Studies on properties of internal sealing of self-compacting concrete using polyethylene glycol

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Self-curing is done in order to fullfill the water requirements of concrete whereas self-compacting concrete is prepared so that it can be placed in difficult positions and congested reinforcements. This investigation is aimed to utilize the benefits of both self-curing as well as self-compacting. The present investigation involves the use of self-curing agent viz., polyethylene glycol (PEG) of molecular weight 4000 (PEG 4000) for dosages ranging between 0.1 to 1% by weight of cement added to mixing water. Two mixes with different w/c ratio were considered in this study. Workability tests such as slump flow, T50, V-funnel, J-ring, L-box were conducted on the fresh concrete whereas water retention and compressive strength were evaluated to determine the properties of hardened concrete. Comparative studies were carried out for water retention and compressive strength for conventional SCC and self-cured SCC. The compressive strength of self-cured SCC are comparable with traditional cured specimens at lower w/c ratio whereas it does not provide satisfactory results at higher w/c ratio.

INTRODUCTION

Self-curing or internal curing is a technique that can be used for providing additional moisture in concrete for more effective hydration of cement and reduced self-desiccation. The demand for curing water (external or internal) can be much greater than in a conventional ordinary Portland cement concrete, if the mineral admixtures react completely in a blended cement system [1]. Autogenous deformation and early-age cracking may occur when this water is not readily available, due to de-percolation of the capillary porosity. Under internal curing condition the strength achieved could be more when compared to saturated curing condition [2]. Concrete which is capable of flowing in to the formwork without segregation, by its own weight without any application of vibration is known as self-compacting concrete. Standard design for self-compacting concrete is not available, hence each self-compacting concrete has to be designed for the particular structure to be constructed. The performance requirements must be defined taking into account the structural conditions such as shape, dimensions, reinforcement density and construction conditions to establish an appropriate mixture proportion for a self-compacting concrete [3]. Self-compacting concrete is highly fluid in nature that makes it suitable for placing in difficult conditions and in sections with congested reinforcement.

Optimum curing of concrete without the need of applying external curing methods was achieved by the chemical ability [4]. Use of chemical reduce evaporation from solution and improve water retention in OPC. Initial surface absorption and compressive strength tests were made to determine surface permeability and strength development. Addition of chemicals to the mix improves water retention in cement paste and also enhances hydration process [5]. On self-cured concrete specimens several durability tests such as initial surface absorption test, the potential difference (PD) chloride diffusion test, depth of carbonation, half-cell corrosion potential test and measurement of freeze / thaw resistance were performed [6]. Mixes used in the investigation: OPC only, OPC with 40% GGBS replacement, OPC with 30% PFA replacement, dosage of self-curing chemical was 0.005 M and 0.1 M. Self-cured concrete specimens with respect to surface quality, chloride diffusion, carbonation and freeze & thaw resistance, provides improved performance when compared to air cured specimens. A combination of wax preferably paraffin wax and glycol preferably polyethylene glycol(PEG),when added to concrete enables internal curing which in many respects is equal to or superior to traditional forms of curing concrete. The internal curing compound used has 10%PEG, 57% paraffin wax, 33% water [7]. The test results were compared with two other curing compounds, membrane curing and no curing condition. The curing compounds used were Compound 1- Water, wax emulsion and high MW polyethylene oxide, Compound 2- Water, paraffin wax, PEG (current invention), Compound 3- Water based polyether's. Based on the comparison it has been found that internal curing composition 2 exhibits moisture retention characteristics similar to those of the solvent borne resin membrane and performs better than 3 day water curing. Internal curing composition 1 and 2 give compressive strength similar to those of the solvent borne resin membrane, however composition 3 shows a significantly lower strength at higher dosages. Two grades of concrete, PEG of two molecular weights, different dosages of PEG and two curing conditions were analysed [8]. PEG of two molecular weights i.e. PEG 600 and PEG 6000 were used at the dosage of 0.1%, 1%, 3% by weight of cement to determine the self-curing properties. It has been observed that polyethylene glycol of low molecular weight was more efficient as a self-curing agent when compared to PEG of high molecular weight; low dosage of polyethylene glycol was more efficient for achieving self-curing concrete when compared to higher dosages. The developed concrete was suitable for rapid placement and had a very good permeability. The influence of mineral admixtures, like fly ash and blast furnace slag, on the flowing ability and segregation resistance of self-compacting concrete was tested with respect to workability tests. The flowing ability of the concrete improved remarkably, when Portland cement was partially replaced with fly ash and blast furnace slag. A new mix design method for self-compacting concrete was proposed in which its observed that lower dosage of PEG was more efficient than higher dosage [9]. Lower molecular weight PEG was more effective than higher molecular weight PEG. SCC with silica fume performs satisfactory than SCC with fly Ash from strength point of view [10]. Area with shortage of water, to improve strength and sustainability of self-compacted concrete, curing compounds can be effectively used, [11].

From the literature review carried out on different materials i.e. Light weight aggregate (LWA) and Super absorbent polymers (SAP) it can be concluded that use of these potential materials tend to decrease the mechanical properties of concrete. Thus in the current program use of shrinkage reducing admixture i.e. PEG has been made in order to get the maximum efficiency in relation to mechanical properties. Also from the earlier investigation carried out in the institution the dosage has been reduced to 0 to 1% to make the concrete more efficient.

Due to air curing compressive strength reduced for all groups. Concretes with mineral admixture have higher relative strengths when compared with concretes without admixtures when cured at steam curing, [12].

