Effect of Internal Curing Agents in Self Compacting Concrete

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Abstract. The scarcity of water is the biggest challenge to India. More amount of water is utilized in construction industries for concrete curing. Steps were taken concentrating in reducing water used for curing. Controlling and monitoring the amount of water in concrete is important for both constructability and service life as the amount of water in concrete controls the properties of concrete. In this project various Internal Curing Agents (ICA) like Super Absorbent Polymer (SAP), Poly Ethylene Glycol (PEG) and water-saturated lightweight aggregate (LWA) are used in Self compacting concrete (SCC) to investigate its influence in gaining strength to reach the target strength of M40. All these materials work in similar manner that they act as a reservoir, hold water and desorbs the readily available water throughout concrete to continue the hydration process. In this paper all the three ICAs are added individually in concrete and its influence on strength is studied. SAP performs well compared to all other internal curing materials on workability aspect. The workability properties like Slump flow, L Box and V Funnel tests were conducted and all the test results satisfies the standards of EFNARC Codal provision. The effect of different dosages of ICAs in concrete leads to variation in strength parameters. ICAs in concrete mixes can be successfully used concrete structures.

Keywords: Self curing Agents, Workability, Compressive strength,

1. Introduction

Curing ensures complete or favourable hydration of cement which is defined as temperature and moisture control procedures [1, 2, 3]. Hydration is mandatory for the development of strength, permeability and capillary porosity reduction which is a chemical reaction of cement and water. It is essential for producing concrete with more durability property and also with adequate mechanical characteristics [4]. Curing of a concrete with relative humidity of 95% and temperature of 20–23°C which is exposure to favourable environmental conditions. It differs according to the governing standard. But in practice such kind of environmental condition can be gained and controlled in a laboratory (environmental chambers or curing rooms). Exposed to a wider range of environmental conditions while mixing and placing of concrete in ‘real life’ is with the temperature between 10 to 40°C and with relative humidity (RH) of 30–95%. In some particular cases, conditions for concrete curing are achieved by these environmental combinations. Even though, application of conditioned curing is a majority requirement [5].

For hydration of cement, sufficient supply of water is related with the most critical aspect of concrete curing conditions. Shrinkage, permeability, strength, abrasion resistance and other properties related to durability are the essential properties of concrete which are affected adversely by loss of...
water from hardened concrete [6]. To meet the project specifications, water required for hydration should be provided in adequate manner or else lack of water may lead the entire project in failure. In case of insufficiently cured concrete, Reduction of service life and expensive repairs would be common characteristics [6, 7]. The specimens cured in water or fog i.e., ‘normal’ laboratory curing is compared with the concrete cured in other environmental conditions [5]. The strength achieved by air cured concrete is as low as 65% the strength achieved by the water cured concrete [8, 9].

The concrete with lightweight aggregates (LWA) is used [10, 11] which have been actually realised as long as by the Internal water curing (or water entrainment) is relatively a new method. LWA are usually pre-saturated with water in such concrete (to achieve the saturated surface dry (SSD) condition) to avoid the workability loss (porous aggregates consumes when part of the mixing water). For example, Campbell and Tobin reported on the beneficial effect of LWA on curing of field concrete [11]. For achieving an internal water curing, the application of small quantities (5–7% of cement by weight) of sand-size LWA were found to be very effective and consequently, for cement hydration can get better conditions and to mitigate the autogeneous shrinkage. LWAs were used for internal curing [12, 13, 14] as different types of natural (pumice) and artificial (such as expanded clay aggregate or keramzite). The internal curing of concrete was realised in order to proposed by Superabsorbent polymers (SAPs) [10]. In cement paste is about 20 times their weight as the absorbing capacity of SAPs, and the application of 0.3–0.6% of SAPs (by weight of cement) is sufficient to provide the adequate curing of concrete. To design an air void system of hardened cement paste is a very effective method and it is also an application of SAPs (which are used in a dry form). It is important to mention that the application of LWA or SAPs (due to the inclusion of additional voids) causes the concrete strength loss and the strength gain due to better hydration is compensated [15]. Reduction water evaporation from the surface of concrete [15] achieved with water-retention additives (usually water-soluble polymers) by internal sealing. In cement mix, the internal curing concrete with water soluble polymers was investigated [16]. Poly-Ethylene Glycol (PEG) and Light Weight Aggregate (LWA) have been used as self-curing agents. Various mixes were prepared and results of fresh and harden property of concrete are carried out.

