EFFECT OF FEW WATER REATAINING CURING TECHNIQUES ON SHEAR STRENGTH OF SELF COMPACTING CONCRETE

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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. 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. It is observed that the behaviour of the design concrete mix is significantly affected by variation in humidity and temperature both in fresh and hardened state. In this paper effect of few water retaining curing techniques on shear strength of M30 grade self-compacting concrete (M30SCC) is discussed and compared with shear strength of normal vibrated concrete of same grade (M30NVC).*

It is concluded that although pond immersion method is best for curing, Polyester film covering can deliver about 82% shear strength compared to immersion method. It can be observed that shear strength of M30SCC is more than M30NVC for polyester film covering while it does not change in case of curing compound techniques.

Keywords: Self compacting concrete, Normal vibrated concrete, Immersion curing, Polyester film covering curing, Curing compound, shear strength.

I. 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). It is a special type of concrete that spreads through the congested reinforcement, reaches every corner of the formwork, and is consolidated under its own weight. It provides excellent filling ability and passing ability, and exhibits good segregation resistant. **Khayat K**, **(1999)** *[6]*

The guiding principle behind the self compacting concrete is that "the sedimentation velocity of a particle is inversely proportional to the viscosity of the floating medium in which the particle exists". SCC has a big role to play because of its substantial benefits in construction both qualitatively and quantitatively. **Coppola *et al.***, **(2004)** *[4]*

Superplasticizer (SP) also called High Range Water Reducers (HRWR) is an essential component of SCC to provide the necessary workability **Okamura and Ouchi**, **(2003)** *[10]*. They reduce the yield stress and plastic viscosity of concrete by their liquefying action **Skarendahl and Petersson**, **(2000)** *[17]*.

Kumbhar *et al.*, (May 2011) *[7]*, 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 the length of time for which it is kept moist, i.e. cured, and also the method of curing. Inadequate or insufficient curing is one of main factors contributing to weak, powdery surfaces with low abrasion resistance and durability.

The same hydration mechanism governs SCC as that of Conventional Concrete **Skarendahl and Petersson**, **(2000)** *[17]*. However a higher content of admixtures and powder materials may exert some influence on hydration development. The setting time of SCC was reported to be twice as long as that of CC due to the superplasticizer and fly ash used.

Cement Concrete & Aggregates Australia **CCAA, (2006)** *[3]***,** 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:

- Either supplying the water from outside (Ponding & Spraying)
- Continuously wetting the exposed surface thereby preventing the loss of moisture from it.
- Leaving formwork in place
- Covering the concrete with an impermeable member
- Application of a suitable chemical (wax etc.)
- 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).

Membrane-forming compounds consisting of waxes, resins, chlorinated rubber, and other materials can be used to retard or reduce evaporation of moisture from concrete. They are the most practical and most widely used method for curing not only freshly placed concrete but also for extending curing of concrete after removal of forms or after initial moist curing. Curing compounds should be able to maintain the relative Humidity of the concrete surface above 80% for seven days to sustain cement hydration. **Goel *et al.*, (2013)** *[5]*

Curing compounds should be applied by hand-operated or power-driven spray equipment immediately after final finishing of the concrete. The concrete surface should be damp when the coating is applied. On dry, windy days, or during periods when adverse weather conditions could result in plastic shrinkage cracking, application of a curing compound immediately after final finishing and before all free water on the surface has evaporated will help prevent the formation of cracks. **Shetty**, **(2009)** *[16]*

Safiuddin *et al.*, (2007) *[15]* noticed that wrapping curing is more efficient than dry-air curing as it results in greater compressive strength, ultrasonic pulse velocity and dynamic modulus of elasticity and lower surface absorption. This is because in wrapped curing moisture movement from the concrete surface was hindered due to the impervious layer of the film and as a result good amount of moisture was available to be used throughout the hydration process.

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 we have chosen few methods of curing in which water retaining curing technique is used:

1. Traditional immersion or pond method – acronym M3I
2. Polyethylene film wrap, 3. External Curing compound and 4. No curing

The effect of these water-retaining curing techniques on the shear strength of M30 grade self-compacting concrete (SCC) is discussed. Also the shear strength of SCC is compared with samples conventionally cured with pond immersion method and with normal vibrated concrete (NVC).