1.1. Objective

The main objective of the investigation focused on the use of water soluble polymeric glycol, selected from a group consisting of polyethylene glycol (PEG) of average molecular weight (M.W) from 200 to 10000 as self-curing agent and to accomplish the optimum dosage for different curing conditions under arid atmospheric conditions. Compressive strength and water retention by varying the percentage of PEG from 0% to 1% by weight of cement for self-compacting concrete was studied and comparison was made with conventional SCC. Concrete weight loss with time was evaluated to determine the water retention capacity.

2.0. MATERIALS USED

2.1. Cement

Ordinary Portland cement was used confirming to IS 12269:1987 [16]. The specific gravity of cement was 3.14; initial setting time and final setting time were 40 minutes and 560 minutes.

2.2. Fine aggregate

The fine aggregate conforming to zone II according to IS 383:1970 [14] was used. The fine aggregate used was obtained from a nearby river course. The fine aggregate used was prepared from two types of sand: Sand-I conforming to Zone-I and Sand-II conforming to Zone-III. 50% of Sand-I and 50% of Sand-II was used to obtain

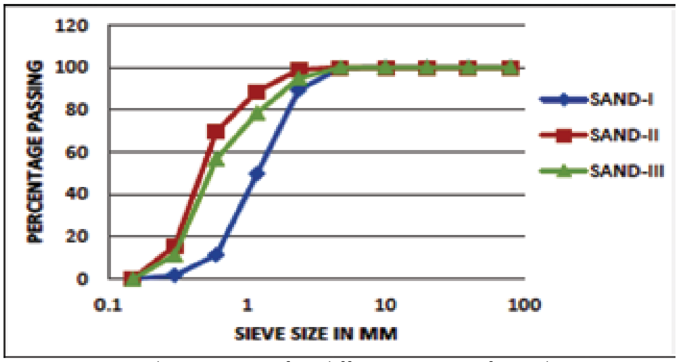

Figure 1. Gradation curve for different types of sand

Sand-III conforming to Zone-II. Figure 1 shows the gradation curve obtained for three types of sand.

Fineness modulus of fine aggregate was 2.59, Bulk density of fine aggregate was 1.45 gm / cc, and specific gravity of fine aggregate was 2.65.

2.3. Coarse aggregate

Coarse aggregate of 20mm size was used confirming to IS 383 [14] is used in this investigation. Fineness modulus of coarse aggregate was 7.3, bulk density of coarse aggregate was 1.5 gm / cc, and specific gravity was 2.80.

2.4. Polyethylene Glycol-4000

Polyethylene glycol is a condensation polymer of ethylene oxide and water. The general formula of polyethylene glycol is H(OCH2CH2)nOH, where n is the average number of repeating oxy-ethylene groups typically from 4 to about 180. A combination with a numeric suffix that indicates the average molecular weight is the abbreviation of PEG. Before adding of water in concrete the chemicals were mixed with water thoroughly. The molecular weight of polyethylene glycol-4000 was 3600 – 4400 and the physical form was of white flakes.

Table 1. Specification of Poly-carboxylate Ether

No.	Specification	Value
1	Form	Liquid
2	Colour	Transparent to slight turbid
3	Relative Density	1.1
4	Solid content (% by weight)	33
5	pH value	7
6	Ash content	0.018
7	Free chloride content (% by weight)	Nil
8	Water Reduction	40%
9	Compatibility	Compatible with all types of cement, fly ash, GGBS etc.,

Table 2. Materials required for Mix A

No.	Material	Quantity (kg/m^3)	Mix Proportion
1	Cement	500	1
2	Fine aggregate	800	1.6
3	Coarse aggregate	775	1.55
4	Fly ash	110	-
5	Micro-silica	40	-
6	Super plasticizer	6	-
7	Water	190	0.38
8	Density	2421	
9	PEG-4000	0%, 0.1%, 0.5%,1% by weight of cement	

2.5. Fly Ash

Specific gravity of fly ash used in this experiment was 2.17.

2.6. Silica Fume

Specific gravity of silica fume was found to be 2.25.

2.7. Poly-carboxylate Ether

To improve the workability high range water reducing admixture commonly called as super plasticizers was used. The specification of poly-carboxylate was shown in Table 1.

2.8. Mix design by Nan-Su Method

For self-compacting concrete mix design procedure by Nan-Su method was adopted. Aggregate binding the paste at hardened state provides strength to SCC and aggregate binding the paste at fresh state gives workability of SCC. Hence, the contents of coarse and fine aggregates, binders, mixing water and SP will be the main factors influencing the properties of SCC. Tables 2 and Table 3 shows the mix calculations for Mix A and Mix C.

Table 3. Materials required for Mix C

No.	Material	Quantity (kg/m^3)	Mix proportion
1	Cement	360	1
2	Fine aggregate	860	2.39
3	Coarse aggregate	788	2.19
4	Fly ash	250	-
6	Super plasticizer	3.6	-
7	Water	198	0.55
8	Density	2449.60	
9	PEG-4000	0%, 0.1%, 0.5%,1% by weight of cement	

Figure 2. Slump flow test

This study is mainly focussed to investigate the strength of self-curing self-compacting concrete by adding poly-ethylene glycol PEG4000 @ 0.1%, 0.5% and 1% by weight of cement to the concrete. Workability tests such as slump flow test, J ring test, U box test, L box and V-Funnel test were conducted for all mixes to know the fresh property of concrete. Compressive strength test was conducted at 7 and 28 days of curing period.

To determine the water retention capacity the cubes were weighed for 3, 7,14,21,28 and 56 days from the date of de-moulding. In this investigation the maximum dosage of self-curing agent was restricted to 1% and minimum dosage to 0.1%. Two different mixes with 28 days cube compressive strengths of concrete were aimed that is 70 MPa and 50 MPa.