2. Materials and test methods

Materials Characterization: As per IS: 12267 – 1987 ordinary Portland cement, 53 grade was used. The micro silica and Nano silica from ELKEM India, Mumbai conforming to IS 15388:2003 was used in this investigation. River sand which is available locally with a fineness modulus of 2.8 and 12.5 mm coarse aggregate with was used. Super plasticiser (SP) used is Conplast SP 430, Sulphonated Naphthalene Polymers type. SAP of size 180 µm -300 µm from Chemzest Enterprises was used. For mixing the concrete Potable water was used. No water used for external curing. The chemical composition of cement and cementitious material are listed in Table 1.
### Table 1: Chemical Composition of Cement and Cementitious Materials

| S. No | Chemical Analysis | Cement (%) | Micro-Silica (%) | Nano-Silica (%) |
|-------|-------------------|------------|------------------|-----------------|
| 1     | SiO₂              | 22.6       | 99.87            | 99.8            |
| 2     | Al₂O₃             | 10.77      | 0.045            | 0.005           |
| 3     | Fe₂O₃             | 5.8        | 0.04             | 0.001           |
| 4     | CaO               | 55.6       | 0.001            | 0.06            |
| 5     | TiO₂              | 0.55       | 0.024            | 0.004           |
| 6     | MgO               | 1.15       |                  |                 |
| 7     | Na₂O              | 0.37       | 0.004            |                 |
| 8     | K₂O               | 0.15       |                  |                 |
| 9     | SO₃               | 1.6        |                  |                 |
| 10    | Loss of ignition  | 1.5        | 0.016            | 0.5             |
| 11    | Insoluble residue | 0.21       |                  |                 |

The properties of aggregates are listed in Table 2.

### Table 2: Physical properties of CA and FA

| No  | Properties                        | CA  | FA  |
|-----|-----------------------------------|-----|-----|
| 1   | Bulk Density (g/cm³)              | 1.50| 1.45|
| 2   | Specific Gravity                  | 2.80| 2.65|
| 3   | Fineness Modulus                  | 7.15| 2.50|
| 4   | Water absorption                  | 1.00| 2.00|

A sample Superabsorbent polymer which is water absorbed is shown in figure 1.

![Superabsorbent Polymer](image)

**Figure 1.** Superabsorbent Polymer

Out of 20 trails the best mix that suits the target strength is shown in table 3.
Table 3: Mix Proportions of Concrete Mixes

| No | Materials    | Quantities (Kg/m³) |
|----|--------------|--------------------|
| 1  | Cement       | 550                |
| 2  | Fine aggregate | 800               |
| 3  | Coarse aggregate | 775             |
| 4  | Water        | 190                |
| 5  | SP* (%)      | 0.8                |
| 6  | SAP* (%)     | 0.3                |
| 7  | PEG* (%)     | 0.5                |
| 8  | LWA* (%)     | 20                 |

* replaced to coarse aggregate  
* percentage to cement

3. Workability

As there is no standard method for SCC one has to go with several trials to achieve desired mix. The flow-ability of a fresh mix concrete is described by slump flow values in unconfined conditions. The passing ability describes the ability of the fresh mix to flow through restricted spaces and slender openings. Figure 2 shows the workability tests of SCC.

![Workability property of SCC](image)

Figure 2. Workability property of SCC (a) Slump Flow test (b) V Funnel Test (c) L Box test

The finess in high level and practically spherical shape of silica fume results in good cohesion and segregation resistance (EFNARC). Table 4 shows the workability properties of SCC as per EFNARC standards.

Table 4: Fresh Properties of Self-Compacting Concrete with self-curing compounds

| Property     | EFNARC       | Conventional | SAP | PEG | LWA |
|--------------|--------------|--------------|-----|-----|-----|
| Slump flow(mm) | 650-800      | 660          | 695 | 680 | 665 |
| L Box        | 0.8-1.0      | 0.8          | 0.9 | 0.95| 0.85|
| V-Funnel (sec) | 6-12         | 9            | 7   | 6   | 9   |
4. Results and discussions

The Workability properties of SCC are conducted and found to be satisfied to the EFNARC standards. The slump flow of normal concrete without addition of ICA is 660mm. The concrete with addition of SAP shows 35 mm flow difference and is shown in figure 3. Addition of Light weight aggregate does not show greater variation in slump flow. Even though the slump flow of such mixes are less than the concrete with SAP it satisfies the EFNARC Criteria. The flow of concrete other than normal concrete is higher because of additional water added in ICAs. Figure 4 and Figure 5 shows the L Box and V funnel test results respectively satisfying EFNARC codal standards. Addition of ICAs did not improve the concrete strength at 28days but maintains. The benefit of adding SAP in concrete is that water quantity needed for curing is largely reduced as no water is supplied to concrete further after casting. But then strength can be increased by addition of cementitious materials along with ICAs in concrete.

