DURABILITY OF SELCOMPACTING AND SELF CURING CONCRETE

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Abstract*: The main reasons for the discrepancies in the performance of Concrete are due to the lack of proper compaction and curing. Hence there is a need of concrete that can flow easily through the congested reinforcement and attain better performance without the need of external curing techniques. Self-curing is done in order to fulfill 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 different self-curing compounds viz., polyethylene glycol (PEG) of molecular weight 4000 (PEG 4000) and 200 (PEG 200), Liquid Paraffin Wax light and liquid paraffin wax heavy for dosages ranging between 0.1 to 1% by weight of cement added to mixing water. Three mixes A, B and C with different w/c ratio were considered in the investigation.Workability tests i.e. slump flow, T_{50}, V-funnel, J-ring, L-box were conducted on the fresh concrete whereas compressive strength, Acid Attack and Sorptivity were evaluated to determine the durability properties of hardened concrete.Comparative studies were carried out for workability, compressive strength, acid attack and sorptivity for conventional SCC and self-cured SCC.The durability properties of self-cured SCC are comparable with traditional cured specimens.

Keywords- self-curing, polyethylene glycol (PEG), *Liquid Paraffin Wax (LPW)*, compressive strength, *acid attack, sorptivity.*

I.INTRODUCTION

Self-Compacting Concrete:

Self-Compacting Concrete (SCC) is a new generation of concrete, which has generated tremendous interest since its initial development in Japan by Okamura in the late 1980's in order to reach durable concrete structures. SCC has gained wide use for placement in congested reinforced concrete structures with difficult casting conditions. For such applications, the fresh concrete must possess high fluidity and good cohesiveness. SCC is considered as a concrete which can be placed and compacted under its self-weight with little or no vibration effort, and which is at the same time, cohesive enough to be handled without segregation or bleeding. It is used to facilitate and ensure proper filling and good structural performance of heavily reinforced structural members. SCC development is a desirable achievement in the construction industry in order to overcome problems associated with cast-in-place concrete. SCC is not affected by the skills of workers, the shape and amount of reinforcing bars or the arrangement of a structure and, due to its high-fluidity and resistance to segregation it can be pumped longer distances. The main advantage of SCC is to shorten construction period and to assure compaction in the structures especially in the confined zones where vibration and compaction is difficult. The other advantages of SCC are

1. It eliminates noise due to vibration.
2. It provides high stability during transport and placement.
3. It provides uniform surface quality and homogenous.
4. It provides greater freedom for design
5. It is useful for casting of underwater structures.

The concept of SCC was proposed in 1986 by Professor Hajime Okamura, but the prototype was first developed in 1988 in Japan, by Professor Ozawa at the University of Tokyo. SCC was developed at that time to improve the durability of concrete structures. Since then, various investigations have been carried out and SCC has been used in practical structures in Japan, mainly by large construction companies. Investigations for establishing a rational mix design method and Self-Compactability, testing methods have been carried out from the viewpoint of making it a standard concrete. SCC is cast so that no additional inner or outer vibration is necessary for the compaction. It flows like "honey" and has a very smooth surface level after placing. With regard to its composition, SCC consists of the same components as Conventional concrete, which are cement, aggregates, and water, with the addition of chemical and mineral admixtures in different proportions. Usually, these concretes have higher workability, superior mechanical properties and/or greater resistance to chemical attack as compared to traditional concrete.

Self-Curing Concrete

In the 21st century, internal curing has emerged as an innovative technology that holds more efficient for making concrete with high resistance to early-age cracking and enhanced sustainability. Since the effective service life of concrete is a key component for producing a sustainable infrastructure, an internal curing can provide a positive approach in increasing the sustainability of our nation's infrastructure. The American Concrete Institute (ACI- 308 / R-01) defined internal curing in its ACI Terminology Guide as "supplying water throughout a freshly placed cementitious mixture using reservoirs, via pre-soaked lightweight aggregates, that readily supply water as needed for hydration or to replace moisture lost through evaporation.

II.OBJECTIVESAND SCOPE OF WORK

1. Development of Self-Compacting Concrete such

that its fresh properties satisfied according to EFNARC specifications.

2. Evaluation of the durability properties of Self Compacting Concrete with and without self-curing agents.
3. Other objective is to compare the use of different self curing agents (i.e. PEG200, PEG4000, liquid paraffin wax light and liquid paraffin wax heavy) and to find out optimum dosage of each self curing agent to attain better durability properties.

III.EXPERIMENTAL PROGRAMME

The experimental study consists of arriving at suitable mix proportions that satisfied the fresh properties of self compacting concrete as per EFNARC specifications. Standard cube moulds of 150mm x 150mm x 150mm made of cast iron were used for casting standard cubes. The standard moulds were fitted such that there are no gaps between the plates of the moulds. If there are any small gaps they were filled with plaster of paris. The moulds were then oiled and kept ready for casting. After 24hrs of casting, specimens were demoulded and transferred to curing tank where in they were immersed in water for the desired period of curing.

The program consists of casting and testing of 3 Mixes (A, B, C) of Self-Compacting Concrete with addition of Self-Curing Compounds such as PEG4000, PEG200, Liquid Paraffin Wax Light and Liquid Paraffin Wax Heavy. A total of 13 batches for each grade of Self-Compacting Concrete, out of which 1 batch is Normal SCC i.e., without Self-Curing Agent, 3 batches of PEG 4000 with addition of 0.1%, 0.5%, 1% by weight of cement, 3 batches of PEG 200 with addition of 0.1%, 0.5%, 1%, 3 batches of Liquid Paraffin Wax Light with addition of 0.1%, 0.5%, 1% and 3 batches of Liquid Paraffin Wax Heavy with addition of 0.1%, 0.5%, 1%. The mix proportion for each grade of Self compacting concrete was designed by using modified Nan Su method. Water reducing admixtures are added into mixes on requirement, till the desired properties are exhibited by them. 4 cubes were casted in each batch, out of which 2 cubes of each batch are tested for 5% HCl (Hydrochloric acid) and Sorptivity test for durability aspects after a 28 days. The details of the specimen's cast are shown in fig.

NOMENCLATURE FOR SPECIMENS

MIX A- 1:1.6:1.55:0.38
MIX B- 1:1.97:1.82:0.45
MIX C- 1:2.39:2.19:0.35
H-PEG 4000(Higher Molecular Weight)
L-PEG 200(Low Molecular Weight)
V-Liquid Paraffin Wax Light
P- Liquid Paraffin Wax Heavy
I-Indoor Curing
W-Wet/Conventional Curing

flow chart showing experimental programme

S.C.A-Self-Curing Agent

i. For example sample with name AW represents Mix A with PEG 4000 and dosage of 0% by weight of cement subjected to wet curing.
ii. Sample AI represents Mix A with PEG 4000 and dosage of 0% by weight of cement subjected to indoor curing.
iii. Sample AH1% represents Mix A with PEG 4000 and dosage of 1% by weight of cement subjected to indoor curing.
iv. Sample BL0.5% represents Mix B with PEG 200 and dosage of 0.5% by weight of cement subjected to indoor curing.
v. Sample CV0.1% represents Mix C with Liquid paraffin wax light and dosage of 0.1% by weight of cement subjected to indoor curing.

