Self-curing concrete with different self-curing agents

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Abstract: Concrete is recognised as a versatile construction material globally. Properties of concrete depend upon, to a greater extent, the hydration of cement and microstructure of hydrated cement. Congenial atmosphere would aid the hydration of cement and hence curing of concrete becomes essential, till a major portion of the hydration process is completed. But in areas of water inadequacy and concreting works at considerable heights, curing is problematic. Self-Curing or Internal Curing technique overcomes these problems. It supplies redundant moisture, for more than sufficient hydration of cement and diminish self-desiccation. Self-Curing agents substantially help in the conservation of water in concrete, by bringing down the evaporation during the hydration of Concrete. The present study focuses on the impact of self-curing agents such as Poly Ethylene Glycol (PEG), Poly Vinyl Alcohol (PVA) and Super Absorbent Polymer (SAP) on the concrete mix of M25 grade (reference mix). The effect of these agents on strength properties of Concrete such as compressive strength, split tensile strength and flexural strength was observed on a comparative basis which revealed that PEG 4000 was the most effective among all the agents.

1. Introduction:
1.1. General
Proper curing provides the desired properties for concrete. Apt curing of concrete structures is important to full fill good performance and durability requirements. In traditional curing this is accomplished by external curing. But, curing is not possible in some occasions such as shortage of water, concreting works at greater heights etc., The several advantages of self-curing are, heightened hydration process, strength development, reduced permeability, increased durability, reduced autogenous shrinkage and fissures etc.,

Water soluble alcohols for instance Poly Vinyl Alcohol (PVA), Poly Ethylene Glycol (PEG), and Super Absorbent Polymer (SAP) are feasible as self curing agents in concrete. Most SAPs are conjoining polyelectrolyte. They imbibe large quantity of water without dissipating because of their ionic nature and conjugate structure. Self- curing admixtures play a compelling role where water is meagre and ergo unable to spare. The mechanism of self curing is holding the preserved water content of concrete structures within it. So concrete structures are not required any additional water for curing purpose. Steady evaporation of moisture happens on an unsheltered exposed face of concrete because of the disparity in chemical potentials between liquid and vapours phases. The polymers combined in the concrete mix chiefly form hydrogen bonds with molecules of water and lower the chemical difference of potential of the molecules, consecutively dwindles the pressure of vapour which in turn diminishes the evaporation rate from the exposed surface. The activity of Super Absorbent Polymer and its aftermath on long term shrinkage and dropping of autogenous shrinkage was monitored. The viable problems that are analogous with the utilization of super absorbent polymer were expressed.
Addition of SAP leads to a significant reduction of mechanical strength [1]. The outcome of Super Absorbent Polymer on the strength characteristics of concrete was examined by enhancing the dosage and quantity of water added. They adjudged that supplement of SAP does not promote reduction in strength characteristics. Use of SAP leads not conserve strength properties but also to hike it while intercepting self-desiccation [2]. The water soluble polymer of measures of 0.05% and 0.1% with percentage replacement of fly ash with cement and its impact on sulphate attack potion on self curing concrete at ages 28 and 56 days was studied. The test result connotes usage of water soluble polymers in concrete has enhanced performance of concrete. It was stated that a Surge in the replacement of fly ash with cement along with PEG dosages, caused a decrease in permeability of concrete. So the perforation of chemicals wane by addition of PEG and the concrete is guarded in resistance to sulphates. It was concluded that Self-curing concrete attains the capability against the sulphates existing in the soils and in the sea waters [3]. Work on self curing self compacting concrete (SCSCC) with Polyethylene Glycols (PEGs) was executed. The impact on compressive strength of M30 grade SCSCC is deemed and correlate with same grade of SCC with traditional immersion curing and dry curing technique. It was observed that curing agent Polyethylene Glycol – 600 (PEG600) provides compressive strength which is about 95% strength of immersion technique on 28th day and 89% of strength when PEG1500 is used [4]. The part of self curing chemicals PEG 4000 and PEG 200 on self compacting mortars championing to improvisation of hydration and C–S–H gel crystallization was reviewed. The experiments were pulled off on two self compacting mortars 1:1 with w/c ratio 0.34 and 1:3 with w/c ratio 0.5 using PEG 4000 and PEG 200. Usage Poly Ethylene Glycol 4000 and PEG 200 on obtained compressive strength values nearing to conventional cured specimens. SEM images of self cured mortars point out better microstructure due to superior hydration than uncured mortar samples. It was regarded that self cured self compacting mortars brought about compact pore structure and scant porosity [5]. Experiments were performed on strength characteristics on self-curing concrete with self-curing agents PVA & SAP and it was noticed that self curing agent PVA had better performance than SAP [6].