II. Materials & Methodology

A. Materials

The materials used for making of M30 grade SCC are mentioned below along with their properties:
Cement: Ordinary Portland cement of 53grade (Sanghi brand) with Specific Gravity 3.15, available in local market. The properties of cement used are given in Table 1.

Table 1: Properties of 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
Final setting time	178min	600min
Compressive strength at 7 days N/mm^2	38.49	43
Compressive strength at 28 days N/mm^2	52.31	53

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

C. 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. **Prajapati *et al.*, (2012)** *[12]* carried out investigations on self compacting concrete using various percentages of fly ash,10% ,20% and 30% by weight of cement as partial replacement of cement. Based on the investigations they concluded that addition of Fly ash resulted in a decreases of super plasticizer content for same or better workability.

Table 2: Properties of Fly-ash

Constituents	Weight by %
Loss on ignition	4.17
Silica (SiO2)	69.40
Iron Oxide (Fe2O3)	3.44
Alumina (Al2O3)	28.20
Calcium Oxide (CaO)	2.23
Magnesium Oxide (MgO)	1.45
Total Sulphur (SO3)	0.165
Insoluble residue	-
Sodium Oxide (Na2O)	0.58
Potassium Oxide (K2O)	1.26

D. 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 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

E. **Superplasticizers (SP):** Polycarboxylates ether condensate (PCE) based superplasticizers were used with brand name Glenium B276 Suretec. Dosage of superplasticizer was fixed with the help of Marsh cone test and fixed at 1.1% of cementitious material. The properties of superplasticizer are: pH≥6, Chloride ion content<0.2% and light brown liquid in color.

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

III. 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 final mix design for reference mix adopted is shown in Table 4.

Table 4: Mix proportions for reference mix design, Materials/m^3

Reference Mix	M30 SCC
Cement Kg	375
Fly-Ash , Kg	175
Fine Aggt., Kg	785
Coarse Aggt., Kg	735
Water, Lit.	214.5
SP	1.1%

IV. Tests Conducted on Fresh SCC

The overall fresh properties of reference M30 SCC mix were conducted. The various tests namely Slump flow & T50 test, J-Ring test, L-Box, U-Box, & V-funnel were conducted on fresh SCC reference mix as per EFNARC guidelines. The slump flow test has spread of 650mm. 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.

V. Water Retaining Curing Methods Used

In the present paper we have chosen different methods of water retaining curing techniques in which water is not used as supplementary curing medium:
Polyethylene film wrap– M3P,
External Curing compound – M3C
No curing – M3N
Traditional immersion or pond method – acronym M3I, has been used for comparison.
Three specimens were cured for each selected technique of curing.

A. **Traditional Pond immersion:** The specimens are placed in a water shallow pond immediately after de-moulding. They remain in pond continuously till the day of testing.
B. **Polyethylene film wrap:** Polyethylene film is a lightweight, effective moisture retarder and is easily applied to complex as well as simple shapes. As recommended by ASTM C 171 the specimens were wrapped with 0.01 mm thick transparent plastic film.

C. **External curing compounds**: This liquid when applied over the surface of concrete members forms an impermeable membrane that minimizes the loss of moisture from the concrete. Two coats of wax based liquids with brand name FAIRCURE was sprayed over the freshly finished specimen.

D. **No curing**: The samples are left in open yard without cover, in ambient temperature. The various acronyms used for specimens of tests are: M3I for Pond Immersion curing, M3P for Polyethylene film warp curing, M3C for external curing compound and M3N for No curing.

