SELF CURING SELF COMPACTING CONCRETE: A SUSTAINABLE AVENUE OF MAKING CONCRETE

PROF. PAMNANI NANAK J*
DR. VERMA A.K**
DR. BHATT DARSHANA R***

*Principal, H.B. Patel Polytechnic, Lunawada, & Research Scholar, SICART, V.V.Nagar, Gujarat, India
**H.O.D, Dept. of Structural Engg., B.V.M. Engineering College, Vallabh Vidyanagar ,Gujarat, India
***Associate Professor, Dept. Str. Engg., B.V.M. Engg. College, Vallabh Vidyanagar, Gujarat, India

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 super plasticizers. 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. Curing techniques and curing duration significantly affects “curing efficiency”. Techniques used in concrete curing are mainly divided into two groups namely, Water adding techniques and Water- retraining techniques. Self curing technique is part of water retaining technique using various methods.

In this paper self curing self compacting concrete (SCSCC) has been studied using Polyethylene Glycols (PEGs). The effect on compressive strength of M30 grade SCSCC is discussed and compared with same grade of SCC with conventional immersion curing and dry curing technique.

It is observed that curing with Polyethylene Glycol – 600 (PEG600) gives very good compressive strength at 28 days about 95% of strength achieved through immersion method for curing; however early age compressive strength of specimens is much lesser than immersion method. At 28 days, curing with Polyethylene Glycol – 1500 (PEG1500) gives compressive strength about 89% of strength achieved through immersion method for curing; and a similar early age compressive strength.

KEYWORDS: Self compacting self curing concrete, Immersion curing, Polyethylene Glycol, compressive 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). SCC has substantial commercial benefits because of ease of placement in complex forms with congested reinforcement (Khayat, K.H., Hu, C. and Monty, H. 1999). Since, self-compactibility is largely affected by the characteristics of materials and the mix proportions, it becomes necessary to evolve a procedure for mix design of SCC. Okamura and Ozawa have proposed a mix proportioning system for SCC (Okamura H., Ozawa K., 1995). In this system, the coarse aggregate and fine aggregate contents are fixed and self-compactibility is to be achieved by adjusting the water /powder ratio and super plasticizer dosage. The coarse aggregate content in concrete is generally fixed at 50 percent of the total solid volume, the fine aggregate content is fixed at 40 percent of the mortar volume and the water /powder ratio is assumed to be 0.9-1.0 by volume depending on the properties of the powder and the super plasticizer dosage. The required water /powder ratio is determined by conducting a number of trials.

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)

Cement Concrete & Aggregates Australia (CCAA) (2006), 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 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.) and combination of such methods.

According to Gowripalan et al. (2001), the mechanism of self curing can be explained as follows: "Continuous evaporation of moisture takes place from an exposed surface due to the difference in chemical potentials (free energy) between the vapour and liquid phases. The polymer added in the mix mainly form hydrogen bonds with water molecules and reduce the chemical potential of the molecules which in turn reduces the vapour pressure. Physical moisture retention also occurs. This reduces the rate of evaporation from the surface.

Self-Curing concrete is the newly emerging trend in the construction industry. Water soluble alcohols are general used as self-curing agents. With conventional ingredients it is possible to design reasonably good fast track concrete mixture using admixture (Karjinni Vilas V., 2012).

Suryawanshi Nagesh carried out an experimental study to investigate the use of water soluble polyvinyl alcohol as a self cutting agent. He concluded that Concrete mixes incorporating self-curing agent has higher water retention and better hydration with time as compared to conventional concrete. Use of 0.48% of polyvinyl alcohol by the weight of cement as a self curing agent provides higher compressive, flexural as well as tensile strength than the strength of conventional mix. With increase in the percentage of polyvinyl alcohol there is a reduction the weight loss of concrete.

The concept of self - curing agents is to reduce the water evaporation from concrete and hence increase the water retention capacity of the concrete compared to conventional concrete. It was found that water soluble alcohols can be used as self curing agents in concrete.

