Effect of Curing Methods on Strength of Self-Compacting Concrete

P V Nandhini1, M Nivethitha2, A Mohanraj3 and V Senthilkumar4

1, 2 UG Student, Department of Civil Engineering, Bannari Amman Institute of Technology, Erode 638401, Tamil Nadu, India.
3 Assistant Professor, Department of Civil Engineering, Bannari Amman Institute of Technology, Erode 638401, Tamil Nadu, India.
4 Assistant Professor, Department of Civil Engineering, Sri Shakthi Institute of Engineering and Technology, Coimbatore 641062, Tamil Nadu, India.

*nandhinipv.ce17@bitsathy.ac.in

Abstract. In this paper three different curing techniques with variation in compressive strength of medium strength, self-compacted concrete are discussed. To achieve the mix design of medium strength self-compacting concrete initially numbers of trials were carried out. Super plasticizer of 0.7% and an internal curing agent, Superabsorbent Polymer of 0.3% together to the weight of cement were added. Once the mix design was achieved, as per ASTM standard three batches of concrete cubes were casted. Slump flow test was carried out in order to determine workability of self-compacting concrete. Concrete cube cured in a curing tank in the laboratory was taken as first batch. The second batch was cured by the application of an internal curing compound. The third batch was cured by Gunny bag Method. Three cubes were tested for compressive strength, from every batch at 7 days, 28 days and 60 days age of concrete. The split tensile strength of concrete was also considered. Graphs were drawn with analyzed results. So it was concluded that to get improved strength and sustainability of self-compacted concrete in areas with shortage of water, curing compound found to be more effective.

Keywords: self compact concrete, tensile strength, curing compound

1 Introduction

Cement hydration is one of the main reasons for concrete curing. Cement hydration is a series of chemical reaction that requires adequate water supply and proper temperature over an extended period of time [1]. It is the name given to the procedures used for promoting the hydration of cement, and consists of the control of temperature and moisture movement from and into concrete. Curing allows uninterrupted hydration of cement and leads to uninterrupted gain in strength. Once it gets cease, strength gain of concrete also stops.

The degree of hydration is affected by curing temperatures and thus it leads to distribution of pore size. For the production of high volume of concrete units, the use of elevated temperature curing techniques to accelerate early strength development has been adopted as one of the standard methods in the precast concrete industry. No much difference was found in the spatial distribution, morphology, and volume of hydrates and other micro-structural feature in the micro-structural examination of two months old concrete cured at 16°C, 42°C and 46°C. However, when it was cured at 80°C within the matrix of all the concrete a network of micro-cracks was evidenced. Concrete increases in strength with age, after
Setting. The strength of the concrete will be attained, if it is properly cured [2, 3]. Application of heat and/or the preservation of moisture within concrete will be affected by curing. If the concrete is casted and cured at a specific constant temperature ranges between 5°C to 46°C, the higher the temperature, the hydration of cement and the strength gain will more rapid, it is generally observed up to 28 days, [4]. Several techniques may, potentially, be used for incorporation of internal curing water in concrete [5]. Several researchers have proposed the use of saturated light weight aggregates to provide “internal” curing for concrete [6, 7]. On the other hand, other researchers used poly-glycol products in concrete mixes as self-curing agent [8]. In this project various curing techniques are adopted and the mechanical properties are tested. In order to improve the strength of the concrete micro silica of 15% to the cement was added. The percentage replacement was fixed based on many literatures.

2 Curing Methods
The methodology must be clearly stated and described in sufficient detail or with sufficient references. OPC 53 grade cement conforming to IS: 12267 – 1987 was used in this project. Micro silica having the chemical properties as shown in table 1 was replaced 15% to the weight of cement. River sand which is available locally with a fineness modulus of 2.8 and 12.5 mm, coarse aggregate was used. Superplasticiser (SP) used is Conplast SP 430; Sulphonated Napthalene Polymers type of 0.7% was adopted. For mixing the concrete, Potable water was used. SAP of 0.3% was used for internal curing. One set of specimen was water cured and the other set was cured by gunny bag method. Mix proportions for M40 grade of concrete is given in table 2.

| Table1. Chemical Composition of Cement and Cementitious Materials |
|-----------------------------------------------|
| No | Chemical Analysis | Cement % | Micro-silica % |
|-----|-------------------|-----------|---------------|
| 1   | SiO₂              | 22.6      | 99.87         |
| 2   | Al₂O₃             | 10.77     | 0.045         |
| 3   | Fe₂O₃             | 5.8       | 0.04          |
| 4   | CaO               | 55.6      | 0.001         |
| 5   | TiO₂              | 0.55      | 0.024         |
| 6   | MgO               | 1.15      | -             |
| 7   | Na₂O              | 0.37      | 0.004         |
| 8   | K₂O               | 0.15      | -             |
| 9   | SO₂               | 1.6       | -             |
| 10  | Loss of ignition  | 1.5       | 0.016         |

| Table2. Mix Proportions |
|-------------------------|
| S.No | Curing          | %   | Quantity in Kg/m³ |
|------|-----------------|-----|-------------------|
| 1    | Cement          |     | 375               |
| 2    | Micro silica    | 15% | 66                |
| 3    | Fine aggregate  |     | 975               |
| 4    | Course aggregate|     | 735               |
| 5    | Water           |     | 190               |
| 6    | Plastizer       | 0.7%| 3                 |
3 Workability Properties

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.

| S.No | Curing                     | Slump Flow | L Box | V Funnel |
|------|---------------------------|------------|-------|----------|
| 1.   | Conventional Concrete     | 720        | 0.9   | 10       |
| 2.   | Concrete with admixtures  | 630        | 0.8   | 8        |

The finess in high level and practically spherical shape of silica fume results in good cohesion and segregation resistance (EFNARC). Table 3 shows the workability properties of SCC as per EFNARC Standard. Figure 1 shows the workability of SCC (a) Slump flow (b) V funnel test. Cubes of size 150 mm x 150 mm x 150mm and cylinder of size 150 mm x 300 mm were cast and allowed for curing.