2. Experimental programme:

2.1 Material Used

The different materials used in this experimental study is as follows

Cement: OPC 53 grade (UltraTech brand) conforming to code IS: 12269-1987[7] having specific gravity of cement 3.1 is used.

2.1.1 Coarse Aggregate. Coarse aggregate used is locally available having maximum size of 20mm conforming to code IS: 383-1970[8] having Specific gravity 2.85.

2.1.2 Fine Aggregate. River sand available in the neighbourhood conforming to code IS: 383-1970[8] comprising specific gravity 2.66 and it comes under grading Zone II.

2.1.3 Self Curing Agents. The Poly Ethylene Glycol 4000, Poly Ethylene Glycol 6000, Poly Vinyl Alcohol (PVA) are used in the present study, supplied by Molychem-Manufactures and agents of laboratory reagents and fine chemicals, Mumbai. The Super Absorbent Polymer (SAP) used in this study is supplied by Sanguine genetics Ltd, Chennai.

2.1.4 Water. Water used in this project is potable water which shall be free from deleterious materials.

2.2 Mix design

The mix design of M25 grade concrete was carried out using IS: 10262-2009[9] and their proportions are presented in Table.1. Different mixes cast were shown in Table 2. Different mixes were cast using various self curing agents and their effects on mechanical properties of concrete were observed. Concrete cubical moulds of size 150mm×150mm×150mm, Cylinder moulds of size 150mm dia. ×300mm height, and Beam moulds of size 100mm×100mm×500mm were used for determination of compressive, Spilt tensile and Flexural strengths of concrete respectively, following the Indian standard code IS: 516-1959[10].
**Table 1.** Mix proportions of M25 grade concrete (Reference Mix) for 1 cubic meter.

| Cement (kg) | Fine aggregate (kg) | Course aggregate (kg) | Water (lit) |
|-------------|---------------------|-----------------------|-------------|
| 399.12      | 679.78              | 1208.73               | 191.58      |

**Table 2.** Different concrete mixes cast.

| M25 Grade concrete mixes cast |
|------------------------------|
| M0  0%                       |
| M1  0.5% PEG 4000            |
| M2  1.0% PEG 4000            |
| M3  1.5% PEG 4000            |
| M4  2.0% PEG 4000            |
| M5  0.5% PEG 6000            |
| M6  1.0% PEG 6000            |
| M7  1.5% PEG 6000            |
| M8  2.0% PEG 6000            |
| M9  0.25% PVA                |
| M10 0.5% PVA                 |
| M11 0.75% PVA                |
| M12 1.0% PVA                 |
| M13 0.25% SAP                |
| M14 0.5% SAP                 |
| M15 0.75% SAP                |
| M16 1.0% SAP                 |

3. Tests on concrete:
In this experimental study, workability of concrete mixes was determined using compacting factor test to have idea to control the quantity of water in cement concrete mix to get uniform strength. The workability of different mixes obtained is tabulated (Table 3.) It is perceived that as percentage of self curing agents increases, compacting factor value also soars.

The strength properties of concrete such as Compressive, Split tensile and Flexural strengths of concrete are determined as per respective codes and results are analysed.

**Table 3.** Workability of concretes mixes.

| M25 Grade Concrete mixes | Compacting Factor | M25 Grade Concrete mixes | Compacting Factor |
|--------------------------|-------------------|--------------------------|-------------------|
| M0 0%                    | 0.91              | M8 2.0% Peg 6000         | 0.92              |
| M1 0.5% Peg 4000         | 0.91              | M9 0.25% PVA             | 0.89              |
| M2 1.0% Peg 4000         | 0.91              | M10 0.5% PVA             | 0.90              |
| M3 1.5% Peg 4000         | 0.915             | M11 0.75% PVA            | 0.91              |
| M4 2.0% Peg 4000         | 0.92              | M12 1.0% PVA             | 0.92              |
| M5 0.5% Peg 6000         | 0.90              | M13 0.25% SAP            | 0.93              |
| M6 1.0% Peg 6000         | 0.91              | M14 0.5% SAP             | 0.95              |
| M7 1.5% Peg 6000         | 0.915             | M15 0.75% SAP            | 0.97              |
|                           |                   | M16 1.0% SAP             | 0.99              |