In this paper authors have studied the effect of chemical based self curing (SC) techniques using Polyethylene Glycols (PEGs) on compressive strength of M30 grade self-compacting concrete and compared with conventional immersion curing and dry curing techniques. Thus the techniques of curing used are:

1. Traditional immersion or pond method – acronym M3I
2. Self curing with PEG600–M3A1
3. Self curing with PEG1500 – M3A2 and
4. Dry curing or Air curing – M3N

II. MATERIALS & METHODOLOGY:

2.1 MATERIALS:

The materials used in developing the reference M30 SCC have following 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

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

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 (K_2O)	1.26

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

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

Polyethylene Glycols (PEGs): Polyethylene glycol is a condensation polymer of ethylene oxide and water with the general formula H(OCH2CH2)nOH, where n is the average number of repeating oxyethylene groups typically from 4 to about 180. The abbreviation (PEG) is termed in combination with a numeric suffix which indicates the average molecular weight. One common feature of PEG appears to be the water-soluble nature. PEG's below 700 molecular weight occur as clear to slightly hazy, colorless, slightly hygroscopic liquids with a slight characteristic odour. PEG's between700-900 are semi-solid. PEG's over 1000 molecular weight are creamy white waxy solids, flakes, or free-flowing powders. In present study we have used PEG600 and PEG1500, one being in liquid state and later in flakes. PEG600 is liquid with molecular weight 1000 g/mole, PH-6, Sp. Gravity-1.12, easily soluble in cold-hot water and methanol.

2.2 MIX PROPORTION OF SCC and PREPERATION 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 L., et al. 1999)**. The doses of PEGs were 0.5% of cement by weight based on literature review.

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	1.07%
Polyethylene Glycol	0.5%

2.3 TESTS CONDUCTED ON FRESH SCC:

Tests on fresh concrete were performed to study the workability of SCC. Fig. 1 show the various tests conducted while the test results and their acceptance criteria as per EFNARC are listed in Table 5.

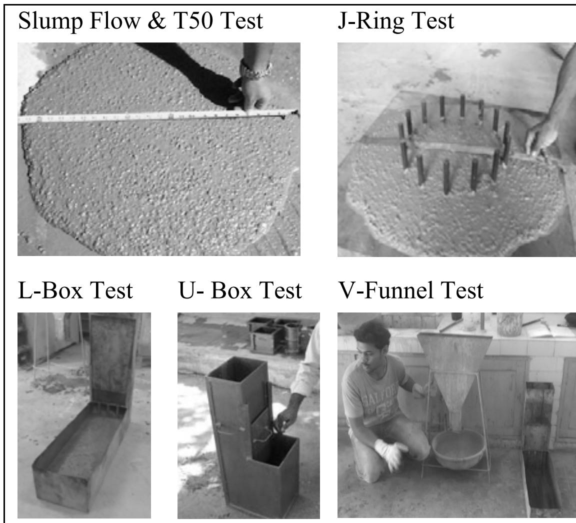

Fig. 1: Tests conducted on fresh SCC

2.4 CURING METHODS USED:

Three specimens were cured for each selected techniques of curing.

Water immersion: The specimens without PEGs are placed in a water shallow pond immediately after de-moulding. They remain in pond continuously till the day of testing.

Polyethylene Glycols: The specimen were cast with PEGs mixed in SCC in fresh state while mixing the ingredients. The specimens after removal of moulds were kept in the ambient temperature. The specimens were kept outside laboratory in semi open covering. No extra treatment or external water was supplied to specimen. The ambient temperature was between 13- 24 ^{o}C with RH 20 – 35%.

The various acronyms used for specimens of tests are: M3I for Pond Immersion, M3A1 for Polyethylene Glycol 600 and M3A2 for Polyethylene Glycol 1500, M3N for Dry curing or Air curing.

2.5 TESTS CONDUCTED ON HARDENED M30 SCC:

In order to find the mechanical properties; Compressive, split tensile, flexural and shear strength required tests were conducted at different ages of concrete for different methods of curing. For each property, three specimens were tested for each method of curing.

Compressive strength: For compressive strength cubes of 150×150×150mm are cast from reference mix of SCC and kept for different types of curing up to 90 days. The specimens are 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)**.