IV.MATERIALS USED

The different materials used in this investigation are

- 53 Grade Ordinary Portland cement
- Fine Aggregate
- Coarse Aggregate
- Super Plasticizer (Chryso Optima P77)
- Silica fume (only for Mix A)
- Fly ash.
- Water
- Self-Curing Compounds- PEG4000, PEG200, Liquid Paraffin Wax Light and Liquid Paraffin Wax Heavy.

a) Cement: Cement used in the investigation was 53 Grade Ordinary Portland cement confirming to IS: 12269 [11]. The specific gravity of cement was 3.14 and specific surface area of 225 m^2/g having initial and final setting time of 40 min and 560 min respectively.

b) Fine Aggregate: The fine aggregate was conforming to Zone-2 according to IS: 383 [12]. The fine aggregate used was obtained from a nearby river source. The specific gravity was 2.65, while the bulk density of sand was 1.45 gram/c.c.

c) Coarse Aggregate: Crushed granite was used as coarse

aggregate. The coarse aggregate was obtained from a local crushing unit having 20mm nominal size, well graded aggregate according to IS: 383[12]. The specific gravity was 2.8, while the bulk density was 1.5 gram/c.c.

d) Water: Potable water was used in the experimental work for both mixing and curing companion specimens.

e) Fly Ash: The fly ash used in the experiments was from Ramagundam thermal power station (NTPC). The specific gravity was 2.17. The fly ash had a silica content of 63.99%, silica+ alumina +iron oxide content of 92.7%, Calcium oxide of 1.71% , Magnesium oxide of 1.0%, Sulphuric anhydride of 0.73% , water and soluble salts of 0.04%, ph value of 10 and a loss on ignition of 2.12.

f) Micro silica: It is an amorphous (non-crystalline) polymorph of silicon dioxide, silica. It is an ultrafine powder collected as a by-product of the silicon and ferrosilicon alloy production and consists of spherical particles with an average particle diameter of 150 nm. The main field of application is as pozzolanic material for high performance concrete. Micro Silica is an ultrafine material with spherical particles less than 1 µm in diameter, the average being about 0.15 µm. This makes it approximately 100 times smaller than the average cement particle. The bulk density of silica fume depends on the degree of densification in the silo and varies from 130 to 600 kg/m^3. The specific gravity of silica fume is generally in the range of 2.2 to 2.3. It typically ranges from 15,000 to 30,000 m^2/ kg. To get better results, the dosage of micro silica is 8% of weight of cement.

g) Super plasticizer: High range water reducing admixture confirming to ASTM C94 commonly called as super plasticizers was used for improving the flow or workability for decreased water-cement ratio without sacrifice in the compressive strength. These admixtures when they disperse in cement agglomerates significantly, decreases viscosity of the paste forming a thin film around the cement particles. In the present investigation, water-reducing admixture CHRYSO FLUID OPTIMA P-77 (poly carboxylic ether based) obtained from Chryso Chemicals, India was used.

Properties of Chryso Fluid Optima P-77:

Physical properties

- Form : Liquid
- Color : Transparent to slight turbid
- Specific Gravity : 1.10 + 0.02
- pH : Minimum 6.0
- Air entrainment : <1.0 % over control mixes.
- Chloride Content : Nil (As per BS: 5075)
- Water Reduction : Upto 40 %

Norms & regulations

CHRYSO Fluid Optima P-77 conforms to IS: 9103 and ASTM–C-494 Type G.

h) Hydrophilic chemicals: PEG Low molecular and high molecular weight, Liquid paraffin wax and solid paraffin wax were used in the study. The chemicals were mixed with water thoroughly prior to mixing of water in concrete. The details of the physical properties of the PEG compounds are shown in Table-1. Similarly, the details of LPW and SPW are shown in Table-2.

Physical Properties of CARBOWAX PEGs

Product	Range of Average Molecular Weight	Range of Average Hydroxyl Number, Mg KOH/g	Liquid Density, g/cc			Melting or Freezing Range, °C	Solubility in Water at 20°C, % by wt	Viscosity at 100°C
			20°C	60°C	80°C			
PEG200	190 to 210	535 to 590	1.124	1.092	1.076	-65	Complete	4.3
PEG 4000	3600 to 4400	25 to 32	Solid	1.093	1.077	53 to 59	66	140.4

Physical and Chemical properties of Paraffin Wax

Sr. No.	Characteristics	Liquid Paraffin Light	Heavy Liquid Paraffin
1.	Specific gravity @ 25°c	Between 0.820 to 0.860	Between 0.850 to 0.880
2.	Dynamic viscosity @ 20°c	Between 25 to 80 mpas	Between 110 to 230 mpas
3	Appearance	Clear colour less liquid.	Clear colour less liquid.
3.	Solubility	Passes	Passes
4.	Sulphur compounds	Compiles as per standards	Compiles as per standards
5.	Solid paraffins	Compiles as per standards	Compiles as per standards
6.	Flash point (PMCC), °c	Min. 150 °c	Min 200 OC
7.	Acidity / alkalinity	Passes	Passes
8.	Light absorption @ 240-280 nm	Less than 0.1	Less than 0.1
9.	Readily carbonisable substances	Passes	Passes

place of procurement and viscosity of Self-Curing Agents

	PEG 4000	PEG 200	Paraffin wax
PLACE OF PROCUREMENT	M/S CENTRAL DRUG HOUSE(P) LTD. NEW DELHI	M/S SDFCL, MUMBAI	M/S SDFCL, MUMBAI
VISCOSITY AT 20°C	ABOUT 12 cS	53-63 Cs	<33.5 cS

MIX DESIGN:

Nan SU method of simple mix design for SCC was used to

arrive at initial trial mixes and then mixes were modified accordingly as per EFNARC to achieve optimum mix proportions satisfying fresh properties , hardened properties and also economy. The proportions arrived for three mixes A,B and C are given below.

Mix proportions and quantity of materials used for Mix 'A'

Sr.No.	Material	Quantity kg/m^3	Quantity for 9 cubes in Kg	Proportions
1)	Cement	500.00	18.00	1.000
2)	Fine Aggregate	800.00	28.80	1.600
3)	Coarse Aggregate	775.00	27.90	1.550
4)	Water	190.00	6.84	0.380
5)	Flyash	110.00	3.96	0.220
6)	MicroSilica	40	1.44	0.080
7)	SP	6.00	0.216	0.012
	Density	2421.00		

Mix proportions and quantity of materials used for Mix 'B'

Sr.No.	Material	Quantity kg/m^3	Quantity for 9 cubes in Kg	Proportions
1)	Cement	430.00	16.50	1.000
2)	Fine Aggregate	847.10	32.52	1.970
3)	Coarse Aggregate	782.60	30.00	1.820
4)	Water	194.00	7.44	0.450
5)	Flyash	180.00	6.93	0.420
6)	SP	5.16	0.198	0.012
	Density	2438.86		

Mix proportions and quantity of materials used for Mix 'C'

Sr.No.	Material	Quantity kg/m^3	Quantity for 9 cubes in Kg	Proportions
1)	Cement	360.00	16.00	1.000
2)	Fine Aggregate	860.00	38.24	2.390
3)	Coarse Aggregate	788.00	35.04	2.190
4)	Water	188.00	8.80	0.550
5)	Flyash	250.00	11.04	0.690
6)	SP	3.6	0.16	0.010
	Density	2449.60		

Tests for fresh properties of SCC:

The final selection of recommended test methods was based mainly on their relation to one or more of the key properties of SCC (filling ability, passing ability, and resistance to segregation) as well as on reproducibility and repeatability. The selection process involved consideration of the outcome of an extensive experimental program in laboratory conditions and on site together with the general advantages and disadvantages of each method (cost, portability, simplicity of operation, and other practical aspects).

The key rheological parameters 'plastic viscosity' and 'yield value' mainly determine the filling ability of SCC; the slump flow and T50 tests demonstrate the best correlation with these, as well as having acceptable to good repeatability and reproducibility.