VI. Shear Strength Test Conducted on Hardened M30 SCC

For finding shear strength L-shape cubes of size (150*150*150mm – 150*90*60), as suggested by **Bairagi and Modhera, (2001)** *[2]*, **Patel**, **(August 2010)** *[11]*, are cast from reference mix of M30SCC and tested after 28 days of curing with different techniques. Three samples were cast for each method of curing. Fig.1 shows the test arrangement for shear strength test.
f_s = P2/A, where, P2 is load at shear plane & A is area of cube at shear plane.. (a)

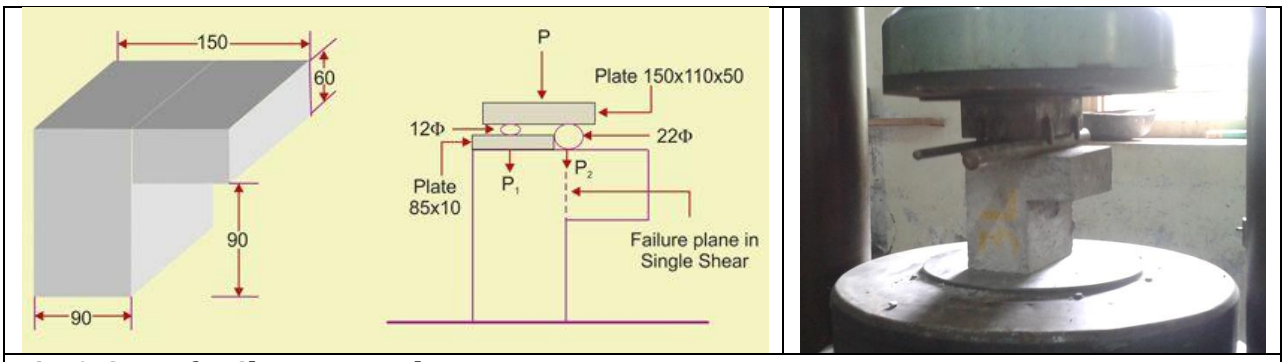

Fig. 1: Setup for Shear strength test

VII. Results and Discussion

A. 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 properties of reference mix M30SCC

Sr. No.	Test Method	Property	Unit	Range as per EFNARC		Test Result
				Min.	Max.	M30SCC
1	Slump-flow	Filling ability	mm	600	800	620
2	T50-Slump flow	Filling ability	sec	2	5	3.8
3	L-box	Passing & Segregation	(h_2/h_1)	0.8	1.0	0.83
4	U-box	Passing & Segregation	(h_2-h_1)	0	30	10.2
5	V-funnel	Filling ability	sec	6	12	9.8

B. Test results of Shear strength for M30SCC and M30NVC:

The average values of shear strength for various specimens at 28 days are presented in Table 6. Fig. 2 shows the 28 days %age shear strength comparison for all the specimens for different curing techniques with reference to immersion strength.

Table 6: 28 days Shear strength for M30SCC & M30NVC

Method/ Acronym	Results	28 days Shear Strength N/mm^2	
		M30SCC	M30NVC
Immersion	S1	4.9	4.1
	S2	5.1	4.3
	S3	5.2	4.4
	Average	***5.1***	***4.3***
	Std. Dev.	0.2	0.1
Polyethylene Film	S1	4.0	3.5
	S2	4.2	3.4
	S3	4.3	3.3
	Average	***4.2***	***3.4***
	Std. Deviation	0.1	0.1
Curing compound	S1	4.3	3.6
	S2	3.7	3.2
	S3	3.8	3.2
	Average	***3.9***	***3.3***
	Std. Deviation	0.3	0.2
No Curing	S1	2.5	2.2
	S2	2.6	2.4
	S3	2.7	2.1
	Average	***2.6***	***2.2***
	Std. Deviation	0.1	0.1