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

III. 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

Sr. No.	Test Method	Unit	Typical range of values as per EFNARC		Results of Tests
			Min.	Max.	Mix M30
1	Slump-flow	mm	600	800	620
2	T50-Slump flow	sec	2	5	3.8
3	L-box	(h_2/h_1)	0.8	1.0	0.83
4	U-box	(h_2-h_1)	0	30	10.2
5	V-funnel	sec	6	12	9.8

3.2 Compressive strength for M30 SCC:

The average compressive strength for various specimens at different ages for M30 SCC is summarized in Table 6.

Table 6: Average Compressive Strength N/mm^2 for M30 SCC

Method/ Acronym	Results	Compressive Strength N/mm^2				
		3 Days	7 Days	28 Days	56 Days	90 Days
Immersion M3I	C1	18.3	30.5	35.3	40.1	44.5
	C2	18.7	32.7	35.8	39.2	43.2
	C3	19.6	31.4	33.6	41.9	46.2

	Average	**18.9**	**31.5**	**34.9**	**40.4**	**44.6**
	Std. Deviation	0.7	1.1	1.2	1.3	1.5
PEG600 M3A1	C1	10.9	24.4	32.7	36.6	40.5
	C2	9.2	24.0	34.9	38.4	41.4
	C3	10.5	25.3	31.8	35.8	39.2
	Average	**10.2**	**24.6**	**33.1**	**36.9**	**40.4**
	Std. Deviation	0.9	0.7	1.6	1.3	1.1
PEG1500 M3A2	C1	16.6	26.6	30.5	36.6	42.3
	C2	17.4	26.2	31.4	37.5	44.0
	C3	17.0	27.0	31.4	41.4	42.7
	Average	**17.0**	**26.6**	**31.1**	**38.5**	**43.0**
	Std. Deviation	0.4	0.4	0.5	2.6	0.9
No Curing M3N	C1	18.3	21.8	25.7	29.2	33.1
	C2	19.2	23.1	25.3	27.9	30.5
	C3	17.9	22.2	24.9	28.3	31.8
	Average	18.5	22.4	25.3	28.5	31.8
	Std. Deviation	0.7	0.7	0.4	0.7	1.3

It is widely accepted that strength at 28 days is considered as governing strength for concrete mix design. It is observed that for M30SCC, immersion method for curing gives maximum compressive strength 34.9 N/mm^2, at 28 days; however 90 days strength is 44.6 N/mm^2, which is 27.9% more than 28 days strength. The good compressive strength can be attributed to proper hydration of cement and reduction in voids due to presence of pozzlonic material like fly ash. For the specimen cured with PEG600, the 28 days compressive strength is 33.1 N/mm^2, about 95% of immersion strength. While 90 days compressive strength is 40.4 N/mm^2, about 116% of 28 days immersion strength. This indicates that though 28 days strength is lower, the design strength can be achieved at later age. High compressive strength of specimens with PEG600 may be attributed to the retention of moisture thereby better hydration process of cement.

For the specimen cured with PEG1500, the 28 days compressive strength is 31.1 N/mm^2, about 89% of immersion strength. While 90 days compressive strength is 43.1 N/mm^2, about 123% of 28 days immersion strength. This indicates that though 28 days strength is lower, the design strength can be achieved at later age. The increase in strength must be due to proper hydration of cement through the water retained by the self curing compound. It can also be observed that PEG600 gives lesser early age strength than PEG1500. This is due to the fact that PEG1500 is more easily soluble in water and releases the retained water at constant pace than PEG600.

The lowest strength is for dry curing 25.3 N/mm^2. The lower strength is due to unavailability of sufficient water for proper hydration of cement. The results are in confirmation of the results of the study by Md. Safiuddin et al. (2007).

It can be observed from results of dry curing that as in the case of conventional concrete, in SCC also curing plays an important role for developing the required strength through the process of hydration. 28 days compressive strength without curing is 25.3 N/mm2 which is 72.5% of immersion strength. However 90 days strength is 91.3% which indicates that with prolonged curing SCC can achieve sufficient strength without curing also.

3.3 Relation between Compressive strength and Age of selected curing technique for M30SCC:

The compressive strength was correlated with age of curing for the different methods of curing by regression analysis using Microsoft Excel software. Fig. 2, 3, 4 & 5 shows correlation between compressive strength and age of curing for immersion and other curing techniques for M30SCC.

