NATIONAL CONFERENCE ON RECENT RESEARCH IN ENGINEERING AND TECHNOLOGY (NCRRET-2015)
INTERNATIONAL JOURNAL OF ADVANCE ENGINEERING AND RESEARCH DEVELOPMENT (IJAERD)
E-ISSN: 2348 - 4470 , PRINT-ISSN:2348-6406

RELATION BETWEEN CURING TECHNIQUE AND EARLY AGE COMPRESSIVE STRENGTH OF SELF COMPACTING CONCRETE

Dr. Pamnani Nanak J.
[1] *Associate Professor, Dr. Jivraj Mehta Inst. Of Technology, DJMIT, Mogar, Anand, nanak_p@hotmail.com*

Abstract— Self-Compacting Concrete (SCC) is highly workable concrete with high strength and high performance that can flow under its own weight through restricted sections without segregation and bleeding. It is observed that the behaviour of the design concrete mix is significantly affected by many factors including variation in humidity and temperature both in fresh and hardened state. In this paper effect of few selected curing techniques on early age (3 & 7 days) compressive strength of M30 grade self-compacting concrete (SCC) is discussed. It is observed that immersion method for curing gives maximum compressive strength while the lowest compressive strength is for ice curing. It is also observed that SCC can prove effective in sea water curing.

Keywords— Self compacting concrete, Immersion curing, ice curing, sea water curing, wet covering, curing period, early age compressive strength.

1 INTRODUCTION

Self-Compacting Concrete (SCC) is highly workable concrete with high strength and high performance that can flow under its own weight through restricted sections without segregation and bleeding (**EFNARC**- European Federation of Producers and Applicators of Specialist Products for Structures, 2002). SCC has many commercial benefits because of ability of placement in complex forms with congested reinforcement. Ouchi *et al*., (2003), [12].

As per Okamura and Ozawa, (1995), [11], SCC is achieved by reducing the volume ratio of aggregate to cementitious materials, increasing the paste volume and using various viscosity enhancing admixtures and superplasticizers. With the use of superplasticizers it is possible to use very low w/c ratio up to 0.25 or even lower and to obtain strength to the tune of 120 MPa or more. SCC is useful for building elements which are usually densely reinforced.

Kumbhar P.D., et. al. (2011), observed that the behaviour of the design concrete mix is significantly affected by variation in humidity and temperature both in fresh and hardened state. The strength of concrete is affected by a number of factors, one of which is the length of time for which it is kept moist, i.e. cured, another being the method of curing. Inadequate or insufficient curing is one of main factors contributing to weak, powdery surfaces with low abrasion resistance and durability.

Exposed surfaces of concrete shall be kept continuously in a damp or wet condition by ponding or by covering with a layer of sacking, canvas, hessian or similar materials and kept constantly wet for at least seven days from the date of placing concrete in case of ordinary Portland Cement-and at least 10 days where mineral admixtures or blended cements are used. IS:456-, (2000), [6]. Cement Concrete & Aggregates Australia CCAA, (2006), [2], in a data sheet mention that curing is the process of controlling the rate and extent of moisture loss from concrete during cement hydration. This can be achieved by various methods such as: supplying the water from outside, wetting the exposed surface, leaving formwork in place, covering the concrete with an impermeable member, application of chemical on external surface, mixing suitable chemical in fresh concrete for internal curing and combination of such methods.

Qureshi *et al.*, (2010), [13] experimented on high strength self compacting concrete by curing with 3 different techniques. First in a temperature controlled curing tank in the laboratory, second under prevailing site conditions and 3rd by application of a curing compound. They noted that 28-days compressive strength of cylinders cured under site conditions was 89 % of the compressive strength of cylinders cured in water tank in the laboratory (i.e., 11 % less). Similarly compressive strength of cylinders cured by applying curing compound was 93 % of the compressive strength of cylinders cured in the laboratory (i.e., 7% less).

