |
| Molecular weight (g/mole)   | 400                                     |
| Appearance                  | Clear liquid                            |
| Colour                      | White                                   |
| Hydroxyl value (mg KOH/g)   | 300                                     |
| Nature                      | Water soluble                           |
| Molecular formula           | H(OCH2CH2)n OH                          |
| Density g/cm³               | 1.125                                   |

Table 4. Specifications of spinacia oleracea and Calotropis gigantea [9]

| Name of the admixture | pH value |
|-----------------------|----------|
| Spinacia oleracea     | 6.59     |
| Calotropis gigantea   | 5.17     |

Table 5. Specifications of SL [36]

| Properties                     | Standard Values |
|--------------------------------|-----------------|
| Specific gravity               | 1.25            |
| Appearance                     | Yellow Brown    |
| Lignosulfonate                 | 55%(min)        |
| Dry matter                     | 95%(min)        |
| Water-insoluble                | 1.5%(max)       |
| Water Reducing capacity        | 8% min          |
| Sulphate                       | 2%-5%           |
| Calcium and magnesium          | 0.5% max        |
| Moisture                       | 7% max          |
3. Literature Survey

R. Malathy., (2017) Conducted experimental work on the new and hardened properties of organic self-curing concrete with 30% fly ash as part of a cement substitute. In this work mostly focuses on the action of internally cured concrete of M20, M30 and M40 by utilizing naturally available vegetative materials like Spinacea pleracea (SP), Calatropis gigantean (CG) and chemical admixture like polyethylene glycol (PEG) at 0.6%, 0.24% and 0.3% (by weight of cement) respectively. Self-curing concrete with these ideal values had a strength activity index more than 1 at 28 days and got 1.15 at 58 this is due to pozzolonic action of fly powder at later ages. This study concentrates on the study of concrete performance in aggressive environments, and all such tests have been positive compared to standard concrete. From the point of view of durability, the weight loss is 15%, 10% and 5% less than regular concrete for ideal values of SP, PEG and CG respectively. The reason behind this is that the cube's pore structure is tight and does not enable additional acid intake. Finally, it was concluded that the vegetative materials added along with poly ethylene glycol as self-curing agents execute good strength, workability and durability characteristics in fly ash mixed concrete, and also these synthetic materials are used in pavements, RCC related works, overhead tanks and pre-stressed concrete structures to accomplish long term strength and high performance.

Nagesh T. Suryawanshi and Sunil B. Thakare., (2018) is used as a combination of meta kaolin as mineral admixture, poly-vinyl alchahol (PVA) and poly acrylic acid (PAA) as chemical admixtures, for self-curing concrete. The experiment was conducted on high strength concrete and a target mean strength of 61.51 N/mm² fixed by various trial mixes. In the study cement is replaced with metakoline at differing proportions between 5% and 15%, and the optimum value was found at 5% and up to 7.5% strength equals to control mix. This regulation mixture includes a variety of different amounts of poly-vinyl alchahol (PVA) and poly-acrylic acid (PAA) applied individually by weight of cement at different percentages of 0.02, 0.04, 0.06, 0.08 and 0.1. The tests have shown that Concrete unified with poly vinyl alcohol of dose 0.04% was found to produce optimum strength of 65.40 N/mm² and Concrete unified with poly acrylic acid of dose 0.02% was found to produce optimum strength of 64.20 N/mm².

Ahmad Mustafa Sabaoon and Navinderdeep Singh., (2019) The primary purpose of this study was to examine the mechanical properties of self-curing concrete by incorporating natural and chemical compounds as self-curing agents, such as wood powder and poly ethylene glycol 400 (PEG-400). The concrete they used is M30 with a particular combination of wood proportion (2%, 4%, 6%, 7%, and 8%) and PEG proportions (0.5%, 1%, 1.5%, 2%, and 2.5%). Lastly, 6% wood powder was found to be an excellent test and again the constant percentage of wood powder (6%) with different PEG combinations was tested in room and outdoor temperature. It has been reported that at room temperature the blend of 6% wood powder with 1.5% PEG obtained excellent performance. In addition to the 6% wood powder and 2.5% PEG blend, the outdoor climate achieved optimum performance.