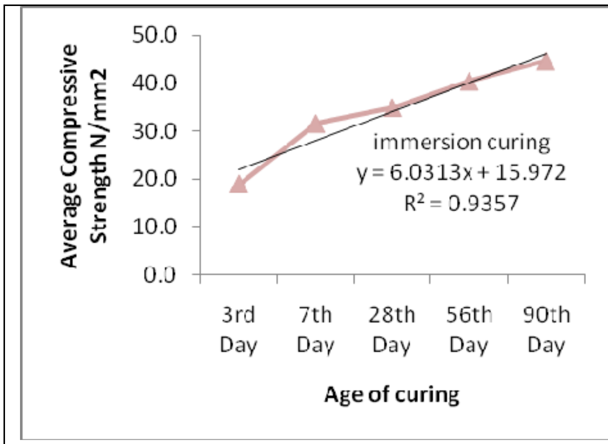

Fig. 2: Relation between compressive strength and Age of curing for water immersion curing for M30SCC

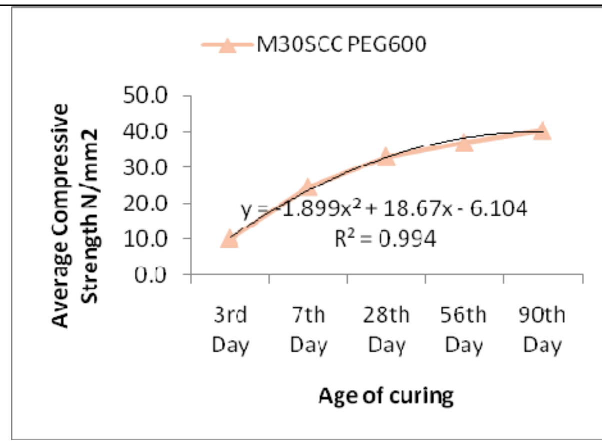

Fig. 3: Relation between compressive strength and Age of curing with PEG600 for M30SCC

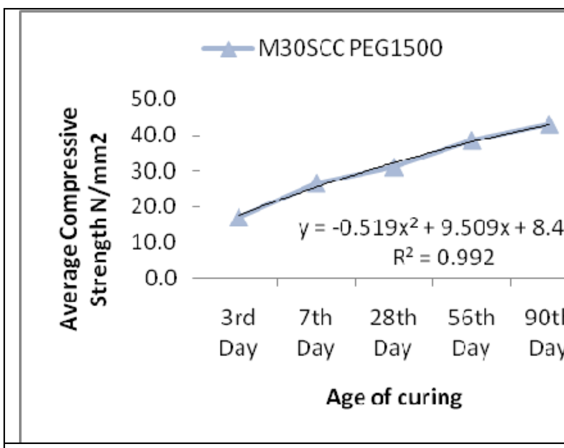

Fig. 4: Relation between compressive strength and Age of curing for PEG1500 for M30SCC

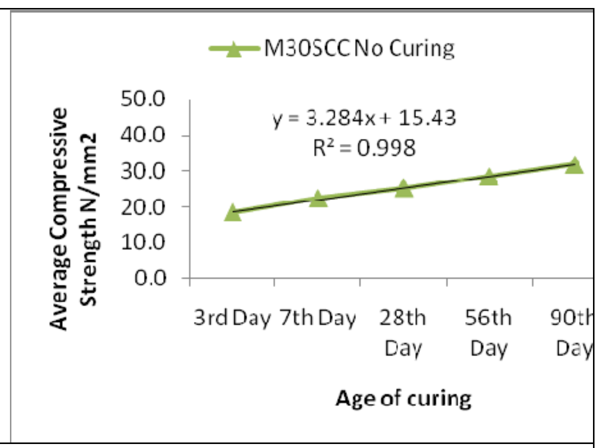

Fig. 5: Relation between compressive strength and Age of curing for Dry curing of M30SCC

For immersion curing the best-fit line exhibited a linear relationship between the compressive strength ranging from 22.0 to 46.1 N/mm^2. The coefficient of determination for the best-fit line was 0.9357, and the correlation coefficient was 0.967. A similar relationship between the compressive strength and curing of concrete was noticed by other researchers (Neville 1996, Al-Feel J. R. & Al-Saffar N. S. 2008; Jagannadha kumar M.V. et al. 2012).