Michael, (2005), [10] investigated the effect of heat treatment on the mechanical properties of SCC. Various SCCs were brought to a maturity corresponding to a durable storage of the concretes for 3 days at 20 °C. On these concretes, the compressive strength, the splitting tensile strength and the static Young's modulus were determined and compared to reference concretes that had been stored for 3 days under standard conditions. The concretes with a low (w/c)-ratio, which are typically used in the precast industry, are hardly affected by the heat treatment conditions. This applies independent from the curing temperature. A high (w/c)-ratio leads in part to marked loss of strength, which in most cases increases with increasing curing temperature. For the splitting tensile strength, heat curing temperatures up to 60 °C can be regarded as uncritical. Beyond this temperature, strength losses compared to standard storage have to be reckoned with.

The strength of concrete is affected by a number of factors, one of which is the length of time for which it is kept moist, i.e. cured, another being the method by which it is being cured. Inadequate or insufficient curing is one of main factors contributing to weak, powdery surfaces with low abrasion resistance..

In the present paper, effect of few curing methods in which water or ice is used as supplementary curing medium, are chosen.

1. Immersion method –M3I
2. Ice curing – M3B
3. Sea water curing – M3S,
4. Gunny Bag or Wet Covering – M5W

The effect of these water-based curing techniques on the early age compressive strength of M30 grade self-compacting concrete (SCC) is discussed.

2 Materials & Methods

2.1 Materials

The materials used in developing the reference M30 SCC have following properties:

2.1.1 Cement

Ordinary Portland cement of 53 grade (Sanghi brand) with Specific Gravity 3.15, available in local market. The properties were checked as per IS:12269-, (2013), [8]. The properties of cement used are given in Table 1.

Table 1
Properties of 53 grade Ordinary Portland cement

PROPERTY	VALUE	IS CODE: 8112–1989 Specifications
Specific Gravity	3.15	3.10-3.15
Consistency	28%	30-35
Initial setting time	35min	30min minimum
Final setting time	178min	600min maximum
Compressive strength at 7 days N/mm^2	38.49 N/mm^2	43 N/mm^2
Compressive strength at 28 days N/mm^2	52.31 N/mm^2	53 N/mm^2

2.1.2 Water

Water is an important ingredient of concrete as it actually participates in the chemical reaction with cement. Potable water was used for mixing.

2.1.3 Sea water

The sea water was brought from gulf of Cambay having salinity 23%..

2.1.4 Fly ash

Class C Fly ash was used with Specific Gravity 2.13, Vanakbori Thermal Station, Dist. Kheda, Gujarat, India. The properties of Fly ash used are given in Table 2.

Table 2
Properties of Fly ash

Constituents	Weight by %
Loss on ignition	4.17
Silica (SiO_2)	69.40
Iron Oxide (Fe_2O_3)	3.44
Alumina (Al_2O_3)	28.20
Calcium Oxide (CaO)	2.23
Magnesium Oxide (MgO)	1.45
Total Sulphur (SO_3)	0.165
Insoluble residue	-
Sodium Oxide (Na_2O)	0.58

Potassium Oxide (K2O)	1.26

2.1.5 Aggregates (FA & CA)

High strength or rich concrete can be adversely affected by use of large size aggregates as discussed in Shetty M.S. (2005), a text book of Concrete Technology. Based on this fact and after studying mix design literature of SCC, the various aggregates used are as under:

Sand, ≤ 4.75mm: Specific gravity 2.55 & Fineness Modulus 2.87, Zone II, Bodeli, Vadodara.

Grit, 4.75 to 12.5mm: Specific gravity 2.75 & Fineness Modulus 5.76, Sevaliya, Kheda District. The properties of aggregates used are checked as per IS:383-, (1970), [5] are given in Table 3.

Table 3
Properties of sand

Particulars	Sand	Grit
Source	Bodeli, Gujarat	Sevalia, Gujarat
Zone	Zone II	-
Specific Gravity	2.55	2.75
Fineness Modulus	2.87	5.76
Bulk Density	1776 kg/m^3	1764 kg/m^3
Colour	Yellowish White	Greyish Black

2.1.6 Chemical admixtures (SP)

Polycarboxylates ether condensate (PCE) based superplasticizers were used Brand name Glenium B276 Suretec. Dosages of superplasticizers 1.1% of cementitious material. The properties of superplasticizer are: pH≥6, Chloride ion content<0.2% and light brown liquid in color.