2.9. Test for fresh properties of concrete

2.9.1. Workability Test

2.9.1.1 Slump flow Test

Concrete was filled in the slump cone without consolidation. Then the cone was lifted and the spread of the concrete was measured. Range of the concrete spread was between 550 to 850 mm. The viscosity of the SCC mixture can be measured by time taken for the concrete to reach a spread diameter of 500 mm once the moment when slump cone is lifted which is known as T50 measurement. Figure 2 shows the slump flow test.

2.9.1.2. J ring test

The filling ability and the passing ability of SCC were determined by using J-ring test. Flow spread, flow time and blocking step are the three parameters that can be measured by the J-ring test. The J-ring test was shown in Figure 3.

Figure 3. J-ring test

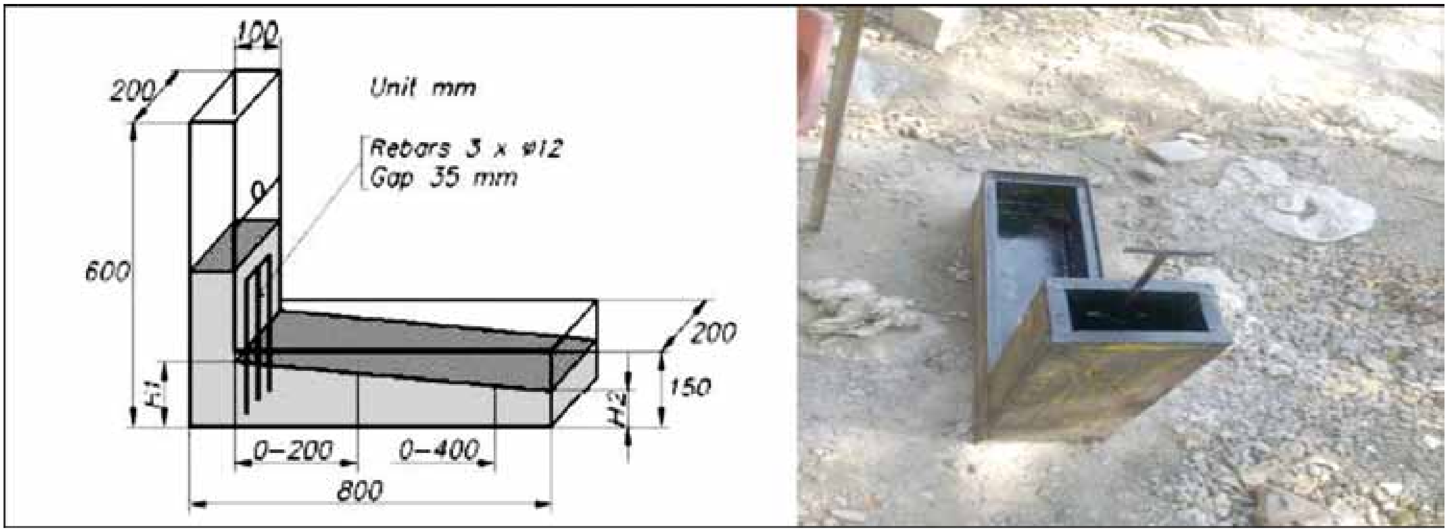

Figure 4. L-box apparatus

2.9.1.3. U box test

The confined flowing ability and the capacity of SCC to flow within confined space can be determined using the U Shape Box. The degree of compatibility can be indicated by the height in which the concrete reaches after flowing through an obstacle.

2.9.1.4. L box Test

L-box tests measures the passing or blocking behaviour of SCC. Figure 4 shows the L-box apparatus.

2.9.1.5. V Funnel test

The time period required for SCC to pass a narrow opening that gives an indication of the filling ability of SCC can be measured using the V-funnel apparatus. The flow time of the V-funnel test is to some degree related to the plastic viscosity. Figure 5 shows the V-funnel test apparatus.

Figure 5. V funnel test

2.10. Test for hardened properties of concrete

2.10.1 Water Retention Test

The ability of the substance to retain water is known as water retention. To perform the water retention test, the cubes were weighed at 3, 7, 14, 21, 28 and 56 days from the date of demoulding. Weight loss for the specimens in indoor curing, and weight gain for the conventional curing were noted and their behaviour was plotted in graph against number of days of curing.

2.10.2 Compressive Strength of Concrete

The compressive strength test was conducted after 7 days and 28 days curing period. Standard cast iron moulds of dimensions 150x150x150mm were used to cast the specimen IS:516-1956 [15]. The capacity of the compressive strength testing machine used was 3000 kN and 1810 kN. Figure 6 shows the concrete cubes under self curing.

Figure 6. Concrete Specimens under self-curing

Table 4. Slump Flow Test Values

Dosage of PEG-4000	Slump flow values (mm)	
	AH	CH
0%	700	670
0.1%	650	590
0.5%	635	640
1%	665	560

3.0. RESULTS AND DISCUSSION

The results have been formulated in the form of tables and graphs for clear interpretation.

3.1. Workability tests

3.1.1 Slump flow test

The test results for slump flow test carried out for both the mixes: Mix A and Mix C. Table 4 shows the slump flow test vales. For both the mixes the slump value obtained confirms the recommended values specified by EFNARC 2005 [13].

3.1.2 T50 Test

The T50 test was carried out for both the mixes: Mix A and Mix C and were tabulated in Table 5.

As per recommendation of EFNARC the T50 test values were within the range.