For curing with PEG600 the best-fit line exhibited a polynomial relationship between the compressive strength ranging from 10.68 to 39.80 N/mm^2. The coefficient of determination for the best-fit line was 0.9945, and the correlation coefficient was 0.9972. Refer Fig. 3. These values of correlation coefficients show an excellent compatibility between two specified properties. Sathanandham T. et al., 2013 has observed similar results with PEG400.

For curing with PEG1500 the best-fit line exhibited a polynomial relationship between the compressive strength ranging from 17.42 to 43.0 N/mm^2. The coefficient of determination for the best-fit line was 0.9923, and the correlation coefficient was 0.9961. Refer Fig. 4. These values of correlation coefficients show an excellent compatibility between two specified properties.

It can be concluded that for M30SCC, compressive strength increases with age of curing and the rate of increase depends on techniques used for curing of concrete. At 28 days the highest strength achieved through immersion method of curing is 34.9 N/mm^2.

It is observed that curing with Polyethylene Glycol – 600 (PEG600) gives very good compressive strength at 28 days about 95% of strength achieved through immersion method for curing; however early age compressive strength of specimens is much less than immersion method. At 28 days, curing with Polyethylene Glycol – 1500 (PEG1500) gives compressive strength about 89% of strength achieved through immersion method for curing; and a similar early age compressive strength.

For dry curing the results exhibited a linear relationship between the compressive strength ranging from 18.72 to 31.86 N/mm^2. The coefficient of determination for the best-fit line for dry curing was 0.998, and the correlation coefficient was 0.999. These values of correlation coefficients show an excellent compatibility between two specified properties. Refer Fig.5.

In all the techniques prolonged curing adds to compressive strength of concrete.

Correlation between Compressive strength with immersion method and other curing technique for M30SCC:

The compressive strength achieved with immersion method was correlated with compressive strength results with other selected methods of curing by regression analysis using Microsoft Excel software. Fig. 6 shows the above mentioned correlation.

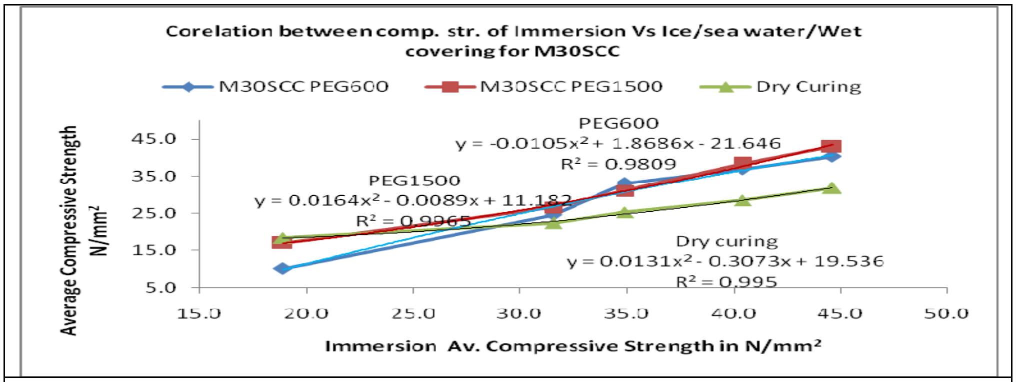

Fig. 6: Correlation between compressive strength of immersion, PEGs and Dry curing for M30SCC

Fig. 6 exhibits the correlation between compressive strength of immersion curing and selected self curing techniques for M30SCC. The correlation equations for best fit line, the coefficient of determination and the correlation coefficient is displayed on the graph. These values of correlation coefficients show a good compatibility between two specified properties.

IV. 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 compressive strength of SCC.
- Self curing offers a compressive strength significantly greater than uncured or Dry cured SCC.
- Immersion curing gives best result for curing in SCC.
- The experimental study shows that the use of water soluble Polyethelene Glycols is possible as a self curing agent.
- It can concluded that self compacting concrete mixes incorporating self-curing agent has good water retention and hydration quality.
- Curing with Polyethylene Glycol – 600 (PEG600) has lesser early age compressive strength than immersion method but good compressive strength at 28 days and later.