2.1.7 Gunny Bag

These are also called jute bags. They retain water and keep the samples wet. The bags were available from local market

2.2 Mix proportion of scc and preparation of specimen

There is no standard method for SCC mix design and many academic institutions, admixture suppliers, ready-mixed, pre cast and contracting companies have developed their own mix proportioning methods. Various trials were performed with 0.01 m^3 of concrete with locally available materials and checked the fresh property tests (Slump flow, J-ring flow, V-funnel, L-box and U-box) according to the standards of European Guidelines and finalized the mix proportion of M30 grade of SCC, considered as a reference SCC The selection of super plasticizer and its doses where fixed using Marsh Cone. Before finalizing the type of superplasticizer and its dosage, Marsh cone method was used to study the effect of water/cement ratio and dosage of superplasticizer type on cement pastes with different superplasticizer dosages. Agullo *et al*., (1999), [1]

Once the mix design was achieved, concrete cubes were cast. Slump Flow Test was carried out on each batch in order to ascertain concrete flow for self-compacting concrete. All concrete batches were prepared in rotating drum mixture. First, the aggregate are introduced and then one-half of the mixing water was added and rotated for approximate two minutes. Next, the cement and fly ash were introduced with superplasticizer already mixed in the remaining water. Most manufactures recommend at least 5 minutes mixing upon final introduction of admixture. The selected mix design for reference mix adopted is shown in Table 4.

Table 4
Mix Proportion for mix design M30 SCC, Materials/m^3

Cement Kg	Fly-Ash Kg	F.A. Kg	C. A.	Water Lit.	SP %
375	175	785	735	214.5	1.07

2.3 Tests conducted on fresh scc

Various tests such as Slump flow & T50 test, J-Ring test, L-Box test, U-Box test & V-funnel test were performed to study the workability of SCC. Test results and their acceptance criteria as per EFNARC, (2002), [3] are listed in Table 5.

2.4 Curing methods used

Three specimens were cured for each selected techniques of curing namely normal water immersion, ice, sea water & wet covering.

Water immersion: The specimens are placed in a water shallow pond immediately after de-moulding. They remain in pond continuously till the day of testing.

Ice curing: The specimens were placed in a ice making drum in an ice factory for the specified period. The temperature inside the drum is maintained at zero °C. The drums were taken out in the morning of the day of testing in order to thaw the ice before testing.

Sea water curing: The sea water was brought to laboratory from bay of Cambay and kept in small drums with specimens inside. This is quite similar to immersion curing.

Wet Covering with Gunny Bags: Wet jute bag covers were placed as soon as the specimens were de-molded to maintain water on the surface of the concrete. They were kept wet continuously for the entire period of experiments.

The various acronyms used for specimens of tests are: M3I for Pond Immersion, M3S for sea water, M3B for ice curing and M3W for Wet Covering.

2.4 Tests conducted on hardened M30 SCC

Compressive strength: For compressive strength cubes of 150×150×150mm were cast from reference mix of SCC and kept for different types of curing up to 90 days. Three specimen were tested after 3, 7, 28, 56 and 90 days, using a calibrated compression testing machine of 2,000 KN capacity as per IS:516-1959, (2004), [7].

Compressive strength $f_c = P/A$, where, P is load & A is area of cube …… (a)

3 RESULTS AND DISCUSSION

3.1 Tests results of fresh SCC:

The overall fresh SCC properties of reference mix are shown in Table 5. The various tests namely Slump flow, L-Box, U-Box, & V-funnel were conducted on fresh SCC reference mix as per EFNARC guidelines. The slump flow test has spread of 620mm. The limiting parameters specified by EFNARC and the results are noted in table 5. It can be observed that the reference mix satisfies all the criteria as per standards specified by EFNARC.

