Study on early age and ultimate compressive strength of M30 grade self-curing concrete

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Abstract: Curing concrete is one of the important stages in making quality concrete. Research has not given due attention to this area. Due to the scarcity of potable water and subsequent need for conservation of water, the construction industry is facing a challenge in ensuring proper and adequate curing of concrete elements. Concrete is one of the largest used construction materials across the world, which can easily be accepted as it has changed the face of rural areas. But in the localities where there is a water insufficiency and in locations of higher elevations, water curing is difficult. There is also a need for reduced water usage for curing for the conservation of potable water for environmental sustainability. These problems can be rectified by using Self-Curing or Internal Curing technique. Self-curing admixtures considerably assist in the preservation of water in concrete, by bringing down the evaporation and transpiration during the hydration of concrete. The present paper is focused to study the performance of M30 grade concrete by using different self-curing compounds like Poly-vinyl alcohol, Liquid paraffin wax, and Polyethylene glycol 400 in comparison with conventional immersion curing.

1. Introduction
Concrete is one of the largest used construction materials across the world, which can easily be accepted as it has changed the face of rural areas. But in the localities where there is a water insufficiency and in locations of higher elevations, water curing is difficult. A lot of water is used for curing concrete across the globe leaving a carbon footprint on the earth. There is also a need for reducing the curing water usage for the conservation of potable water for environmental sustainability. Proper curing is necessary to meet the strength and durability requirements of any structure or structural component. This can be achieved by conventional external curing applied after mixing, placing and finishing of structural components made by concrete. Conventional curing is broadly categorised into five types.

a) Immersion curing: Submersion of concrete normally done during testing of concrete specimens in the laboratory.

b) Ponding: Used where water can be effortlessly held on the surface of the concrete elements like slabs and pavements. A layer in the form of a small bund of sand or earth is kept on the border of the surface to retain water on it.
c) Fogging: Misting or Fogging is adopted in conditions where temperatures are less than the freezing point. Fogging raises and maintains the moisture over the concrete surface by showering a fine fog of water.

d) Wet Covering: Curing of hardened concrete while it is wet with a wet plastic sheet to cover it adequately without harming the solid's surface is wet covering. Covering can be done by a plastic sheet, sand, canvas, burlap or straw. The cover has to be kept wet during this entire process.

e) Plastic Sheeting: Curing concrete with plastic sheeting requires covering every uncovered region of the concrete as quickly as time permits after casting without harming the concrete shape. When the plastic sheeting is used over level surfaces, like concrete pavements or surfaces, it should be ensured that no edge is left uncovered.

f) Layer Forming Curing Compounds: Curing compounds are either mixed or sprayed on the surface of the concrete to retain moisture in concrete thereby ensuring effective hydration of cement without the need for an additional supply of water. One type of these compounds forms an impermeable layer that impedes the loss of dampness from the concrete. Another type retains the moisture in concrete by restricting the loss of moisture due to evaporation and transpiration.

Hence, Self-curing is a method that can be used to give extra moisture in concrete for more effective hydration of cement and reduce self-desiccation. The concrete in which the water is used for mixing is restricted inside the concrete by using some chemical admixture called “Self-Curing Concrete”. Self-curing compounds are Polymers that are added to the mix to form a hydrogen bond with water molecules that reduce the chemical potential of the water molecules. The differential free energy between vapour and liquid phases results in the uninterrupted vanishing of water content from the concrete surface exposed to the atmosphere. This results in a reduction of vapour pressure and hence the rate of evaporation and transpiration from the surface leading to adequate availability of water for cement hydration.