Figure 1. a. Slump flow  b. V Funnel tests

Figure 2 shows the test on mechanical properties of SCC.

Figure 2. a. Compressive strength  b. Split tensile strength
Beam Details
The Beam is designed as a singly reinforced beam. The beam is designed as per Code IS 456: 2000. Thus the beam details are given below:

Beam Size $= 1000 \times 150 \times 220$ mm,
Cover $= 25$ mm
Main rod $= 3$ no’s of $10$mm Ø rods
Hanger rods $= 2$ no’s of $8$mm Ø rods
Stirrups $= 2$ legged stirrups of $8$mm Ø rods @ $200$mm
$f_y$ $= Fe 415$
$f_{ck}$ $= 40$ Mpa

![Figure 3. Flexural strength](image)

The beam as stated in V is tested as per the codal procedure. The two point load is applied at the distance of $L/3$. The clear span of beam is adopted as $800$mm & the concentric loading is given during the testing of the beam. Deflecto-meter is said to measure the deflection value of the beam. The test results are given in table 3. Testing of beam is as shown in fig 3.

4 Results and discussions
The Workability properties of SCC are conducted and found to be satisfied to the EFNARC standards. The normal concrete without addition of mineral admixtures shows slump flow of $720$mm. The concrete with addition of mineral admixtures shows $90$ mm flow difference. The flow of concrete added admixtures is lower because of frictional effect due to more fine powder.

The concrete containing no admixtures was tested at $28$ days of curing as shown in figure 4. The strength of concrete at $7$ days in self curing method is decreased to about $20\%$ and $13\%$ respectively to water curing and gunny bag curing. At $28$ days the strength of self curing decreases to about $10.5\%$ and $8\%$ respectively to water curing and gunny bag curing. The strength of concrete added internal curing SAP improved its strength at $60$ days. This implies that sufficient amount of water [9] is supplied to concrete that confirms continuous hydration process that took place within the concrete system. Formation of hydration products makes concrete system more dense and compacted leading to improvement in strength at later days.
The strength increases by 5% and 10% respectively to water curing and gunny bag curing. This improvement in strength is attributed to formation of new materials during hydration process.

When concrete is added with Micro-silica then the strength of concrete tends to increase drastically. The strength of concrete at 7 days in self curing method is decreased to about 15% and 12% respectively to water curing and gunny bag curing. At 28 days the strength of self curing decreases to about 9% and 5% respectively to water curing and gunny bag curing. The strength of concrete added internal curing SAP improved its strength at 60 days. The strength increases by 9% and 14% respectively to water curing and gunny bag curing. This improvement in strength is attributed to formation of new materials during hydration process that made the concrete system more dense resulting in higher strength at later ages. The other method of curing may not provide sufficient water for hydration process but continuous hydration process is possible only by internal curing. The strength of concrete containing mineral admixtures is as shown in figure 5. The split tensile strength of concrete containing admixtures is shown in figure 6.
Table 4 gives the test result of flexural strength of concrete.

| S.No | Loadings (KN) | Deflection (mm) | Remark                  |
|------|---------------|-----------------|-------------------------|
| 1.   | 0             | 0               |                         |
| 2.   | 10            | 0.02            |                         |
| 3.   | 20            | 0.25            |                         |
| 4.   | 30            | 0.46            |                         |
| 5.   | 40            | 0.66            |                         |
| 6.   | 50            | 0.87            |                         |
| 7.   | 60            | 1.11            | First Crack             |
| 8.   | 70            | 1.34            |                         |
| 9.   | 80            | 1.65            |                         |
| 10.  | 90            | 1.98            |                         |
| 11.  | 100           | 2.21            |                         |
| 12.  | 110           | 2.53            |                         |
| 13.  | 120           | 2.82            |                         |
| 14.  | 130           | 3.15            |                         |
| 15.  | 140           | 3.50            |                         |
| 16.  | 150           | 4.00            |                         |
| 17.  | 155           | 4.52            | Ultimate crack load & Maximum deflection |

Figure 6. Split tensile strength of (a) conventional (b) micro silica added concrete in N/mm²
5. Summary and Conclusions
The concrete without silica fume showed higher flow rate than concrete containing silica fume. The strength of concrete by normal curing method can be adopted if there has availability of water as it gives higher strength than any other method of curing. However Self cuing is best sitet at the sites where there is no availability of water and the strength of concrete though decreases initially, improves after 28 days of time. The strength formation is attributed to formation of new materials during hydration process. This envisage continuity in hydration process even after 28 days of time because of the availability of internal water required for continuing the process. Also the unhdrated residual materials that are left behind due to unavailability of water will be hydrated because of Internal curing offered by SAP. The strength of concrete achieved by gunny bag method is closer to conventional method of curing. But water can be saved by adopting this method of curing. The split tensile strength of concrete gets decoder for self curingmethod.

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