Table 5

Fresh SCC properties of reference mix

Test conducted	Unit	Values as per EFNARC		Results of Tests
		Min.	Max.	M30
Slump-flow	mm	600	800	620
T50-Slump flow	sec	2	5	3.8
L-box	(h_2/h_1)	0.8	1.0	0.83
U-box	(h_2-h_1)	0	30	10.2
V-funnel	sec	6	12	9.8

3.2 Compressive strength for M30 SCC

The compressive strength for various specimens at different ages for selected curing methods, its average values and standard deviation is summarized in Table 6. For further analysis the average value of samples is taken in consideration. Table 7, shows the percentage Av. compressive strength with reference to Immersion strength for different ages of concrete.

Table 6
Compressive Strength N/mm² for selected methods of curing for M30 SCC

Method/ Acronym	Results	Compressive Strength N/mm²	
		3 Days	7 Days
Immersion M3I	C1	18.3	30.5
	C2	18.7	32.7
	C3	19.6	31.4
	Average	***18.9***	***31.5***
	Std. Deviation	0.7	1.1
Ice M3B	C1	17.4	23.1
	C2	16.6	21.8
	C3	17.9	20.9
	Average	***17.3***	***21.9***
	Std. Deviation	0.7	1.1
Sea water M3S	C1	18.7	31.8
	C2	21.4	33.1
	C3	20.9	31.0
	Average	***20.3***	***32.0***
	Std. Deviation	1.4	1.1
Wet Covering M3W	C1	20.9	29.6
	C2	20.5	30.5
	C3	21.8	29.2
	Average	***21.1***	***29.8***
	Std. Deviation	0.7	0.7

Table 7

% age Av. Compressive Strength with ref. to Immersion

Strength for M30 SCC

Acronym	Curing Methods	3D	7D
M3I	Immersion	100.0	100.0
M3B	Ice	91.5	69.6
M3S	Sea water	107.7	101.4
M3W	Wet Covering	111.5	94.5

Fig.1: % age Compressive strength development with ref. to immersion curing techniques at 3 days

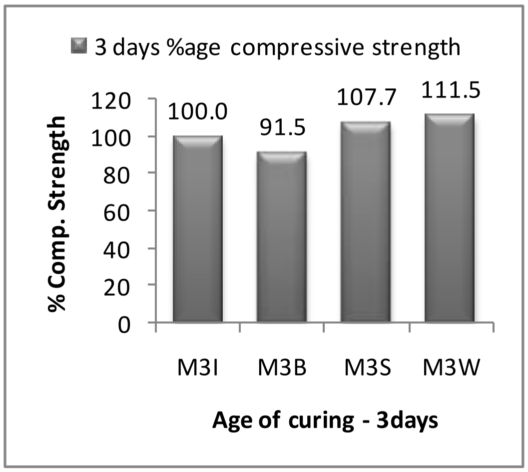
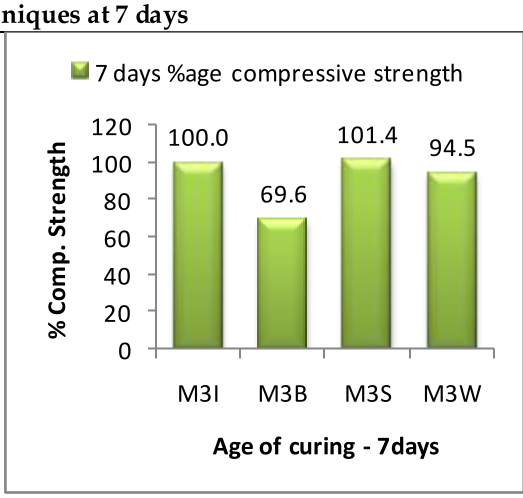


Fig.2: %age Compressive strength development with ref. to immersion curing techniques at 7 days



It is observed that for M30SCC at 3 days, wet covering achieves the highest strength 21.1 N/mm^2, about 12% higher than immersion strength. The higher strength may be due improved pore structure and lower porosity resulting from greater degree of hydration without any loss of moisture from the concrete specimen. However at 7 days the strength is lesser than immersion method.