Table 5. T50 Test Values

Dosage of PEG-4000	T50 (sec) (T50 values 2-5 seconds as per EFNARC)	
	AH	CH
0%	3.69	2.4
0.1%	3.72	2.32
0.5%	2.5	2.5
1%	3.4	3.4

Table 6. J-ring Test Values

Dosage of PEG-4000	J-ring values (mm) (J-ring values 0-10 mm as per EFNARC)	
	AH	CH
0%	5	8
0.1%	10	7
0.5%	9	7
1%	9	7

Table 7. L-box Test Values

Dosage of PEG-4000	L-box values (mm) (L-box values 0.8-1.0 as per EFNARC)	
	AH	CH
0%	0.94	0.87
0.1%	0.82	0.875
0.5%	0.835	0.88
1%	0.9	0.89

3.1.3. J-Ring test

The test results for J-ring test carried out for both the mixes: Mix A and Mix C and were shown in Table 6. The J-ring values are within the prescribed limit specified by EFNARC.

3.1.4. L-Box test

The test results for L-box test carried out for both the mixes : Mix A and Mix C. Table 7 shows L-box test values. Based on the test values its can be stated as both the mixes showing good passing ability.

3.1.5. V-Funnel test

The test results for V-Funnel test carried out for both the mixes: Mix A and Mix C and was tabulated in Table 8.

3.1.6. V-Funnel (5 min) test

The test results for V-Funnel (5 min) test carried out for both the mixes i.e. Mix A and Mix C was tabulated in Table 9.

Table 8. V-Funnel Test Values

Dosage of PEG-4000	V-funnel values (sec) (V-funnel values 6-12 seconds as per EFNARC)	
	AH	CH
0%	11.5	9.77
0.1%	9.7	6
0.5%	13.33	6.52
1%	11	8.53

Table 9. V-Funnel (5 min) Test Values

Dosage of PEG-4000	V-funnel values (5 min) values (sec)	
	AH	CH
0%	17	10.64
0.1%	11	7.76
0.5%	16.3	8.5
1%	14	9.8

Table 10. Average Weight loss of cubes for Mix A at different ages in gms

Dosage of PEG-4000	3 days	7 days	14 days	21 days	28 days	56 days
AI%	54	68	80	94	109	150
AH-0.1%	23	30	37	43	46	68
AH-0.5%	47	59	65	72	79	122
AH-1%	48	57	66	74	80	126

Table 11. Average Weight loss of cubes for Mix C at different ages in gms

Dosage of PEG-4000	3 days	7 days	14 days	21 days	28 days	56 days
CI%	113.66	138.77	152	163	183	211
CH-0.1%	149.5	172.4	201.5	211	216.8	222
CH-0.5%	135	156.8	171.8	180.42	186.71	200
CH-1%	114.6	135.7	161.85	169.57	177	188

3.1.7. Water Retention Test

3.1.7.1 Water Retention Test Results for Mix A

SCC with high molecular weight PEG-4000 subjected to indoor curing was studied by weighing the samples at regular intervals of 3, 7, 14, 21, 28 and 56 days, with digital weighing machine. Weight loss is evaluated as the difference between the weight of the cube when demoulded and the weight of the cube at the designated day. The average weight loss for different dosage of PEG-4000 at different ages of curing for Mix A is shown in Table 10.

SCC with 0% PEG showed maximum weight loss at all the ages compared to other dosages such as 0.1%, 0.5%, and 1%. This attributes that addition of PEG-4000 lowers the weight loss. SCC with 0.1% PEG dosage shows minimum weight loss as compared to other dosages thus showing maximum water retention. Increasing the dosage of PEG increases the weight loss thus 1% PEG having the maximum weight loss. Figure 7 shows the average weight loss of cubes for Mix A.

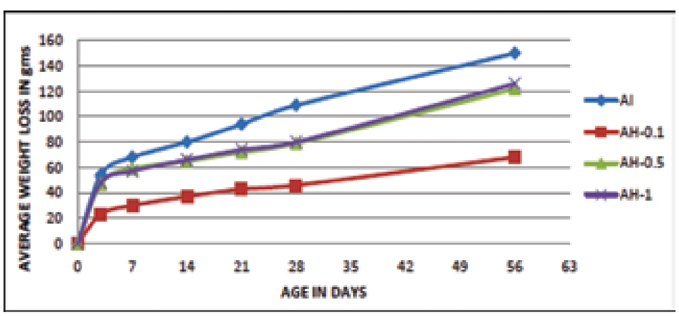

Figure 7. Average weight loss of cubes for Mix A

3.1.7.2. Water Retention Test Results for Mix C

SCC with high molecular weight PEG-4000 subjected to indoor curing was studied by weighing the samples at regular intervals of 3, 7, 14, 21, 28 and 56 days, with digital weighing machine. Weight loss is evaluated as the difference between the weight of the cube when demoulded and the weight of the cube at the designated day. The average weight loss for different dosage of PEG-4000 at different ages of curing for Mix C was shown in Table 11.

SCC with 0.1% PEG showed maximum weight loss at all the ages compared to other dosages i.e. 0%, 0.5%, 1%. This attributes that addition of PEG-4000 increases the weight loss. SCC with 1% PEG dosage shows minimum weight loss as compared to other dosages thus showing maximum water retention. Figure 8 shows the average weight loss of cubes for Mix Cat different ages. Also among PEG dosages 0.1% dosage shows maximum weight loss. Among PEG dosages increasing the dosage lowers the weight loss. SCC without self-curing agent showed less weight loss up to 21 days but after weight loss increases and the least weight loss is shown by CH-1%.