3.1. Compressive strength of concrete:
The apparatus for compression test arrangement is shown in figure 1. The compressive strength of reference mix (M0) and all other mixes prepared, using different self curing agents such as PEG 4000, PEG 6000, PVA and SAP are as shown in Table 4.
For 1.5% PEG 4000, the obtained compressive strength 37.85 N/mm$^2$ is maximum and it is 10.60% more than the reference mix (34.22 N/mm$^2$) and the same is presented in figure 2. For PEG 6000, the maximum compressive strength obtained was 35.63 N/mm$^2$ at 1.0% which is 4.12% more to reference mix (34.22 N/mm$^2$). For PVA, the maximum compressive strength obtained was 36.15 N/mm$^2$ at 0.25% which is 5.64% more to reference mix (34.22 N/mm$^2$). For SAP, it is pointed out that the compressive strength decreases irrespective of the percentages of SAP. The final conclusion out of the discussion on the result, the absolute maximum compressive strength is obtained for 1.5% PEG 4000.

**Table 4.** Compressive, Split Tensile, and Flexural strengths of different Concrete Mixes.

| Mix No | Percentage of Self curing agents | Compressive strength [N/mm$^2$] | Split tensile strength[N/mm$^2$] | Flexural tensile strength[N/mm$^2$] |
|--------|---------------------------------|---------------------------------|---------------------------------|-----------------------------------|
| M0     | 0 0 0 0                          | 34.22                           | 3.04                            | 3.02                              |
| M1     | 0.5 0 0 0                         | 32.44                           | 2.69                            | 2.84                              |
| M2     | 1.0 0 0 0                         | 34.07                           | 2.83                            | 3.06                              |
| M3     | 1.5 0 0 0                         | 37.85                           | 3.22                            | 3.23                              |
| M4     | 2.0 0 0 0                         | 31.48                           | 2.51                            | 2.98                              |
| M5     | 0 0.5 0 0                         | 34.59                           | 3.08                            | 2.96                              |
| M6     | 0 1.0 0 0                         | 35.63                           | 3.27                            | 3.30                              |
| M7     | 0 1.5 0 0                         | 32.44                           | 3.15                            | 3.18                              |
| M8     | 0 2.0 0 0                         | 30.29                           | 3.04                            | 2.92                              |
| M9     | 0 0 0.25 0                        | 36.15                           | 3.16                            | 3.04                              |
| M10    | 0 0 0.50 0                        | 34.81                           | 2.76                            | 2.86                              |
| M11    | 0 0 0.75 0                        | 33.92                           | 2.61                            | 2.81                              |
| M12    | 0 0 1.00 0                        | 31.70                           | 2.59                            | 2.52                              |
| M13    | 0 0 0 0.25                       | 31.63                           | 2.58                            | 2.53                              |
| M14    | 0 0 0 0.50                       | 29.48                           | 2.44                            | 2.47                              |
| M15    | 0 0 0 0.75                       | 26.22                           | 2.19                            | 2.24                              |
| M16    | 0 0 0 1.00                       | 22.37                           | 2.12                            | 2.02                              |
3.2. Split tensile strength of concrete:

The arrangement of the split tensile strength apparatus is shown in figure 3. The split tensile strength of reference mix (M0) and all other mixes prepared, using different self curing agents such as PEG 4000, PEG 6000, PVA and SAP are as shown in Table 4.

For PEG4000, the maximum split tensile strength obtained was 3.22 N/mm² at 1.5% which is 5.92% more to reference mix (3.04 N/mm²). For 1.0% PEG 6000, the obtained split tensile strength 3.27 N/mm² is maximum and it is 7.57% more than reference mix (3.04 N/mm²) and the same is shown in figure 4. For PVA, the maximum split tensile strength obtained was 3.16 N/mm² at 0.25% which is 3.95% more to reference mix (3.04 N/mm²). For SAP, it was noticed that the split tensile strength decreased for all percentages of SAP. The final conclusion out of the discussion on the result, the absolute maximum split tensile strength is obtained for 1.0% of PEG 6000.