Furthermore, the slump flow equipment is currently widely used in concrete practice, and the method is very simple and straightforward. Thus the slump flow combined with T50 was selected as the first priority test method for the filling ability of SCC. The V-funnel or Orimet tests are recommended as second priority alternatives to the T50 measurement.

The passing ability of fresh SCC can be tested by L-box or J-ring. There is some, but not very good, correlation between their results. The repeatability and reproducibility are acceptable to good for both tests. For the L-box test, a long practical experience was available, which led to a well-documented blocking criterion and correlation with the behavior in real construction elements was shown to be good. For the J-ring test, no clear information is available on the blocking criterion, but it could be a potential method for combining the measurement of the different properties of filling and passing ability. After detailed evaluation, the consortium selected both L-box and J-ring as the test methods for passing ability with equal priority. It is important to note that recommendations only go as far as proposals for the test methods for standardization. No acceptance criteria were formulated in this project, but these have subsequently been considered by a European group of organizations representing concrete producers and users, in which several of the project consortiums participated.

These guidelines also do not give any specific recommendations on which methods should be used on site and which in the laboratory. However, from practical considerations, it seems logical that the acceptance testing on-site could be based on the slump test solely (possibly combined with T50); while for initial type testing all test methods listed in first priority could be used. For particular purposes, the reference test methods could be extended or replaced by one or more of the alternative methods.

TESTS FOR DURABILITY PROPERTIES OF CONCRETE

1) Compressive Strength:

The cube specimens were tested on compression testing machine of capacity 2000kN. The bearing surface of the machine was wiped off clean and any loose sand or other material removed from the surface of the specimen .The specimen was placed in the machine in such a manner that the load was applied to opposite sides of the cubes as caste that is, not top and bottom. The axis of the specimen was carefully aligned at the center of the loading frame. The load applied was increased continuously at a constant rate until the resistance of the specimen to the increasing load breaks down and no longer can be sustained. The maximum load applied on the specimen was recorded. The details of compressive strength results for specimens without and with

nano silica were compared. The cube specimen under compressive test is shown in fig

UTM where cubes are tested for compressive strength

2) Acid attack study:

The chemical resistance of the concrete was studied through chemical attack by immersing them in an acid solution. After 28days curing period of the specimens of each batch were taken and their surfaces were cleaned with a soft nylon brush to remove weak reaction products and loose materials from the specimen. The initial mass, body diagonal dimensions value were measured. 2specimens of each batch of concrete were immersed in 5% HCl.

Preparation of 5% HCl:

Volume of HCl = 100 ml

Mass of HCl (36.5% purity) = 100 x 1.18=118 grams

Actual mass of HCl = 36.5/100 x 118= 42.07 grams

5% HCl= actual mass HCl / (mass HCl + mass water)

5/100 = 42.07/(118+x)

X =731 ml of water.

i.e., for 100ml of 36.5% HCl, 731ml volume of water is added to make 5% HCl solution.

The mass, diagonal dimensions values are measured at 3, 7, 14, 21, 28 days of immersion. Compressive strength is measured after 28days of immersion Before testing, each specimen is removed from the baths, brushed with a soft nylon brush and rinsed in tap water. This process removes loose surface material from the specimens. Mass change, reduction in compressive strengths values and diagonal dimensions are observed.

For determining the resistance of concrete specimens to aggressive environment such as acid attack, the durability factors as proposed by the philosophy of ASTM (666-1997). In the present investigation, the "Acid Durability Factors" are derived directly in terms of relative strengths. The relative strengths are always compared with respect to the 28 days value (i.e. at the start of the test)

The "Acid Durability Factors" (ADF) can be calculated as follows.

ADF = Sr N / M

Where, Sr - Relative Strength at N days, (%)

N - Number of days at which the durability factor is needed.

M - Number of days at which the exposure is to be terminated.

So M is 28 in this case.

The extent of deterioration at each corner of the struck face and the opposite face is measured in terms of the acid diagonals (in mm) for each of two cubes and the "Acid Attack Factor" (AAF) per face is calculated as follows.

AAF = (Loss in mm on eight corners of each of 2 cubes)/4.

3)Sorptivity study :

The sorptivity tests were carried out on all batches of SCC with size of 15x15 x15cm. The preparation of samples also included water impermeability of their lateral faces, reducing the effect of water evaporation. The test started with the registration of samples weight and afterwards they were placed in a recipient in contact with a level of water capable to submerge them about 5 mm as shown in Fig . After a predefined period of time, the samples were removed from the recipient to proceed to weight registration. Before weighing, the samples superficial water was removed with a wet cloth. Immediately after weighting, the samples were replaced in the recipient till reach the following measuring time. The procedure was repeated, consecutively, at various times such as 15 min, 30 min, 1 h, 2 hrs, 4 hrs, 6 hrs, 24 hrs, 48 hrs ,72 hrs, 7days, 14days and 28days.

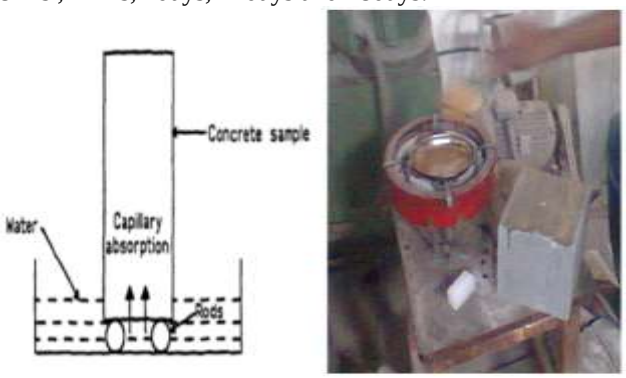


Figure Sorptivity test, applying wax on the sides of the cube specimen

Because of a small initial surface tension and buoyancy effects, the relationship between cumulative water absorption (kg/m^2) and square root of exposure time (t$^{0.5}$) shows deviation from linearity during first few minutes. Thus, for the calculation of sorptivity coefficient, only the section of the curves for exposure period from 15 min to 72 hrs, where the curves were consistently linear, was used.

The sorptivity coefficient (k) was obtained by using the following expression:

$$\frac{W}{A} = k\sqrt{t}$$

Where W = the amount of water adsorbed in (kg);

A = the cross-section of specimen that was in contact with water (m^2);

t = time (min);

k = the sorptivity coefficient of the specimen (kg/m^2/min$^{0.5}$).

V.RESULTS AND DISCUSSIONS

Fresh Properties of Self-Compacting Concrete with PEG for Mix "A" :

	EFNARC RANGE	PLAIN SCC	PEG 4000			PEG 200		
		0%	0.10%	0.50%	1%	0.10%	0.50%	1%
SLUMP FLOW(mm)	550-850	700	650	635	665	810	825	870
T 50 (sec)	2-5	3.69	3.72	3.41	3.29	3.8	3.44	2.5
J-RING (mm)	0-10	5	10	9	9	7	6	5
L-BOX	0.8-1.0	0.94	0.82	0.835	0.85	0.93	0.945	0.96
V-FUNNEL (Sec)	6-12	11.5	9.7	13.33	11.3	9.9	9.02	8.97
V 5min (sec)	9-15	17	11	16.3	14.2	12.4	13.5	13.36
SP %		1.2	1.2	1.2	1.2	1.2	1.2	1.2

Fresh Properties of Self-Compacting Concrete with LPW for Mix "A" :