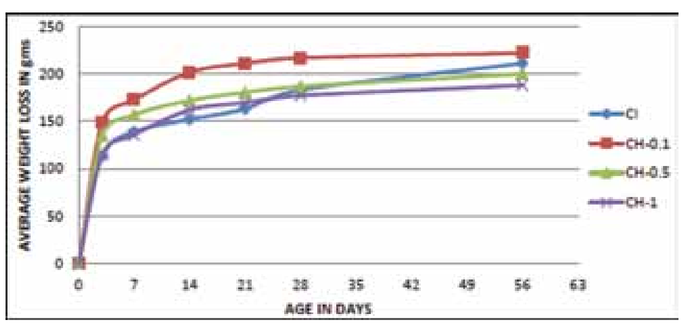

Figure 8. Average Weight loss of cubes for Mix C at different ages in gms

Table 12. Relative Weight Loss for Mix A

Dosage of PEG-4000	7 days weight loss (C1)	28 days weight loss (C2)	56 days weight loss (C3)	7 days relative weight loss (C4 =C1/A1)	28 days relative weight loss (C5 = C2/A1)	56 days relative weight loss (C6 = C3/A1)
AI	68	109	150	1	1	1
AH-0.1	30	46	68	0.44	0.42	0.45
AH-0.5	59	79	122	0.86	0.72	0.81
AH-1	57	80	126	083	0.73	0.84

Table 13. Relative Weight Loss for Mix C

Dosage of PEG-4000	7 days weight loss (C1)	28 days weight loss (C2)	56 days weight loss (C3)	7 das relative weight loss (C4 =C1/A1)	28 days relative weight loss (C5 = C2/A1)	56 days relative weight loss (C6 = C3/A1)
CI	138.77	183	211	1	1	1
CH-0.1	172.4	216.8	222	1.24	1.18	1.05
CH-0.5	156.8	186.71	200	1.12	1.02	0.94
CH-1	135.7	177	188	0.97	0.96	0.89

3.1.8. Relative Weight Loss for Mix A with respect to Indoor Curing

The relative weight loss is found for Mix A with respect to Indoor Curing. The relative weight loss is evaluated at the age of 7, 28, 56 days by dividing the weight losses of specimens by AI. Table 12 shows the test results of relative weight loss for Mix A. The results were plotted in Figure 9.

At 7 days, all the dosages have relative weight loss less with respect to indoor cured specimen with AH-0.1 showing the least relative weight loss. Figure 9 shows the relative weight loss for Mix A at a curing period of 7 days and 28 days. At 28 days similar results were obtained as of 7 days relative weight loss and the weight loss in terms of increasing order AH-0.1<AH-0.5<AH-1. Thus at 28 days also AH-0.1 shows the minimum relative weight loss. Similar results were obtained for 56 days curing period also. Thus at all the ages AH-0.1 shows the minimum weight loss and all the dosages of PEG-4000 having less relative weight loss.

3.1.9. Relative Weight Loss for Mix C with respect to Indoor Curing

The relative weight loss was found for Mix C with respect to Indoor Curing. The relative weight loss was evaluated at the age of 7, 28, 56 days by dividing the weight losses of specimens by CI. The results are shown in Table 13. The results was plotted and shown in Figures 10

At 7 days, all the dosages are having relative weight loss higher with respect to indoor cured specimen except CH-1

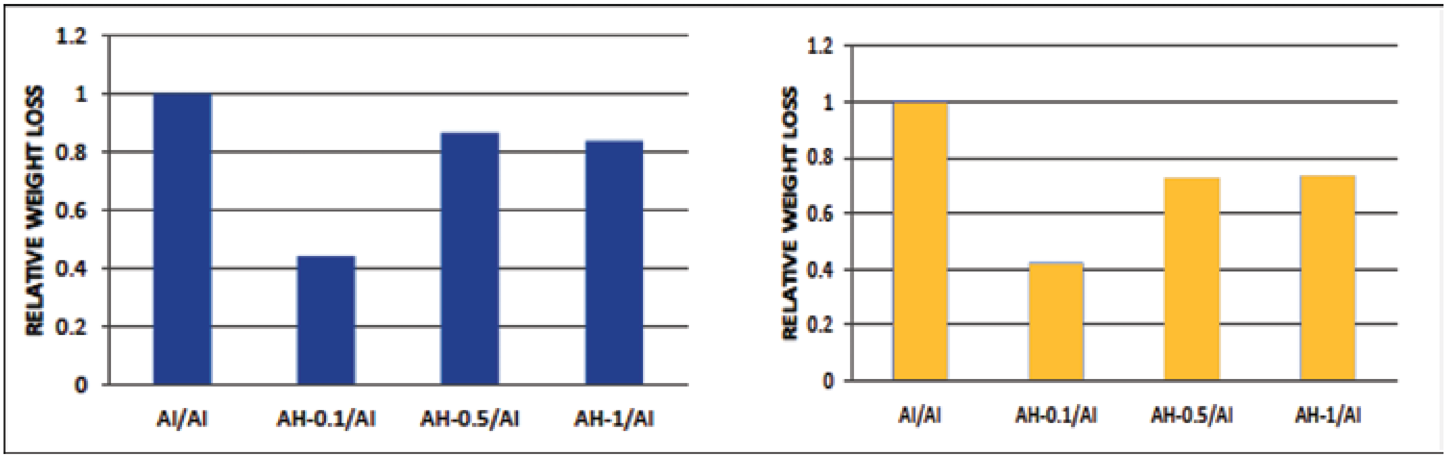

Figure 9. (Left) Relative weight loss for Mix A (7 days). (Right) Relative weight loss for Mix A (28 days) [wrt indoor curing]

showing the least relative weight loss. Water retention for CH-0.1, CH-0.5 is less than indoor curing. At 28 days, all the dosages have higher relative weight loss except CH-1. Among PEG dosages CH-1 shows minimum relative weight loss.

At 56 days, CH-0.5 and CH-1 show relative weight loss less than CI thus showing some water retention without curing. whereas, CH-0.1 shows value higher than C1 thus not showing desired water retention.