2. Literature review

Many researchers have worked on studying the effect of using curing compounds on various properties of concrete. Amal Viswam (2016) [1] done their study on Self Curing Concrete and observed that concrete mixes with self-curing admixtures have higher water retention when compared to those with conventionally cured mixes. The weight loss was considered as a measure of loss of water due to evaporation and transpiration. Concrete mixes with self-curing admixtures show the effective hydration with time under drying state compared to concrete with conventional curing. Nithya et al. (2017) [2] studied compressive strength property of self-curing concrete using a self-curing agent PVA. Maximum compressive strength of the considered mix obtained at optimum dosage of 0.5%. The slump of M30 grade concrete mix was increased with an increased percentage of PVA. From their study, it was concluded that concrete mixes with self-curing agent show good results and it can be used in the place of conventional concrete. Rajeswari Unnithan and Sarah Anil (2017) [3] conducted an experimental study on self-curing concrete with lightweight aggregate using polyethylene glycol as an admixture. From the results of the mechanical properties of concrete, it was observed that self-curing concrete resulted in higher strength than that of conventionally cured concrete mixes. Shikha Tyagi (2017) [4] compared the compressive strength property of self-cured concrete and conventionally cured concrete. For the study, they considered different concrete grades i.e., M20, M25, M30 and M40. By using curing compound LPW, maximum compressive strength was achieved which was nearly 99% of that achieved through normal curing method for all considered concrete grades. Ahmad Mustafa Sabaoon and Navinderdeep Singh (2018) [5] studied the performance of self-curing concrete made using self-curing agent, polyethylene glycol-400. From the test results, it was observed that maximum compressive strength for M20 and M25 grade concrete occurs at 1% dosage. A decrease in strength was observed at 2% dosage for both grades. Ankita Arsude and Dhawale (2018)[6] studied the characteristics of self-curing concrete by using self-curing agent Polyethylene Glycol-400 (PEG-400). They found maximum compressive strength, modulus of rupture and split tensile strength at 1% dosage of the self-curing agent. Karthick and Amrin Sulthana
(2018) [7] studied the properties of self-curing concrete using various self-curing admixtures. From the result, they found that self-curing agent Sodium Polycrylate shows better results than Paraffin wax coating. Gaddam Sai Krishna (2018) [8] performed an experimental study on self-curing concrete by partial replacing cement by red mud and fine aggregate by quarry dust in various percentages. PEG 400 was used as a self-curing admixture. Self-curing agent dosage of 0.5% to the weight of cement recommended for M40 grade of concrete. Vaseem Akram and Balachandiran (2018) [9] studied the mechanical properties of self-curing concrete by using PVA at different percentages i.e., 0.5%, 1%, 1.5% and 2%. Mechanical properties like compressive strength and split tensile strength were studied. From the study, they found that the optimum percentage of PVA was 1.5% which gives higher strength. Soorya Tharshini and Belciya Mary (2018) [10] examined the compressive strength property of self-curing concrete. Compressive strength of self-curing concrete (SC) was increased by 15.9% when compared to conventional curing concrete (CC). Lidiya and Preethi (2018) [11] performed an experimental investigation on self-curing concrete using self-curing agent PEG-600. From the obtained results, it was found that self-curing concrete performs better when compared to concrete mix with conventional curing. At 1.5% dosage of PEG-600 in M50 grade concrete, obtained maximum compressive strength. Compressive strength of self-curing concrete was increased by 13% when compared to concrete mix with conventional curing. Vikram et al (2018) [12] done their study on self-curing concrete with the utilization of chemical agent. The optimum dosage of self-curing agents PEG-400 and PEG-600 was 1% weight of cement. Zameer and Karthik (2018) [13] examined the strength characteristics of self-curing concrete included with fly ash. At an optimum percentage of self-curing agents, it provides good results. An unnecessary increase in dosage of self-curing agent leads to a decrease in the strength of concrete.

In the present study, an attempt is made to compare the performance of M30 grade self-curing concrete in terms of its compressive strength by using different self-curing admixtures i.e. polyvinyl alcohol, Liquid paraffin wax and Polyethylene glycol 400. Early age and ultimate compressive strength of self-curing concrete with above mentioned self-curing agents are compared with conventional concrete to know the suitability.

3. Experimental Program
All the ingredients of concrete are tested for their suitability of making concrete. Table 1, 2 and 3 present the properties of the concrete ingredients used in this study.

*Cement* - Ordinary Portland Cement (53 grade)

| Sl. No. | Property       | Test Result |
|---------|----------------|-------------|
| 1       | Specific gravity | 3.15        |
| 2       | Fineness modulus | 96%         |
| 3       | Initial setting time | 47 minutes |
| 4       | Final setting time | 225 Minutes |

*Fine aggregate* - Locally available river sand

| Sl. No. | Property          | Test Result |
|---------|-------------------|-------------|
| 1       | Specific gravity  | 2.79        |
| 2       | Fineness modulus  | 2.75%       |
| 3       | Bulking of sand   | 25%         |
Coarse aggregate - Crushed angular coarse aggregate

Table 3. Results of tests on coarse aggregate

| Sl. No. | Property            | Test Result |
|--------|---------------------|-------------|
| 1      | Specific gravity    | 2.78        |
| 2      | Nominal max. Size   | 20mm        |

Water - Locally available potable water

Chemical Admixtures - Self-curing admixtures used for the present study are as follows.
1. Poly Ethylene Glycol (PEG) [0.5%]
2. Liquid Paraffin Wax (LPW) [1%]
3. Poly Vinyl Alcohol (PVA) [1.5%]

Mix proportions of Self Curing Concrete

Table 4 presents the mix proportions for ‘M30 grade concrete with a workability of 30 mm slump’ in terms of quantities of materials in kg per 1 cum

Table 4. Mx proportions

| Cement      | Fine aggregate | Coarse aggregate | Water    | Water/cement ratio |
|-------------|----------------|------------------|----------|--------------------|
| 438.13 kg   | 603.84 kg      | 1149.48 kg       | 189 litres | 0.4                |

4. Results and Discussions

This section presents the comparison of compressive strength and workability results for all the four mixes

4.1 Workability

Minimum workability of about 30 mm is required assuming the concrete is used for making VRCC (Vibrated Reinforced Concrete). Table 5 shows the workability test results from the slump cone test. From the results, it is observed that there is an increase in the slump value by 33.33% for M30 grade concrete with PVA [0.5%] and PEG400 [1.5%] when compared to the conventional concrete mix. In the case of M30 grade concrete with LPW [1%], there is no variation of the slump. The improvement in workability after adding the curing compounds can be attributed to the restricted loss of moisture in the fresh concrete mix.