- Curing with Polyethylene Glycol – 1500 (PEG1500) gives good compressive strength equivalent to strength with immersion curing technique.
- Self curing compounds can be effectively used in the areas with water scarcity. Sustainability of water can be achieved by using suitable chemical compounds for curing of SCC.

REFERENCES

1. Agullo L., et al., "Fluidity of cement pastes with mineral admixtures and superplasticizer – A study based on the Marsh cone test", Materials in Structures 1999, 32 (221) 479- 485.
2. Al-Feel J.R. & Al-Saffar N.S., "Properties of Self Compacting Concrete at Different Curing Condition and their Comparison with properties of Normal Concrete", Al-Rafidain Engineering, 2009, Vol.17, No.3, pp. 30-38.
3. Cement Concrete & Aggregates Australia (CCAA), "Curing of Concrete – A data sheet", 2006.
4. EFNARC (2002) (European Federation of Producers and Applicators of Specialist Products for Structures), Specification and Guidelines for Self-Compacting concrete.
5. Gowripalan N., Marks R. and Sun R., "Early age properties of self cured concrete", Proceedings of Concrete Institute of Australia, Perth 2001,pp 655-662.
6. IS 456-2000, "Plain & Reinforced concrete-Code of Practice", Bureau of Indian Standards, New-Delhi, India, 4th revision, page 27.
7. IS: 516-1959, "Methods of tests for strength of concrete", Bureau of Indian Standards, New-Delhi, India.
8. Jagannadha Kumar M.V., Srikanth M., Dr. Rao K. Jagannadha, "Strength characteristics of self-curing concrete", International Journal Of Research Engineering & Technology (IJRET), 2012, pp. 51-57.
9. Karjinni Vilas V., Bhavikatti Mushtaq Ahmed, " Effect of Non-Chloride Hardening Accelerator and Type of Curing on the Compressive Strength of Pavement Concrete, Produced With Slag Cement", 2012, ZENITH International Journal of Multidisciplinary Research, Vol. 2, Issue 3, ISSN 2231-5780.
10. Khayat, K.H., Hu, C. and Monty, H., "Stability of Self-Consolidating Concrete, Advantages, and Potential Applications", Proceedings of First International RILEM, Symposium on Self-Compacting Concrete, 1999, pp. 143-152.
11. Kumbhar P.D**.**, Rajaramnagar, and Murnal P., "Effect of Humidity and Temperature on Properties of High Performance Concrete", NBM Construction Information, 2011, New Delhi, India.
12. Md. Safiuddin et al., "Effect of Different Curing Methods on the Properties of Microsilica Concrete", Australian Journal of Basic and Applied Sciences, 2007, ISSN 1991-8178, 1(2): pp. 87-95.
13. Neville, A.M., 1996. Properties of Concrete, Fourth and Final Edition. John Wiley and Sons, Inc., New York, USA.
14. Okamura H., Ozawa K., "Mix Design for Self-Compacting Concrete", Concrete Library of Japanese Society of Civil Engineers, June 25, 1995, p. 107-120.
15. Qureshi L. A., Bukhari I. A, M.J. Munir, "Effect of Different Curing Techniques on Compressive Strength of High Strength Self Compacting Concrete", Bahaudin Zakriya University, 2010, Multan Pakistan.
16. Sathanandham T. et al., "Preliminary Studies Of Self Curing Concrete With The Addition Of Polyethylene Glycol", International Journal of Engineering Research & Technology (IJERT), Vol. 2 Issue 11, November – 2013, pp. 313-323
17. Shetty M.S., Text book, "Concrete Technology- Theory & Practice", S. Chand & Company, New Delhi, India, 2005, Chapter 7, Strength of Concrete.
18. Suryawanshi Nagesh Tatoba**, "**Assessment of the properties of Self-Cured Concrete**"**, portal http://www. engineeringcivil.com /assessment-of-the-properties-of-self-cured-concrete.html.