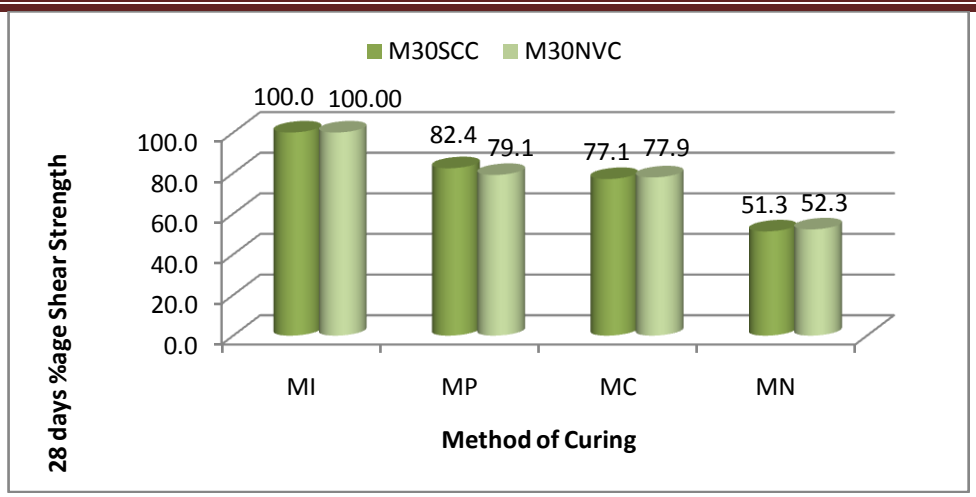

Fig.2: %age Shear strength for different curing methods w.r.t. Immersion strength

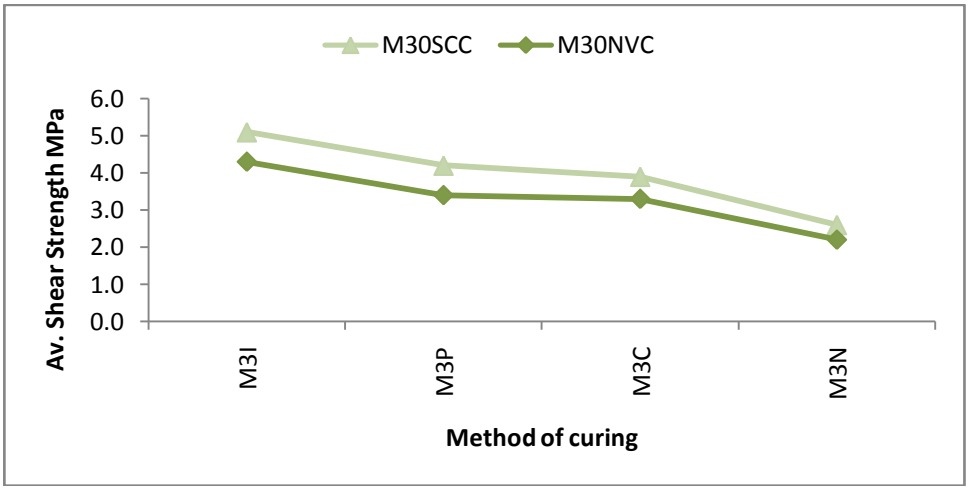

Fig. 3: Comparison of 28 days Shear strength between M30SCC & M30NVC

It can be observed that at 28 days age, maximum shear strength for M30SCC is 5.1 N/mm^2, which is for Immersion method of curing. Polyethylene film curing gives 4.2 N/mm^2 about 83% of immersion curing strength. Curing with external curing compound has strength about 77%. The shear strength without any curing has reduced to 51.3%, which is the lowest. This indicates that the shear strength of SCC is greatly affected by curing.

It can be observed that shear strength of M30SCC is more than M30NVC in all the curing techniques (Fig.3). This is due to the fact that SCC uses robust mix designs which results in improved aggregate interlock that increases concrete shear strength **Missouri-University-of-Science-and-Technology**, **(2012)** *[9]*. The results are in confirmation with the finding by **Sable and Rathi**, **(2012)** *[14]* who noted the shear strength of SCC is higher than NCC because of addition of superplasticizer in SCC to maintain flowability gives proper compaction of concrete which enhance all properties of SCC. However these results are in contrast to the findings of **Lachemi *et al.***, **(2005)** *[8]* who noted that SCC has lower shear strength compared to CC because of the presence of comparatively smaller amount of coarse aggregates in SCC.

VIII. CONCLUSION

- It has been verified, by using the slump flow, U-tube tests and other tests on fresh SCC that self-compacting concrete (SCC) achieved consistency and self-compactability 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 shear strength of SCC.

- Immersion curing gives best result for curing in SCC while use of polyethylene is observed to be the second best amongst the selected methods.
- The strength of SCC reduces a lot without curing.
- Shear strength of M30SCC is more than M30NVC in all the curing techniques.

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