![Slump Flow in mm](image)

**Figure 3. Slump Flow of SCC**

![L Box test of SCC](image)

**Figure 4. L Box test of SCC**

![V Funnel test of SCC](image)

**Figure 5. V Funnel test of SCC**

The addition of SAP in concrete reduces the strength of concrete initially. This is because of formation of voids in concrete after the stored water gets released. Hence SAP did not able to improve the strength of concrete. Whereas on the other side the strength of concrete is improved to about 10% which indicated sufficient water was present for hydration process. The following table 5. and figure 6. shows the Compressive strength of concrete at 7, 28 and 56 days.
| S.No | Internal Curing Agents | 7 Days | 28 Days | 56 Days |
|------|------------------------|--------|--------|--------|
| 1    | Conventional           | 25.61  | 39.11  | 60.43  |
| 2    | LWA                    | 22.24  | 36.89  | 64.32  |
| 3    | SAP                    | 20.46  | 38.67  | 66.47  |
| 4    | PEG                    | 24.16  | 36.50  | 61.25  |

The strength achieved through PEGs is almost same as concrete cured conventionally by water immersion method. Though the strength is improved to about 6% at 28 days, it reduces to 1.36% as the concrete gets aged.

Light weight aggregate enables strength improvement to about 6.5% which significantly improves the strength of concrete at 28 days.

5. Conclusion
1. Self-compacting concrete for M40 grade concrete has been developed successfully. The optimum percentage of SAP to be added to achieve the target strength was determined as 0.2% with constant SP as 0.8% to the weight of cementitious materials.
2. The strength achieved through PEGs is almost at par with conventional concrete (immersion method).
3. Even though addition of SAP reduces the strength of concrete initially, the strength gets maintained at 28 days and further the strength of concrete is increased over a period of time.
4. Compared to conventional concrete, addition of light weight aggregates increases the strength about 5.67% at 28 days of curing and further it increases to about 6.5% at 56 days.
5. On the whole the addition of internal curing agents reduces the strength at early ages but significant improvement in strength can be achieved as days passes.

6. References
[1] ACI Committee 308 a. Standard Specification for Curing Concrete.
[2] ACI 308.1-98. Farmington Hills, MI: American Concrete Institute.
[3] ACI Committee 308 b. Guide to Curing Concrete, ACI 308R-01, ACI Manual of Concrete Practice, Farmington Hills, MI: American Concrete Institute.

[4] Bentz D P and Stutzman P E 2006 Curing, Hydration, and Microstructure of Cement Paste ACI Materials Journal 348–356.

[5] Neville A M 2000 Properties of Concrete, Upper Saddle River, NJ: Prentice Hall.

[6] Patel R G, Killoh D C, Parrott L J and Gutteridge W A 2005 Influence of Curing at Different Relative Humidities upon Compound Reactions and Porosity in Poole T S (ed.) Guide for Curing Portland cement Concrete Pavements 1 Pub. No. FHWA-RD-02-099.

[7] Hooton R D, Geiker M R and Bentz E C 2002 Effects of Curing on Chloride Ingress and Implications on Service Life ACI Materials Journal, Pub. No. 99-M20 99(2).

[8] Price W H 1951 Factors Influencing Concrete Strength. ACI Journal Proceedings 47(2) 417–432.

[9] Moreno B C G, González J A H, Mariano R R M, Lucero L A A R and Sobolev K Efectos del Curado en la 2007 Resistencia a Compresión del Concreto Normal, Reporte de Investigación, UANL, Mexico (in Spanish).

[10] Kovler K. and Jensen O M 2005 Novel Techniques for Concrete Curing Concrete International, 27(9) 39–42.

[11] Campbell R H and Tobin R E 1967 Core and Cylinder Strengths of Natural and Lightweight Concrete. ACI Journal, 64(4) pp 190–195.

[12] Yeginobali A, Sobolev K, Soboleva S and Tokyay M 1998 High Strength Natural Lightweight Aggregate Concrete with Silica Fume. Proceedings of the VI CANMET/ACI International Conference on Fly Ash, Silica Fume, Slag and Natural Pozzolans in Concrete, (Bangkok, Thailand), SP178-38 pp. 739–758.

[13] Duran-Herrera A, Aitcin P C and Petrov N 2007 Effect of Saturated Lightweight Sand Substitution on Shrinkage in 0.35 w/b Concrete ACI Materials Journal 104(1) pp 48–52.

[14] Villarreal V H and Crocker A A 2007 Better Pavements through Internal Hydration: Taking Lightweight Aggregate to the Streets Concrete international 2 pp 32–36.

[15] Kovler K and Jensen O M 2005 Novel Techniques for Concrete Curing. Concrete International, 27(9) pp 39–42.

[16] El-Dieb Amr, El Maaddawy Tamer and Mahmoud Ahmed 2012 Water-Soluble Polymers as Self-Curing Agents in Cement Mixes, Advances in Cement Research, 24(5) pp 291-299.