The work carried out by G. Thrinath, P. Sundara Kuma., (2017) on internal curing concrete by Polyethylene Glycol (PEG) as cement replacement would investigate the compressive and bending qualities of the M30 grade concrete. Cement is partially superseded by PEG-400 as 0.5 %, 1 %, 1.5 % and 2 % by weight of cement. The experimental program was accomplished for assess the compressive, split tensile and the flexural strength of concrete for given mix. 500 * 100 * 100 mm prisms are designed for 3, 7 and 28 days bending studies. As the percentage of PEG-400 increases, the workability of concrete is also rising. The study showed that the ideal PEG-400 dosage is 1% for compressive and split tensile strength, in the bending test 0.5%.

M. V. Jagannadha Kumar, K. Jagannadha Rao, B. Dean Kumar, V. Srinivasa Reddy., (2018) The aim of this study is to discover an ideal mix proportion of self-curing concrete for different grades M20, M40 and M60 by supplementing poly ethylene glycol (PEG-400) as internal curing agent. The ideal measurements of PEG (communicated in rate by weight of concrete) embraced for M20, M40 and M60 grades internal cured concrete are 1%, 0.5% and 0.5% separately. In this study, various fresh and solidified properties at different ages such as 28, 60, 90, 180, and 365 days are evolved. The tests of
NDT, such as Rebound Hammer and Ultrasonic Pulse Velocity, are also used for the quality and properties, such as structure integrity and compression strength. It is observed that there is a reduction in the weight loss and better pore structure of concrete, as the grade and the ages of self-curing concrete with PEG are increased. It was concluded that rebound numbers indicated that the surface hardness of self cured concrete was superior when compared to traditionally cured concrete.

Daud Mohamad, Wani Mohd Sapuan., (2017) this paper exhibits the impact of using baby diapers polymer as an internal curing admixture in self curing concrete. In this process, baby diaper powder was used in different proportions (1%, 2%, 3 %, 5 % and 10 %) of cement weight. Various tests are carried out using 100mm*100mm*100 mm cube moulds on the new and solidifying characteristics of concrete. Hardened concrete characteristics are performed at room temperature at 3, 7, 28 and 90 days of air curing. With expanding the level of infant diapers flowability of concrete is expanded got maximum slump at 10%. Eventually it is found that at 1% diaper polymer concrete got optimum values in terms of compressive strength. Due to the polymer inside the concrete, the concrete that has a higher percentage of polymers had absorbed large amounts of water compared with the fewer polymers.

Cvk chaitanya, Priya Prasad, D. Neeraja, A. Ravitheja (proceedings) A study is being carried out in order to report on the use of pre-saturated lightweight aggregates(LECA) has been well established to counteract self-desiccation and autogenous shrinkage. In this research properties of concrete with M30 grade are carried out with different dosages of LECA (0%, 10%, 15%, and 20% by volume) as self-curing agent for water retention. They are concentrated primarily on the compressive, split and flexure properties and not involved on fresh and durability properties. Ultimately, the study concluded that the solidified properties of concrete are raised up to 15% of LECA. At 15% of LECA the compressive, split tensile and flexure strengths are raised by 1.67%, 1.29%, and 2.47% respectively compared to control mix.

Sanjay Kumar R, Suganya Devi K, (2016) deals with self-curing reinforced concrete beams enclosed with steel I section by utilizing Poly ethylene glycol (PEG-400) as internal curing agent and comparisons have been made between basic curing concrete beams. In this study, an attempt was also made to replace sand with barite powder (BaSO4) by up to 30%. RC beams with size 150 mm x 200 mm x 1200 mm are enclosed with the ISMB 100 hot rolled steel section of 1 m long. Flexure strength tests are carried out on these beams after 28 days and have seen that the self-curing beam and self-curing beam enclosed with I section withstand 13 percent and 50 percent progressively extreme burden contrasted with the checking beam. What's more, going to the self-curing beam with barite powder was 17 per cent lower strength than checking beam. Since, barite powder was able to absorb water more easily.

Mohammad Balapour A, Weijin Zhao (2020) the essential objective of this assessment was to assesses the likely utilization of a novel lightweight total (LWA), spherical permeable responsive aggregate (SPoRA), delivered from squander coal bottom debris, for self-curing of concrete. SPoRA’s engineering properties needed for concrete internal curing were evaluated including specific gravity, porosity, sphericity, water absorption, and desorption of water. In comparison with commercial LWAs, SPoRA has three main features which make it better: a round shape to expand the concrete workability, better absorption properties to assimilate and desorb water for inside curing, and a shiny surface with crystalline interior structure to give surface reactivity the cementitious grid while having attractive inner crystalline quality. Through X-ray processed tomography (XCT), the high porosity of SPoRA (39.6%–57.8%, by volume) was estimated and verified, XCT assessment additionally demonstrated that the pore structure of SPoRA is very much associated, permitting put away water to travel through the pore structure to the external surface during the self-desiccation of concrete. It can be inferred that SPoRA made from low- and high-calcium bottom ashes is successful LWAs which can be used in concrete for internal curing purposes.