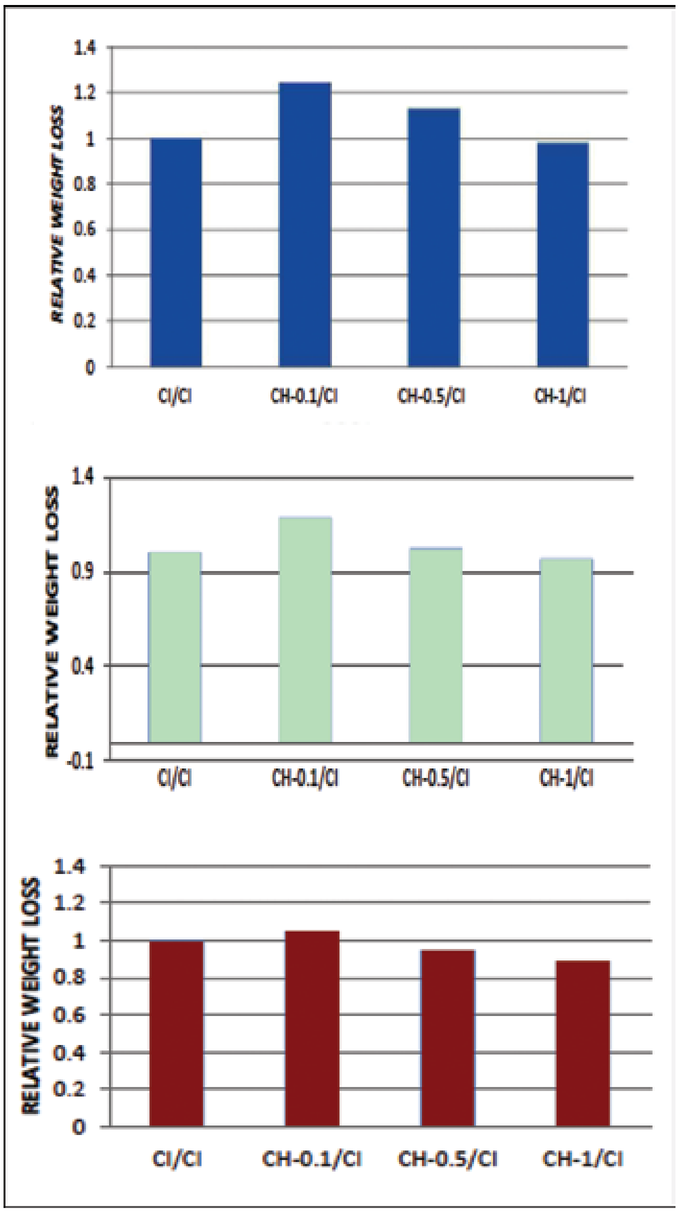

Figure 10. (Top) Relative weight loss for Mix C (7 days). (Centre) Relative weight loss for Mix C (28 days). (Bottom) Relative Weight Loss for Mix C at 56 days [wrt indoor curing]

Table 14. Compressive strength for Mix A at 7 and 28 days

Dosage of PEG-4000	7 days compressive strength (Mpa)	28 days compressive strength (Mpa)
AI	49.63	68.86
AW	52.84	75.73
AH-0.1	55.39	73.87
AH-0.5	50.22	66.12
AH-1	56.83	71.81

3.1. 10. Compressive Strength Test

3.1.10.1. Compressive Strength Results for Mix A

The compressive strength test was conducted at 7 and 28 days of curing period for conventional concrete with wet and indoor curing and also for concrete with different dosages (0.1%, 0.5% and 1%) of self-curing agent. The compressive strength values are listed in Table 14.

The plot for compressive strength of Mix A with varying dosage of PEG-4000 at the age of 7 days and 28 days was shown in Figure 11. It has been observed that at 7 days, AI showed minimum compressive strength value among all other specimens. Compressive strength of AH-1 was found maximum among all the specimens hence it showed better results than wet curing also. At 28 days, AH-0.5 showed minimum compressive strength value among all the dosages. AW showed highest values among all the specimens at 28 days. Among PEG dosages AH-0.1 showed better results and were on par with wet curing. Thus AW shows high later strength and low early strength as compared to AH-1, whereas AH-1 shows high early strength and low later strength as compared to AW.