3.3. Flexural strength of concrete:

The arrangement for flexural strength test is shown in figure 5. The flexural tensile strength of reference mix (M0) and all other mixes prepared, using different self curing agents such as PEG 4000, PEG 6000, PVA and SAP are as shown in Table 4.
For 1.5% PEG 4000, the obtained flexural tensile strength 3.23 N/mm² is maximum and it is 7.00% more than the reference mix (3.02 N/mm²). For 1.0% PEG 6000, the obtained flexural tensile strength 3.30 N/mm² is maximum and it is 9.27% more than the reference mix (3.02 N/mm²) and the same is presented in figure 6. For PVA, it was observed that maximum flexural tensile strength was obtained 3.04 N/mm² at 0.25% of PVA which was 0.66% more compared reference mix (3.04 N/mm²). For SAP, it was observed that the flexural tensile strength decreases irrespective of the percentages of SAP. The final conclusion out of the discussion on the result, the absolute maximum flexural strength is obtained for 1.0% of PEG 6000.

4. Results and discussion:
Strength properties of various concrete mixes using self curing agents (PEG 4000, PEG 6000, PVA and SAP) were discussed. The effects related to compressive, split tensile and flexural strengths of concrete are given in Table 4.

5. Conclusion:
Based on experimental study on the limited scale, the following observations are made regarding the strength properties of self curing concrete by using four different self curing agents such as Poly Ethylene Glycol 4000, Poly Ethylene Glycol 6000, PVA and SAP.

1. As the percentage of self curing agents are increasing in concrete, proportionately its workability also increasing.
2. Among the four self curing agents, the maximum compressive strength of 37.85 N/mm² was obtained with respect to M25 grade concrete when 1.5% of PEG 4000 was used in concrete mix.
3. Among all self curing agents, the maximum split tensile strength of 3.27 N/mm² was obtained when 1.0% of PEG 6000 was used.
4. The maximum flexural strength of 3.30 N/mm² was obtained among all agents concrete when 1.0% of PEG 6000 was used in concrete mix.
5. The strength properties of concrete akin compressive, split tensile and flexural tensile strengths appeared decreased by using of SAP when juxtaposed to reference mix.
6. From the foregoing observations, it was concluded that among all self curing agents used, maximum compressive strength was obtained with PEG 4000 and maximum Flexural strength and split tensile strength with PEG 6000.

References:
[1] Ole mejlhelden jensen, Per freiesleben hansen 2002 Water-entrained cement-based materials II experimental observations Cement and Concrete Research 973–78
[2] Marianne tange hasholt, Ole mejlhelden jensen, Konstantin kovler, Semion zhutovskyy 2012 Can super absorbent polymers mitigate autogenous shrinkage of internally cured concrete without compromising the strength Construction and Building Materials 226–30
[3] Aielstein rozario A, Freeda Christy C, Hannah angelin M 2013 Experimental studies on effects of sulphate resistance on self-curing concrete Int. J. of Engineering research and technology 909–16
[4] Pammani nanak J, Verma AK, Bhatt darshana R 2014 Self curing self compacting concrete: a sustainable avenue of making concrete J. Int. Academic research for multidisciplinary 112–23
[5] Sri rama chand madduru, Swamy naga ratna giri pallapothu, Rashith kumar pancharathi, Rajesh kumar garje, Raveena chakilam 2016 Effect of self curing chemicals in self compacting mortars Construction and Building Materials 356–64
[6] Manoj Kumar P and Gopla Krishna Sastry KVS 2016 Strength characteristics of self curing concrete with different curing agents Int. J. of Innovative Research InScience, Engineering and Technology 5 16511–17.
[7] IS: 12269-1987 Specifications for 53-Grade Portland cement (New Delhi: Bureau of Indian Standards)
[8] IS: 383-1970 Specification for course and fine aggregates from natural sources for Concrete (New Delhi: Bureau of Indian Standards)
[9] IS: 10262-2009 Recommended guidelines for concrete mix design (New Delhi: Bureau of Indian Standards)
[10] IS: 516:1959 Methods of tests for strength of concrete (New Delhi: Bureau of Indian Standards)