Vaisakh G, Dr. M S Ravi Kumar, P Siva Bala, (2018) the primary goal of this research was examine the various properties of M50 grade self- curing concrete by using poly ethylene glycol(PEG-400) as
internal curing agent. The impact of PEG content on quality pointers like compressive, split tensile and elasticity modulus and durability markers like electrical resistivity, water sorptivity, chloride permeability, and water sorptivity were concentrated by differing percentage of PEG 400 from 0 to 2% with 0.5% of span. As the PEG content increased, there is an increasing trend in the mechanical properties due to hydration reaching its completeness up to a PEG content of 1.5%. In terms of compressive, tensile and elasticity modulus, the specimens exhibited less strength beyond 1.5%. Moreover, with increasing PEG content to 1.5%, water absorption decreases and then increases. Water sorptivity and permeability to the chloride also show similar trends. Concrete resistivity increases with PEG content increase to 1.5% and decreases with further PEG increase.

S. El-Dieband, T. A. El-Maaddawy, (2018) conducted experiment on assessment of reinforcement corrosion protection of self-curing concrete by utilizing water-soluble polymers like poly ethylene glycol (PEG) and poly acryl amide (PAM). They performed numerous experiments such as electrical resistivity, permeability checking, chloride ion penetrability, and durability indices on concrete with separate dosages of PEG+PAM together were held at 0.025% by cement weight. The PEG and PAM weight ratios were varied; the first ratio was 80% PEG and 20% PAM (SC-80PEG-20PAM), and the next ratio was 60% PEG and 40% PAM (SC-60PEG-40PAM). Rapid chloride ion penetrability (RCPT) and water permeability tests were conducted on disc specimens cut from concrete cylinders, with a diameter of 100 mm and thickness of 50 mm. The electrical resistivity was conducted on concrete cylinders with a diameter of 100 mm and a length of 200 mm. It is noticed that all the tests results are got better results at SC mixtures SC-100PEG and SC-80PEG-20PAM compared to SC-60PEG-40PAM.

Zaheer Ahmed, Harshith H J, Dr. Mushtaq Ahmed Bhavikatti and Akshatha B A., (2019) made analysis on the mechanical properties of self-curing concrete with the application of light expanded clay aggregate (LECA) as a natural mixture. In this study, coarse aggregates are replaced by light expanded clay aggregates up to 20% for M30 grade concrete. These light expanded clay aggregates are immersed in water around 24 hours while using LECA as a curing agent. This pre wetted aggregates are used for preparing moulds. They perform compressive cube strength testing by replacing LECA aggregates by 5%, 10%, 15%, and 20%. However, it has been found that low compressive strength is attained beyond 5% replacement of LECA compare to control concrete.

T. A SajanaKhader and T.SShabana., (2018) investigate the Mechanical Properties of internal curing Concrete by adding Sodium Lignosulphonate(SL) and Poly vinyl alcohol(PVA) as self-curing agents.

M35 grade concrete is used at a rate of PVA 0.24%, 0.48%, 0.96% and SL 0.5%, 1%, 1.5%, 2% by weight of cement. PVA and SL can retain moisture for a long period of time. The investigation revealed that the mix of 0.48% PVA and 1% SL gives optimum values of mechanical properties when compared to all other mixes. And also in the view of durability aspect it gives better resistance against acid and chloride attack. Finally, it was concluded that Compressive strength and Split Tensile strength expanded by 23.94% and 50.7% respectively for 0.48% PVA and 1% SL at 28 days.