Sea water curing method gives second highest compressive strength at 3 days. It is about 8% more than strength achieved by immersion method at 3 days. However at 7 days it achieves highest strength little more than immersion curing. The development of good compressive strength in sea water may be due to presence of certain alkalis which accelerates the early strength of concrete. Shetty, (2009), [15]. This may be due to the accelerating effects of some of the sea salts like NaCl, K2SO4 which cause a more rapid dissolution of compounds of cement particularly tricalcium silicate in water and hence facilitates more rapid hydration of concrete. This is in confirmation with Md Moinul *et al*., (2012), [9].

The good compressive strength is also attributed to proper hydration of cement and reduction in voids due to presence of pozzlonic material like fly ash. The results are in confirmation of the results of the study by Safiuddin *et al*., (2007), [14].

The lowest strength is for ice curing 17.3 and 21.9 N/mm^2 at 3 and 7 days respectively, about 9% and 30% lesser than immersion curing. Initial strength gain, after mixing of water until de-molding, exhibits better strength at 3 days. But later at 7 days the strength reduces. This is due to the reason that at around -3 to -4°C, enough of the pore water will freeze so that hydration will completely stop. Grace, (2006), [4].

This indicates that for extreme weather conditions SCC can prove effective for sea water while cold weather does not cater sufficient strength

4 CONCLUSION

- With the use of various tests- slump flow and other tests on fresh SCC, it is verified that self-compacting concrete (SCC) achieves consistency and selfcompactability under its own weight, without any external vibration or compaction.

- It is concluded from above study that method of curing has considerable effect on the early age compressive strength of SCC.
- Sea water curing gives best early age strength for curing in SCC while ice curing is observed to be the weakest.
- Wet covering method of curing gives almost parallel early age compressive strength compared to immersion method strength with saving in water.

5 REFRENCES

1. Agullo L., Toralles-Carbonari B., Gettu R. and Aguado A., (1999), "Fluidity of cement pastes with mineral admixtures and superplasticizer—a study based on the Marsh cone test", *Materials and Structures*, 32(7), pp. 479-485.
2. CCAA, (2006), "Curing of Concrete – A data sheet", *Cement Concrete & Aggregates Australia*, Australia.
3. EFNARC, (2002), "European Guidelines for Self-Compacting Concrete", Surrey GU9 7EN, UK.
4. Grace W. R., (2006), "Cold weather concreting", Cambridge, USA.
5. IS:383-, (1970), "Specification for coarse and fine aggregates from natural sources for concrete", Bureau of Indian Standards, New-Delhi, India.
6. IS:456-, (2000), "Plain & Reinforced concrete-Code of Practice", Bureau of Indian Standards, New-Delhi, India.
7. IS:516-1959, (2004), "Methods of tests for strength of concrete", Bureau of Indian Standards, New-Delhi, India.
8. IS:12269-, (2013), "Specification for 53 Grade Ordinary Portland Cement", Bureau of Indian Standards, New-Delhi, India.
9. Md Moinul I., Al-Amin M., Islam M. S. and Islam M. M., (2012), "Suitability of sea water on curing and compressive strength of structural concrete", *Journal of Civil Engineering (IEB)*, 40(1), pp. 37-45.
10. Michael S., (2005), "Heat curing of self-compacting concrete", *Otto-Graf-Journal*, 16, pp. 167-183.
11. Okamura H. and Ozawa K., (1995), "Mix design for self-compacting concrete", *Concrete library of JSCE*, 25(6), 107-120.
12. Ouchi M., Nakamura S.-A., Osterberg T., Hallberg S.-E. and Lwin M., (2003), "Applications of self-compacting concrete in Japan, Europe and the United States", *International Symposium on High Performance Concrete (ISHPC), Tokyo, Japan*.
13. Qureshi L., Bukhari I. and Munir M., (2010), "Effect of Different Curing Techniques on Compressive Strength of High Strength Self Compacting Concrete", *http://www.claisse.info/supplementaryabstracts.htm*.
14. Safiuddin M., Raman S. and Zain M., (2007), "Effect of different curing methods on the properties of microsilica concrete", *Australian Journal of Basic and Applied Sciences*, 1(2), pp. 87-95.
15. Shetty M. S., (2009), "Text book of Concrete Technology: Theory and Practice", New Delhi, India, *S. Chand & Company*.