	EFNARC RANGE	PLAIN SCC	LPW Light			LPW High		
		0%	0.10 %	0.50 %	1%	0.10 %	0.50 %	1%
SLUMPFLOW(mm)	550-850	700	645	660	675	775	745	695
T 50 (sec)	2-5	3.69	2.1	2.3	2.45	2.07	2.4	2.48
J-RING (mm)	0-10	5	10	9	8	6	7	7
L-BOX	0.8-1.0	0.94	0.87	0.895	0.9	0.91	0.9	0.9
V-FUNNEL (Sec)	6-12	11.5	9	11.8	11.9	9.55	10.46	9.25
V 5min (sec)	9-15	17	12	13.8	14.5	13	13.77	12
SP %		1.2	1.4	1.4	1.4	1.3	1.4	1.6

Fresh Properties of Self-Compacting Concrete with PEG for Mix "B" :

	EFNARC RANGE	PLAIN SCC	PEG 4000			PEG 200		
		0%	0.10 %	0.50 %	1%	0.10 %	0.50 %	1%
SLUMPFLOW(mm)	550-850	700	660	790	795	625	610	690
T 50 (sec)	2-5	2.5	3.14	3.04	3.4	2.92	3.15	2.38
J-RING (mm)	0-10	7	8	5	5	8	9	8
L-BOX	0.8-1.0	0.92	0.91	0.945	0.955	0.86	0.83	0.88
V-FUNNEL (Sec)	6-12	7.02	6.3	7	7.3	7.72	7.27	6.12
V 5min (sec)	9-15	9.54	9.5	10.3	10.3	9.34	9.56	9.09
SP %		1.2	1.2	1.2	1.2	1.2	1.3	1.2

Fresh Properties of Self-Compacting Concrete with LPW for Mix "B" :

	EFNARC RANGE	PLAIN SCC	LPW Light			LPW High		
		0%	0.10 %	0.50 %	1 %	0.10 %	0.50 %	1%
SLUMPFLOW(mm)	550-850	700	730	705	745	760	730	775
T 50 (sec)	2-5	2.5	2.87	3.43	3.26	3.21	3.53	2.27
J-RING (mm)	0-10	7	7	8	7	6	7	5
L-BOX	0.8-1.0	0.92	0.88	0.9	0.89	0.84	0.83	0.83
V-FUNNEL (Sec)	6-12	7.02	8.29	7.67	8.5	7.6	7.44	7.82
V 5min (sec)	9-15	9.54	12	12.9	13.3	11.42	11.4	12
SP %		1.2	1.2	1.2	1.2	1.2	1.2	1.2

Fresh Properties of Self-Compacting Concrete with PEG for Mix "C" :

	EFNARC RANGE	PLAIN SCC	PEG 4000			PEG 200		
		0%	0.10 %	0.50 %	1%	0.10 %	0.50 %	1%
SLUMPFLOW(mm)	550-850	670	590	640	560	650	660	770
T 50 (sec)	2-5	2.4	2.32	2.5	3.4	2.05	2	2.35
J-RING (mm)	0-10	8	7	7	7	6	6	5
L-BOX	0.8-1.0	0.87	0.875	0.88	0.89	0.93	0.92	0.955
V-FUNNEL (Sec)	6-12	9.77	6	6.52	8.3	6.429	5	6.85
V 5min (sec)	9-15	10.64	7.76	8.5	9.8	9.02	6.45	9.42
SP %		1.3	1	1	1	1	1	1

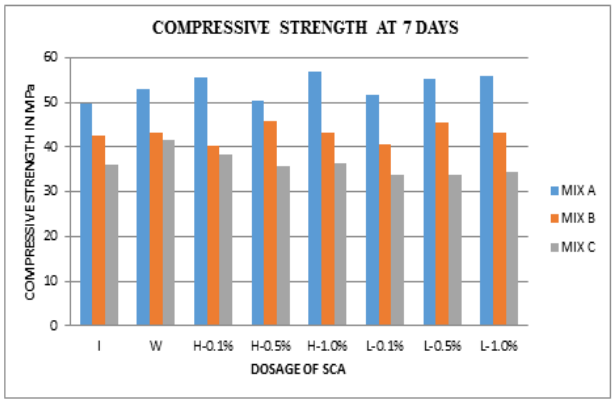
Fresh Properties of Self-Compacting Concrete with LPW for Mix "C" :

	EFNARC RANGE	PLAIN SCC	LPW Light			LPW High		
		0%	0.10 %	0.50 %	1%	0.10 %	0.50 %	1%
SLUMPFLOW(mm)	550-850	670	770	575	600	570	565	655
T 50 (sec)	2-5	2.4	2	3.56	3.98	2.14	2.99	2.39
J-RING (mm)	0-10	8	8	9	9	10	10	10
L-BOX	0.8-1.0	0.87	0.9	0.84	0.81	0.83	0.82	0.86
V-FUNNEL (Sec)	6-12	9.77	5.8	7.18	8.9	6.44	8.43	7.5
V 5min (sec)	9-15	10.64	7.8	9.69	11.89	7.22	8.98	10
SP %		1.3	1.2	1.3	1.4	1.4	1.2	1.1

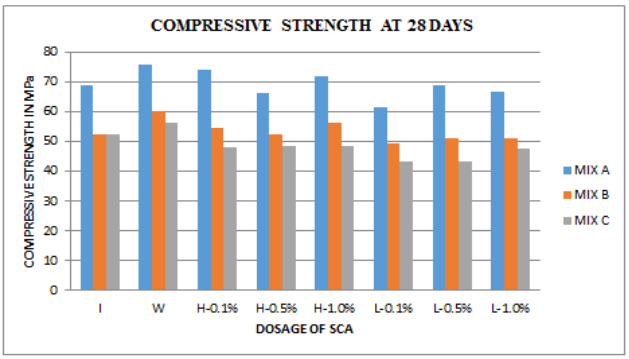
Effect of Self-Curing agents on Compressive Strength:

Average Compressive Strength of SCC with and without PEG

	MIX A		MIX B		MIX C	
	7DAYS	28DAYS	7DAYS	28DAYS	7DAYS	28DAYS
I	49.64	68.87	42.52	52.39	36.04	52.19
W	52.84	75.73	43.29	60.13	41.46	56.4
H-0.1%	55.4	73.87	40.09	54.45	38.16	47.87
H-0.5%	50.23	66.12	45.91	52.39	35.7	48.39
H-1.0%	56.83	71.81	43.03	56.11	36.49	48.59
L-0.1%	51.6	61.61	40.42	49.34	33.85	43.23
L-0.5%	55.33	68.96	45.45	50.91	33.85	43.09
L-1.0%	55.85	66.81	43.03	51.01	34.43	47.8



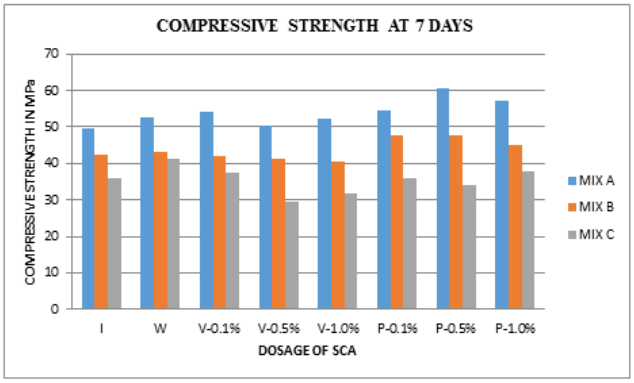
Average compressive strength of SCC without and with PEG at 7 days