**Table 6.** A summary of the various research works published on internal curing concrete.

| Author                  | Admixture | Quantity of admixture in percentages | Type of concrete and grade | Mechanical properties | Durability properties          |
|-------------------------|-----------|-------------------------------------|---------------------------|-----------------------|-------------------------------|
| Cvk chaitanya et al., [2]| LECA      | 0%, 10%, 15%, and 20% by volume of aggregate. | M30                       | Optimum results obtained at 15% of LECA. |                                |
| Vaisakh G et al., [4]   | PEG-400   | 0.5%, 1%, 1.5%, and 2%.             | M50                       | In terms of compressive, tensile and elasticity | Water sorptivity chloride permeability and |
| Author(s) | Additives | Mixtures | Results |
|-----------|-----------|----------|---------|
| Sanjay Kumar R et al., [7] | PEG-400 and barite powder | Barite powder-30% | Modulus, the specimens exhibited optimum results at 1.5% and Concrete resistivity also exhibits maximum results at 1.5% |
| R. Malathy et al., [9] | Spinacea pleracea, Calotropis gigantean and PEG | Spinacia oleracea and Calotropis gigantea at 0.6% and 0.24% respectively by weight of cement, and PEG-0.3% | Got better results compared to conventional concrete at optimum percentages of curing agents. The percentage loss in strength is less when compared to conventional concrete is about 15% for Spinacia oleracea, 10% for PEG and 5% for Calotropis gigantean. |
| Ahmad Mustafa Sabaoon et al., [10] | Wood powder and PEG-400 | Wood powder-2%, 4%, 6%, 7%, and 8% and PEG-0.5%, 1%, 1.5%, 2%, and 2.5% | The combination of wood powder and PEG at 6% and 2% respectively have beneficial outcome. |
| Vaseem Akram N et al., [11] | PVA | 0%, 0.5%, 1%, 1.5%, and 2% | The properties of concrete got optimum results at 15% of PVA. |
| B. Ajitha et al., [12] | PVA | 0%, 0.03%, 0.06%, 0.12%, and 0.24% | 0.24% of PVA gives the optimum values of compressive strength and workability. |
| Nagesh T. Suryawanshi et al., [13] | PVA and PAA | 0.02%, 0.04%, 0.06%, 0.08% and 0.1% | High strength concrete and combine with PVA and PAA solely improve mechanical properties of concrete. Metakaolin by 7.5% and Optimum results at 10% of silica fume and 0.4% of PEG. Rapid chloride permeability and water sorptivity values got better values at 5% of silica fume and 0.4% of PEG. |
| Bala Subramanian et al., [14] | PEG-400 | 0.2%, 0.3% and 0.4% | Silica fume based concrete, M60, M70 and M80. Got optimum results at 10% of silica fume and 0.4% of PEG. Rapid chloride permeability and water sorptivity values got better values at 5% of silica fume and 0.4% of PEG. |
| T. A Sajana Khader et al., [15] | SL and PVA | SL- 0.5%, 1%, 1.5%, 2% and PVA- 0.24%, 0.48%, 0.96% | Got optimum values of Compressive strength and Split Tensile strength at 0.48% PVA and 1% SL at 28 days. Better resistance against acid and chloride attack by adding self-curing agents. |
4. Research Gap
An exhaustive report was experienced by gathering a wide scope of research articles. By directing a comprehensive literature survey, it was identified that huge experimentation has been done on basic properties of concrete by adding self-curing natural and chemical admixtures. In spite of the fact that there has been broad work done on the mechanical properties of self-curing concrete with the assistance of moulds however there was no relevant research regards to the durability of concrete and reinforced moulds however there was no relevant research regards to the durability of concrete and reinforced structures like beams, columns and slabs. To utilize self-curing concrete, it is necessary to survey the behavior of the concrete in terms of durability and load carrying capacity of RC structures. This territory has not yet been investigated.

5. Scope for Future Research
Despite a broad assessment has been done in the basic properties of concrete. Future research is important to comprehend the advancement in durability of concrete and also to study the different properties of reinforced concrete structures.
6. Conclusion
Based on the literature review, following ends can be acquired:

- The solution to many problems posed by lack of curing water is self-curing / inner curing concrete.
- The self-curing material has a greater hydrating effect than traditional concrete under drying conditions.
- It is observed that when the quantity of poly ethylene glycol (PEG) increases the slump value rises.
- It has been observed that using 1-2% of poly ethylene glycol (PEG) as chemical admixture in different grades of concrete gives strength equal to normal concrete and also rises the strength up to 8-15%.
- Self-curing concrete is more effectual of reducing autogenous shrinkage.
- The mix of 0.48% Poly vinyl alcohol (PVA) and 1% Sodium Lignosulphonate(SL) gives optimum values in point of strength and durability as compared to all other mixes.
- Some vegetative materials like Spinacea pleracea and Calatropis gigantean added along with poly ethylene glycol as self-curing agents perform better mechanical properties.
- From the study it is noticed that by adding LECA the compressive and flexural strength of concrete is decreased, but the workability of concrete is increased.
- To order to improve the properties of concrete, other chemical admixtures were also applied to concrete along with LECA.

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