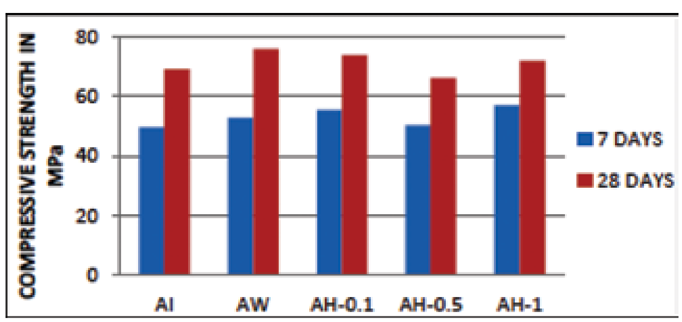

Figure 11. Compressive strength for Mix A at 7 days and 28 days

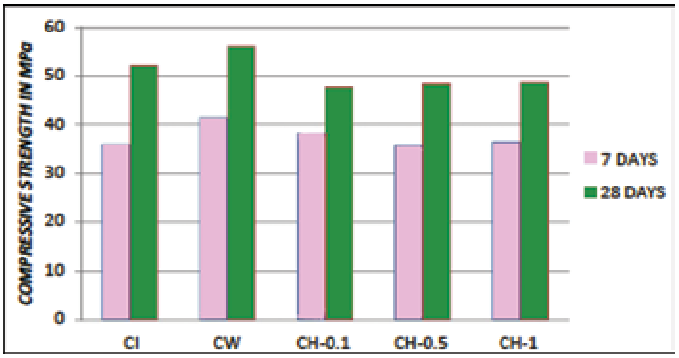

Figure 12. Compressive strength for Mix C at 7 and 28 days

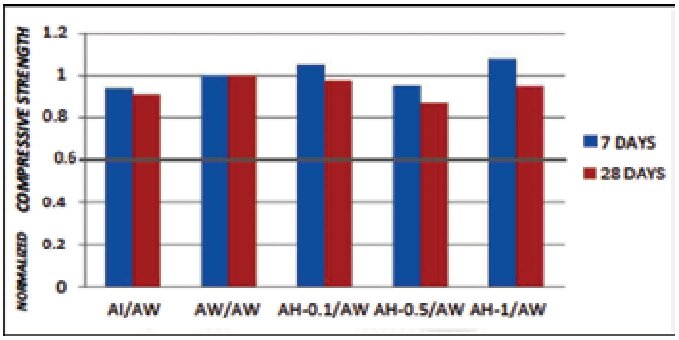

Figure 13. Normalized Compressive Strength for Mix A at 7 days and 28 days (wet curing)

3.1.10.2. Compressive Strength results for Mix C

The compressive strength test was conducted at 7 and 28 days of age for conventional concrete with wet and indoor curing and also for concrete with different dosages (0.1%, 0.5% and 1%) of self-curing agent. The compressive strength value was presented in Table 15.

The plot for compressive strength of Mix C with varying dosage of PEG-4000 at the age of 7 and 28 days was shown in Figure 12. At 7 days, CH-0.5 showed minimum compressive strength value among all other specimens. Compressive strength of CW was found to be maximum among all the specimens. Among specimens other than CW, CH-0.1 showed better strength at 7 days. At 28 days, CH-0.1 showed minimum compressive strength value among all the dosages. CW showed highest values among all the specimens at 28 days. Among PEG dosages CH-1 showed better results. Thus CW shows both high early strength and high later strength also. Also CI showed higher strength at 28 days than all PEG dosages. Thus use of PEG does not tend to increase the strength aspect in case of lower strength SCC.

Table 15. Compressive strength for Mix C at 7 and 28 days

Dosage of PEG-4000	7 days compressive strength (Mpa)	28 days compressive strength (Mpa)
CI	36.03	52.19
CW	41.46	56.11
CH-0.1	38.16	47.67
CH-0.5	35.70	48.40
CH-1	36.49	48.59

Normalized compressive strength values for Mix A with respect to wet curing

The normalized compressive strength value for Mix A was evaluated at the age of 7 days and 28 days with respect to wet curing specimens. The normalized value was evaluated by dividing the compressive strengths by AW at 7 days and 28 days. Table 16 shows the normalized values obtained for Mix A in wet curing. Figure 13 shows the compressive strength of Mix C with varying dosage of PEG-4000 at the age of 7 days and 28 days.

Based on the test results it can be observed that at 7 days, AH-1 was having the maximum normalized compressive strength for wet curing followed by AH-0.1. Indoor curing shows the least normalized strength. Also AH-0.5 shows lesser value. At 28 days, all the specimens show lesser normalized strength with respect to AW. However

Table 16. Normalized compressive strength values for Mix A (Wet Curing)

Dosage of PEG-4000	7 days compressive strength (Mpa) (C1)	28 days compressive strength (Mpa) (C2)	7 days normalised strength (C3 =C1/AW)	28 days normalised strength (C4 = C2/AW)	Relative strength (C3 =C1/C2)
AI	49.63	68.86	0.939	0.90	0.72
AW	52.84	75.73	1	1	0.69
AH-0.1	55.39	73.86	1.04	0.97	0.74
AH-0.5	50.22	66.11	0.95	0.87	0.75
AH-1	56.83	71.80	1.07	0.94	0.79

Table 17. Normalized compressive strength values for Mix C (wet curing)

Dosage of PEG-4000	7 days compressive strength (Mpa) (C1)	28 days compressive strength (Mpa) (C2)	7 days normalised strength (C3 =C1/AW)	28 days normalised strength (C4 = C2 /AW)	Relative strength (C3=C1/C2)
CI	36.03	52.18	0.86	0.93	0.69
CW	41.46	56.11	1	1	0.73
CH-0.1	38.16	47.67	0.92	0.84	0.80
CH-0.5	35.70	48.39	0.86	0.86	0.73
CH-1	36.49	48.59	0.88	0.86	0.75

AH-0.1 shows normalized strength near to 1. AH-0.5 shows normalized strength less than indoor curing.

Normalized Compressive Strength Values for Mix C with respect to Wet Curing

The normalized compressive strength values for Mix C are evaluated at the age of 7 and 28 days with respect to wet curing specimens. The normalized values were evaluated by dividing the compressive strengths by CW at 7 and 28 days. The normalized values obtained were shown in Table 17.

Normalized compressive strength for Mix C at 7 days and 28 days (wet curing) was shown in Figure 14. At 7 days, all the specimens were having less normalized compressive strength. Among PEG dosages CH-0.1 performance was better than CH-1.CH-0.5 shows least normalized compressive strength. CI also shows higher value than CH-0.5. At 28 days, CW is having the maximum normalized compressive strength in wet curing followed by CI. CH-0.1, CH-0.5, CH-1 does not give normalized strength on par with CI. Thus their addition may be insignificant.