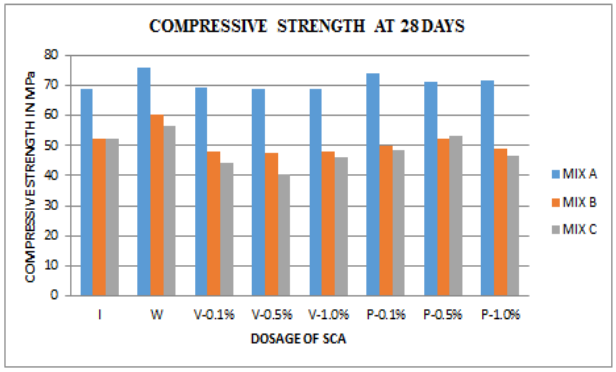
Average compressive strength of SCC without and with PEG at 28 days

Average Compressive Strength of SCC with and without Paraffin Wax

	MIX A		MIX B		MIX C	
	7DAYS	28DAYS	7DAYS	28DAYS	7DAYS	28DAYS
I	49.64	68.87	42.52	52.39	36.04	52.19
W	52.84	75.73	43.29	60.13	41.46	56.4
V-0.1%	54.15	69.36	42.18	48.07	37.47	44.08
V-0.5%	50.55	68.77	41.33	47.58	29.62	40.61
V-1.0%	52.19	68.67	40.48	48.17	31.68	45.91
P-0.1%	54.61	73.87	47.67	49.93	35.9	48.46
P-0.5%	60.49	71.02	47.87	52.38	33.94	52.97
P-1.0%	57.03	71.51	44.93	49.15	37.96	46.76



Average compressive strength of SCC without and with Paraffin Wax at 7 days



Average compressive strength of SCC without and with Paraffin Wax at 28 days

Acid attack

In acid attack studies on Self-Curing SCC, the effect of 5% HCl acid were studied. The various observations made are explained below.

Visual observation

In the first stage of the test the change in the physical state of the specimens after 3, 7, 14, 21, 28 days of immersion is observed. For the specimens immersed in 5% HCl, voids were observed on the surface and edges were lost after 28days.

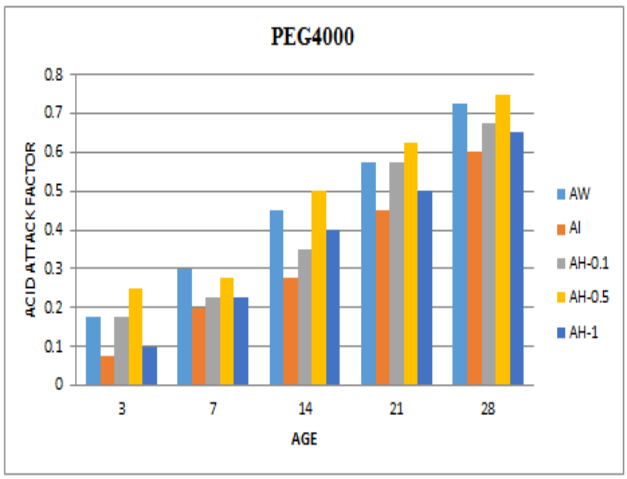
Specimen of normal SCC immersed in 5% HCl

Acid Attack Factor:

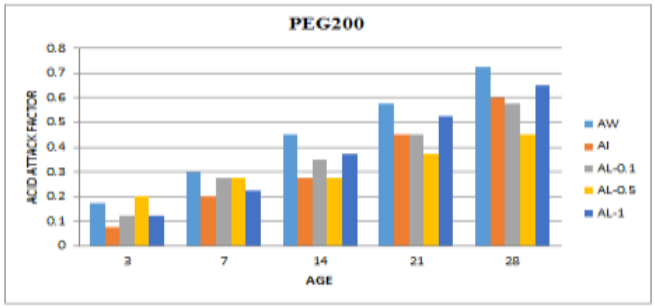
The Acid Attack Factor (AAF) of the specimens were observed and plotted against the number of immersion days in acids as shown in the following Table 4.6, 4.7 and Figures

Acid Attack Factor for Mix A cubes immersed in 5% HCl

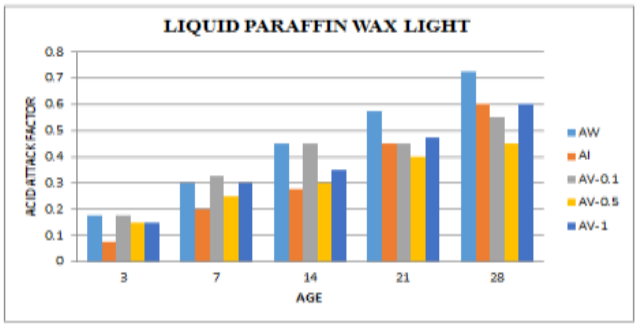
	ACID ATTACK FACTOR				
	3 days	7 days	14 days	21 days	28 days
AW	0.175	0.3	0.45	0.6	0.725
AI	0.075	0.2	0.275	0.45	0.6
AH-0.1	0.175	0.225	0.35	0.6	0.675
AH-0.5	0.25	0.275	0.5	0.65	0.75
AH-1	0.1	0.225	0.4	0.45	0.65
AL-0.1	0.125	0.275	0.35	0.5	0.375
AL-0.5	0.2	0.275	0.275	0.35	0.45
AL-1	0.125	0.225	0.375	0.55	0.65
AV-0.1	0.175	0.325	0.45	0.45	0.55
AV-0.5	0.15	0.25	0.3	0.4	0.45
AV-1	0.15	0.3	0.35	0.55	0.6
AP-0.1	0.175	0.325	0.375	0.55	0.625
AP-0.5	0.125	0.2	0.375	0.5	0.625
AP-1	0.2	0.325	0.425	0.6	0.75



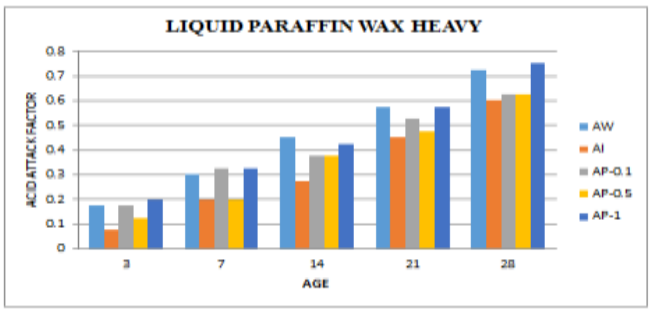
Acid Attack Factor for cubes of mix A containing PEG4000



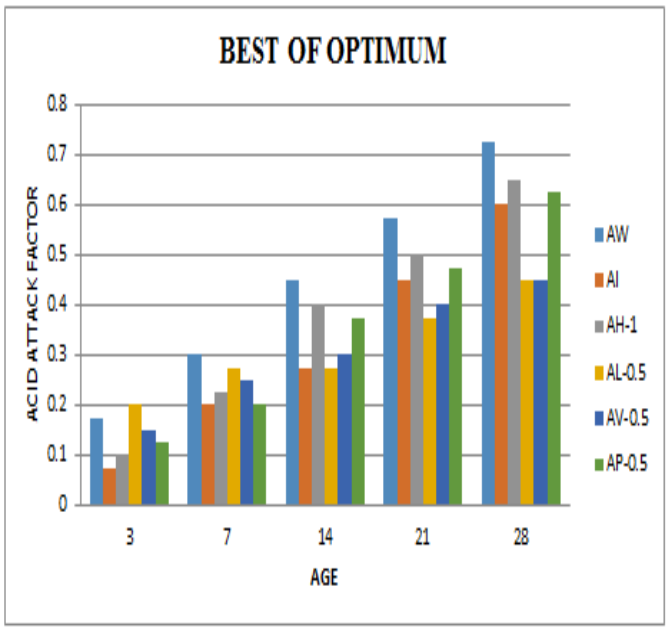
Acid Attack Factor for cubes of mix A containing PEG200