Table 5. Results of the slump cone test

| Mix Designation | Mix Description                  | Slump (mm) |
|-----------------|----------------------------------|------------|
| CM              | M30 Conventional mix             | 30         |
| SCC-PVA         | M30 mix with Poly Vinyl Alcohol [0.5%] | 40         |
| SCC-LPW         | M30 mix with Liquid Paraffin Wax [1.0%] | 30         |
| SCC-PEG         | M30 mix with Poly Ethylene Glycol - 400 [1.5%] | 40         |

4.2 Compressive Strength

The standard cube samples of 15 cm size are tested in 3000 kN Compression Testing Machine. The cube samples each for the various percentage of LPW, PVA, PVG-400 were prepared to determine the 7 days, 14 days, and 28 days compressive strength. Table 6 shows the compressive strength results for
7, 14 and 28 days by using PVA, LPW and PEG-400. Based on the results graphs are plotted and shown in Figures 1, 2 and 3.

**Table 6.** Compressive strength results of various mixes at 7, 14- and 28-days curing period

| Mix Designation | Mix Description | Compressive strength N/mm² |
|-----------------|----------------|---------------------------|
|                 |                | 7 days | 14 days | 28 days |
| CM              | M30 Conventional mix | 26.16 | 35.55 | 44.29 |
| SCC-PVA         | M30 mix with Poly Vinyl Alcohol [0.5%] | 33.77 | 35.73 | 40.54 |
| SCC-LPW         | M30 mix with Liquid Paraffin Wax [1.0%] | 28.32 | 30.44 | 40.85 |
| SCC-PEG         | M30 mix with Poly Ethylene Glycol - 400 [1.5%] | 31.77 | 35.2 | 40.48 |

**Figure 1.** presents the compressive Strength of M30 grade concrete with conventional curing and self-curing agents at 7 days curing period.

From figure 1, it is observed that when compared to the conventional method of curing, all three curing compounds improve the compressive strength of concrete after 7 days. There is an increase in the compressive strength by 22% for Poly-vinyl alcohol, 7% for Liquid paraffin wax and 17% for poly-ethylene glycol 400. Hence, adding Poly-vinyl alcohol as curing compound to concrete will result in highest early age strength followed by Poly Ethylene Glycol - 400 and Liquid Paraffin Wax respectively.

**Figure 2.** presents the compressive Strength of M30 grade concrete with conventional curing and self-curing agents at 14 days curing period.
Figure 2. Compressive Strength of M30 grade concrete with conventional curing and self-curing agents at 14 days curing period

From the figure 2, it is observed that when compared to the conventional method of curing there is an increase in the compressive strength by 0.5% for Poly-vinyl alcohol, and decrease in the compressive strength by 14% for Liquid paraffin wax and 0.98% for poly-ethylene glycol 400. The marginal increase in 14 days strength for Poly-vinyl alcohol is observed because it has already attained maximum strength in 7 days. Further, although there is a decrease in the compressive strength by 14% for Liquid paraffin wax and 0.98% for poly-ethylene glycol 400 when compared with compressive strength of conventional mix at 14 days, their strengths are more than their respective 7 days strength. This means that the curing compound is working and the mixes have been continuously gaining strength.

Figure 3. presents the compressive Strength of M30 grade concrete with conventional curing and self-curing agents at 28 days curing period.

From the figure 3, it is observed that when compared to the conventional method of curing there is a slight decrease in the compressive strength by 8% for Poly-vinyl alcohol, by 7.76% for Liquid paraffin wax and 8.6% for poly-ethylene glycol 400. The conventional method of curing i.e. immersion of specimens in potable water at room temperature results in maximum ultimate compressive strength when compared to the concretes with various curing compounds used in this study. However, the strengths of concrete with all the three curing compounds resulted in the attainment of the almost same strength and beyond target mean strengths. Further, in the construction industry, immersion curing of
concrete elements like beams, columns and slabs is not practically possible and water for curing is sprayed twice or thrice a day on gunny bags wound around these elements. Hence, the curing compound is a very good alternative to conventional curing and will surely result in strengths acceptable. The use of curing compounds should also be encouraged in the construction industry in light of the urgent need for potable water conservation.

5. Conclusions
From the study, it has been concluded that usage of self-curing agents doesn’t show considerable reduction in the compressive strength property. Hence, it is recommended to adopt self-curing concrete to conventional curing concrete where we can find an inadequacy of water and the pumping of water is difficult (i.e., in the case of high-rise buildings).

Even though the observed compressive strength values are reduced for the considered self-curing agents when compared to the conventional concrete, but these values achieved the target compressive strength. Among all the considered self-curing agents, Liquid paraffin wax (LPW) performs better at 28 days curing period. The use of curing compounds should also be encouraged in the construction industry in light of the urgent need for potable water conservation.

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