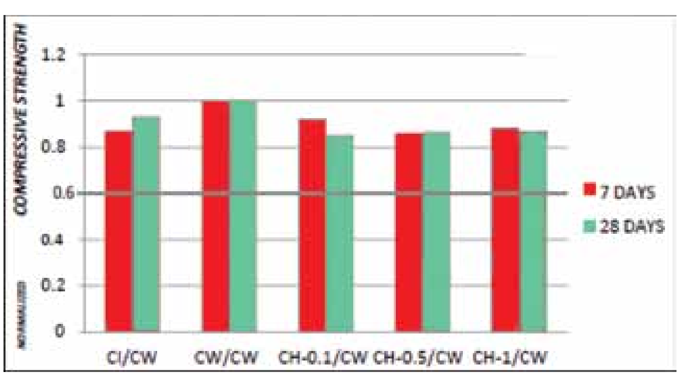

Figure 14. Normalized Compressive Strength for Mix C at 7 days and 28 days (wet curing)

3.1.10.3. Relative 7 days Compressive Strength for Mix A and Mix C with respect to 28 days Strength

The relative 7 days compressive strength with respect to 28 days compressive strength is evaluated for Mix A and C to determine the development of early age strength with respect to later age strength. The relative values were given in Table 16. AH-1 shows the maximum relative 7 day strength i.e. approximately 79% thus developing very high early strength but could not develop high later strength. AW shows minimum relative 7 day strength thus developing good later strength. Among PEG dosages increasing the dosage increases the relative strength. AI specimens are also having relative 7 days strength less than all the dosages of PEG-4000. The relative values are given in Table 17. Figure 15 shows the relative 7 days compressive strength for Mix A and Mix C. CH-0.1 shows the maximum relative 7 day strength i.e. approximately 80% thus developing very high early strength but could not develop high later strength. CI shows minimum relative 7 day strength thus developing good later strength followed by CW.

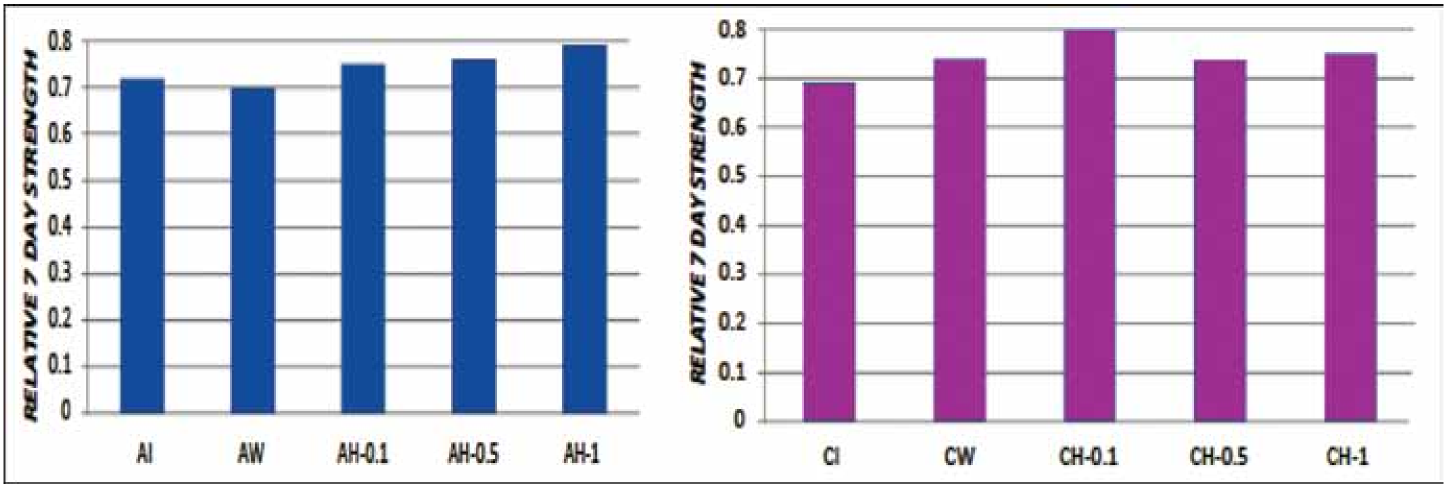

Figure 15. (Left) Relative 7 days compressive strength. (Right) Relative 7 days compressive strength w.r.t 28 days strength for Mix A w.r.t 28 days strength for Mix C

4.0. CONCLUSIONS

Based on the tests conducted the following conclusions can be drawn:

For water retention increasing the percentage dosage of PEG-4000 increases the weight loss for lower w/c ratio. Thus lower dosage showing better water retention for lower w/c ratio. Increasing the percentage dosage of PEG-4000 decreases the weight loss for higher w/c ratio. Thus for higher w/c ratio higher dosage shows better water retention. Weight loss is more in initial ages compared to later ages for both the grades of concrete. However the loss is more in initial ages for lower grade compared to higher grade. This may be attributed to better sealing of lower w/c ratio in higher grade of concrete.

With increase in age of curing; there is general increase in the weight loss. However the loss was more at lower grade as compared to high grade. Water retention of SCC with low w/c ratio improves with the addition of PEG-4000 and the optimum dosage is found to be 0.1% .Water retention of SCC with high w/c ratio improves only at high dosage of PEG-4000. Thus the optimum dosage for high w/c ratio is found to be 1%.

For Compressive Strength compressive strength of SCC with lower w/c ratio improves with the addition of PEG-4000 and is almost equivalent to wet curing. Thus PEG-4000 inclusion proves to be beneficial. The optimum PEG dosage at lower w/c ratio was found to be 0.1%. Compressive strength of SCC with high w/c ratio does not show favourable results and were observed to be less than indoor curing for all the dosages. Thus addition of PEG-4000 for high w/c ratio is insignificant.

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