Acid Attack Factor for cubes of mix A containing PWL



Acid Attack Factor for cubes of mix A containing PWH

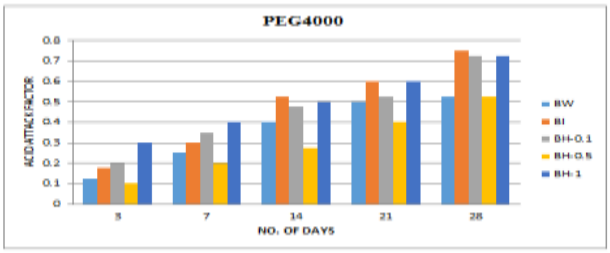


best self-curing agent along with optimum dosage for mix A

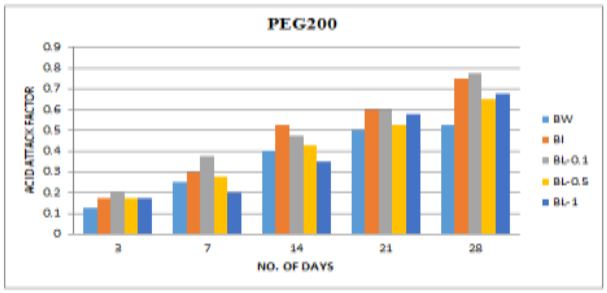
ACID ATTACK FACTOR FOR MIX "B" :

Acid Attack Factor for Mix B cubes immersed in 5% HCl

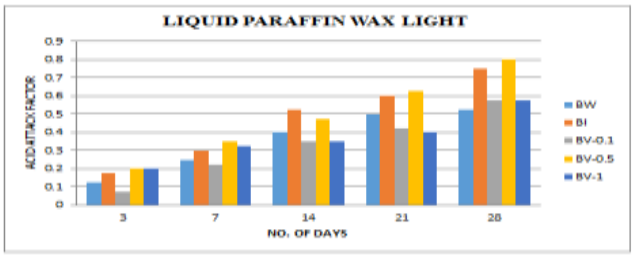
	ACID ATTACK FACTOR				
	3 days	7 days	14 days	21 days	28 days
BW	0.125	0.25	0.4	0.5	0.525
BI	0.175	0.3	0.525	0.6	0.75
BH-0.1	0.2	0.35	0.475	0.525	0.725
BH-0.5	0.1	0.2	0.275	0.4	0.525
BH-1	0.3	0.4	0.5	0.6	0.725
BL-0.1	0.2	0.375	0.475	0.6	0.775
BL-0.5	0.175	0.275	0.425	0.525	0.65
BL-1	0.175	0.2	0.35	0.575	0.675
BV-0.1	0.075	0.225	0.35	0.425	0.575
BV-0.5	0.2	0.35	0.475	0.625	0.8
BV-1	0.2	0.325	0.35	0.4	0.575
BP-0.1	0.125	0.25	0.3	0.425	0.575
BP-0.5	0.3	0.375	0.5	0.675	0.825
BP-1	0.325	0.35	0.425	0.575	0.75



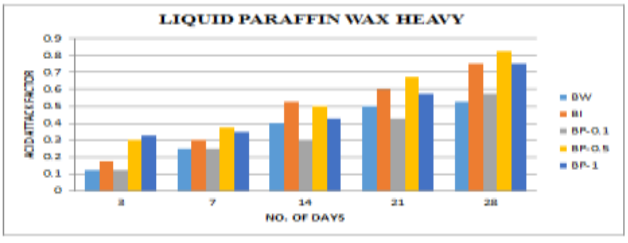
Acid Attack Factor for cubes of mix B containing PEG4000



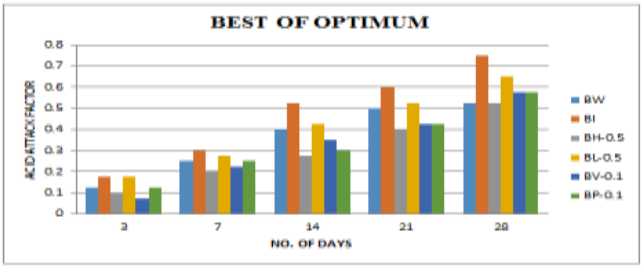
Acid Attack Factor for cubes of mix B containing PEG200



Acid Attack Factor for cubes of mix B containing PWL



Acid Attack Factor for cubes of mix B containing PWH

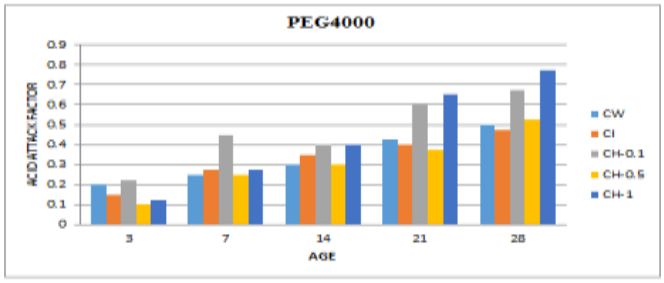


best self-curing agent along with optimum dosage for mix B

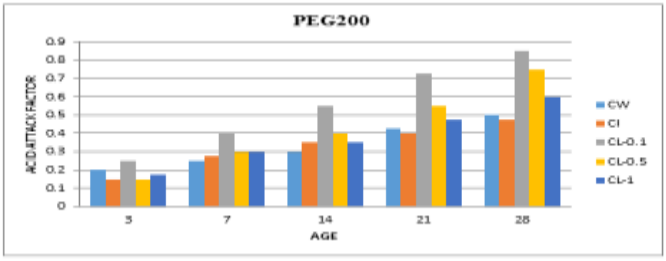
ACID ATTACK FACTOR FOR MIX "C":

Acid Attack Factor for Mix C cubes immersed in 5% HCl

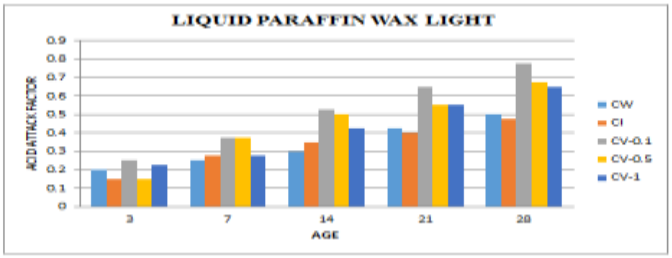
	ACID ATTACK FACTOR				
	3 days	7 days	14 days	21 days	28 days
CW	0.2	0.25	0.3	0.425	0.5
CI	0.15	0.275	0.35	0.4	0.475
CH-0.1	0.225	0.45	0.4	0.6	0.675
CH-0.5	0.1	0.25	0.3	0.375	0.525
CH-1	0.125	0.275	0.4	0.65	0.775
CL-0.1	0.25	0.4	0.55	0.725	0.85
CL-0.5	0.15	0.3	0.4	0.55	0.75
CL-1	0.175	0.3	0.35	0.475	0.6
CV-0.1	0.25	0.375	0.525	0.65	0.775
CV-0.5	0.15	0.375	0.5	0.55	0.675
CV-1	0.225	0.275	0.425	0.55	0.65
CP-0.1	0.15	0.275	0.35	0.43	0.575
CP-0.5	0.1	0.175	0.275	0.375	0.55
CP-1	0.1	0.225	0.3	0.425	0.525



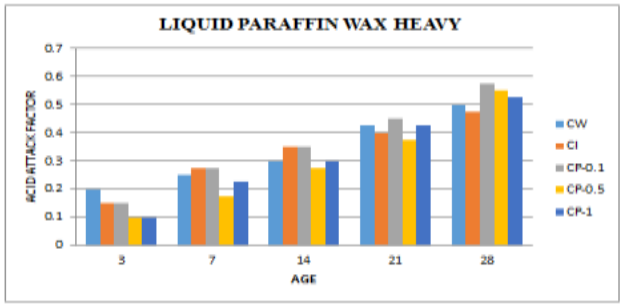
Acid Attack Factor for cubes of mix C containing PEG4000



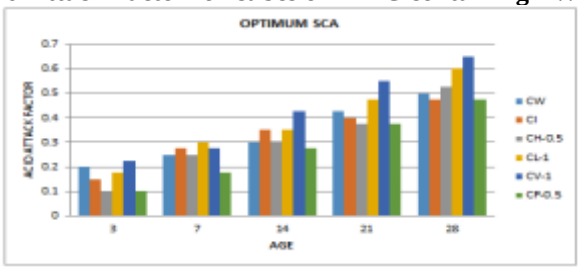
Acid Attack Factor for cubes of mix C containing PEG200



Acid Attack Factor for cubes of mix C containing PWL



Acid Attack Factor for cubes of mix C containing PWH



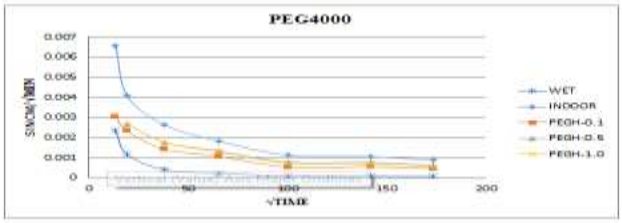
best self-curing agent along with optimum dosage for mix C

SORPTIVITY:

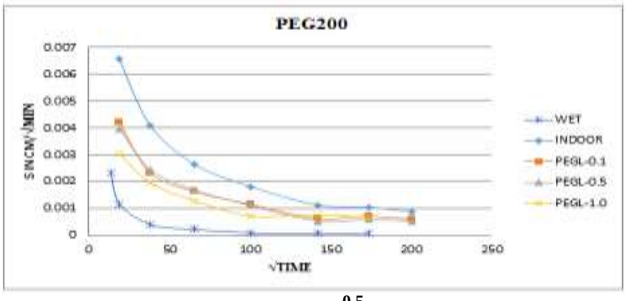
The water absorption and Sorptivity coefficient of the specimens were observed and plotted against the in square root of time in minutes as shown in the following Table 4.8 and 4.9 and Figures

Sorptivity for Mix A cubes

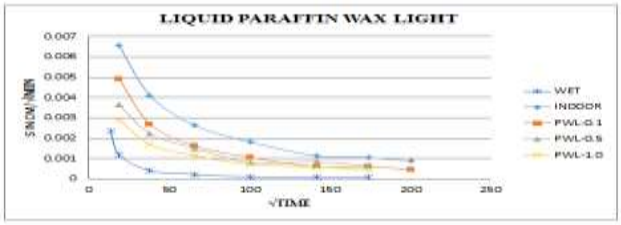
	18.97	37.94	65.72	100.39	141.98	173.89	200.79
INDOOR	0.00656	0.00410	0.00264	0.00181	0.00113	0.00105	0.00089
WET	0.00234	0.00117	0.00041	0.00022	0.00009	0.00008	0.00007
PEGH-0.1	0.00303	0.00234	0.00142	0.00106	0.00053	0.00056	0.00046
PEGH-0.5	0.00443	0.00269	0.00176	0.00133	0.00078	0.00077	0.00062
PEGH-1.0	0.00445	0.00269	0.00176	0.00128	0.00072	0.00069	0.00058
PEGL-0.1	0.00422	0.00234	0.00162	0.00115	0.00063	0.00072	0.00060
PEGL-0.5	0.00398	0.00246	0.00169	0.00111	0.00053	0.00059	0.00053
PEGL-1.0	0.00539	0.00305	0.00196	0.00128	0.00072	0.00077	0.00066
PWL-0.1	0.00492	0.00269	0.00162	0.00106	0.00059	0.00061	0.00044
PWL-0.5	0.00586	0.00363	0.00223	0.00131	0.00081	0.00084	0.00064
PWL-1.0	0.00468	0.00293	0.00169	0.00115	0.00072	0.00059	0.00046
PWH-0.1	0.00586	0.00351	0.00216	0.00133	0.00091	0.00097	0.00082
PWH-0.5	0.00539	0.00328	0.00196	0.00128	0.00075	0.00079	0.00062
PWH-1.0	0.00539	0.00305	0.00183	0.00137	0.00085	0.00084	0.00073



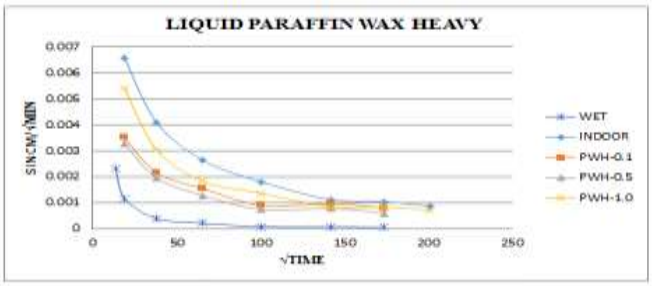
Sorptivity Coefficient Vs time$^{0.5}$ for PEG 4000 of mix A



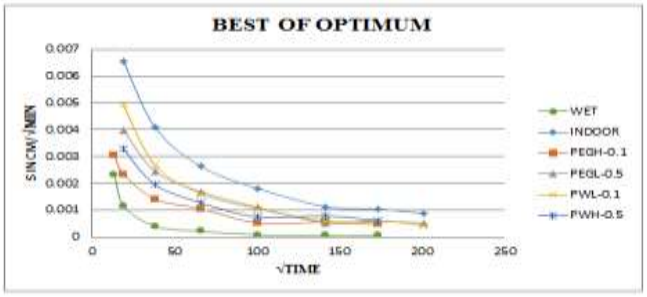
Sorptivity Coefficient Vs time$^{0.5}$ for PEG 200 of mix A



Sorptivity Coefficient Vs time$^{0.5}$ for LPWL of mix A



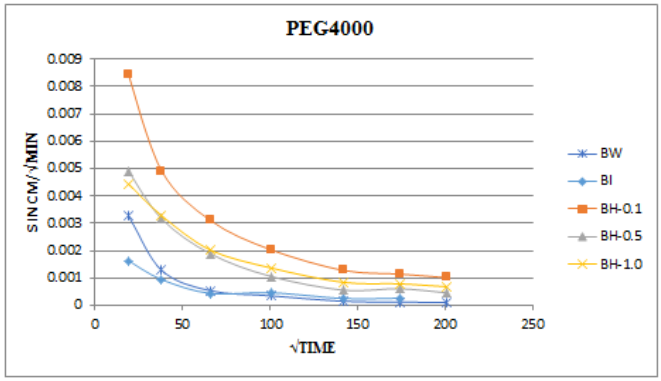
Sorptivity Coefficient Vs time$^{0.5}$ for LPWH of mix A



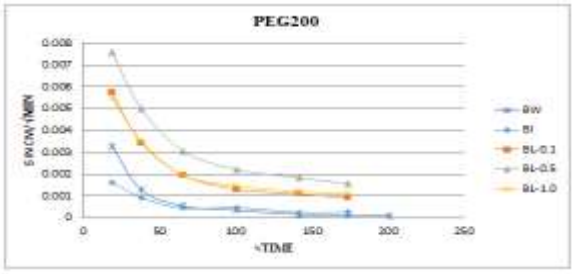
optimum dosage of self-curing compounds for mix A

Sorptivity for Mix B cubes

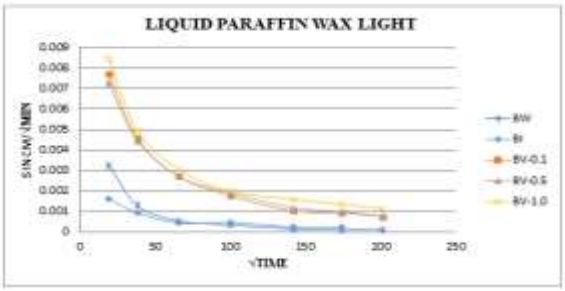
	18.97	37.94	65.72	100.39	141.98	173.89	200.79
BI	0.0028	0.0016	0.0009	0.0004	0.0005	0.0003	0.0003
BW	0.0033	0.0013	0.0005	0.0004	0.0002	0.0001	0.0001
BH-0.1	0.0084	0.0049	0.0031	0.0020	0.0013	0.0012	0.0010
BH-0.5	0.0049	0.0032	0.0019	0.0011	0.0006	0.0006	0.0005
BH-1.0	0.0045	0.0033	0.0020	0.0014	0.0008	0.0008	0.0007
BL-0.1	0.0096	0.0057	0.0034	0.0019	0.0013	0.0011	0.0009
BL-0.5	0.0126	0.0076	0.0050	0.0031	0.0022	0.0018	0.0016
BL-1.0	0.0094	0.0055	0.0035	0.0019	0.0015	0.0012	0.0012
BV-0.1	0.0077	0.0046	0.0027	0.0018	0.0010	0.0009	0.0008
BV-0.5	0.0073	0.0045	0.0027	0.0019	0.0012	0.0010	0.0008
BV-1.0	0.0084	0.0049	0.0030	0.0020	0.0016	0.0014	0.0012
BP-0.1	0.0066	0.0049	0.0032	0.0022	0.0018	0.0013	0.0012
BP-0.5	0.0103	0.0056	0.0034	0.0019	0.0014	0.0012	0.0011
BP-1.0	0.0063	0.0036	0.0022	0.0011	0.0008	0.0007	0.0007



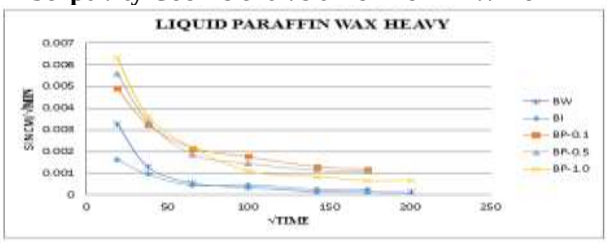
Sorptivity Coefficient Vs time$^{0.5}$ for PEG 4000 of mix B



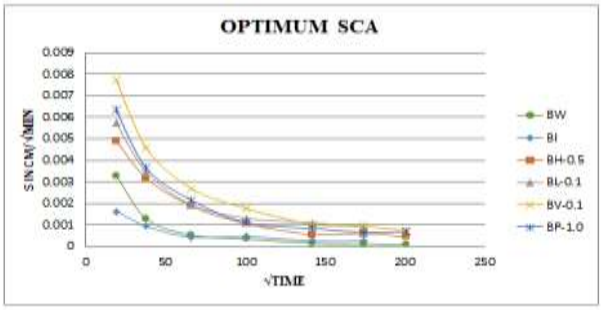
Sorptivity Coefficient Vs time$^{0.5}$ for PEG 200 of mix B



Sorptivity Coefficient Vs time$^{0.5}$ for LPWL of mix B



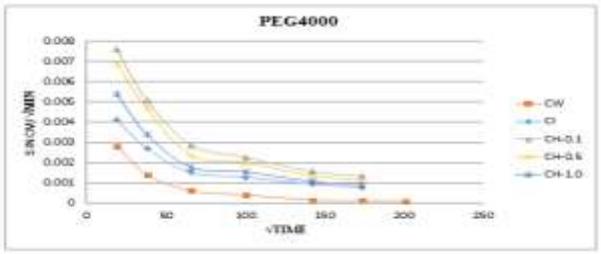
Sorptivity Coefficient Vs time$^{0.5}$ for LPWH of mix B



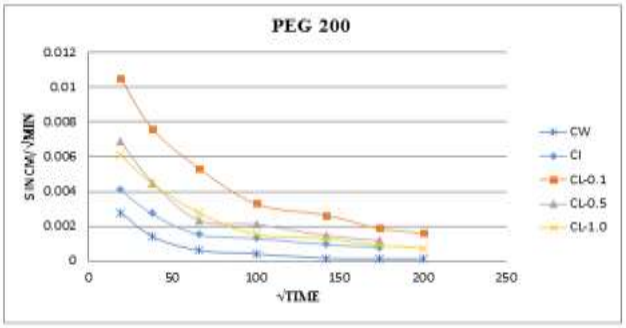
optimum dosage of self-curing compounds for mix B

Sorptivity values for Mix C

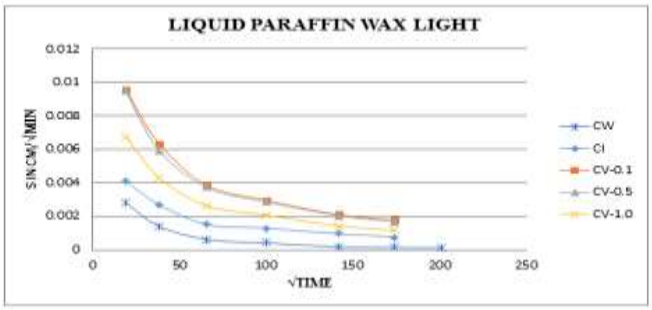
	18.97	37.94	65.72	100.39	141.98	173.89	200.79
CI	0.0063	0.0041	0.0027	0.0015	0.0013	0.0009	0.0008
CW	0.0028	0.0014	0.0006	0.0004	0.0002	0.0001	0.0001
CH-0.1	0.0108	0.0076	0.0051	0.0029	0.0023	0.0016	0.0013
CH-0.5	0.0101	0.0069	0.0047	0.0023	0.0020	0.0014	0.0012
CH-1.0	0.0084	0.0054	0.0034	0.0018	0.0015	0.0011	0.0009
CL-0.1	0.0105	0.0076	0.0053	0.0033	0.0026	0.0019	0.0016
CL-0.5	0.0101	0.0069	0.0045	0.0023	0.0021	0.0015	0.0012
CL-1.0	0.0061	0.0045	0.0028	0.0015	0.0013	0.0009	0.0007
CV-0.1	0.0141	0.0096	0.0064	0.0039	0.0029	0.0021	0.0018
CV-0.5	0.0143	0.0095	0.0060	0.0037	0.0028	0.0020	0.0017
CV-1.0	0.0101	0.0068	0.0043	0.0026	0.0021	0.0014	0.0012
CP-0.1	0.0171	0.0100	0.0063	0.0040	0.0030	0.0022	0.0019
CP-0.5	0.0103	0.0061	0.0034	0.0021	0.0017	0.0013	0.0012
CP-1.0	0.0148	0.0085	0.0055	0.0035	0.0027	0.0020	0.0017



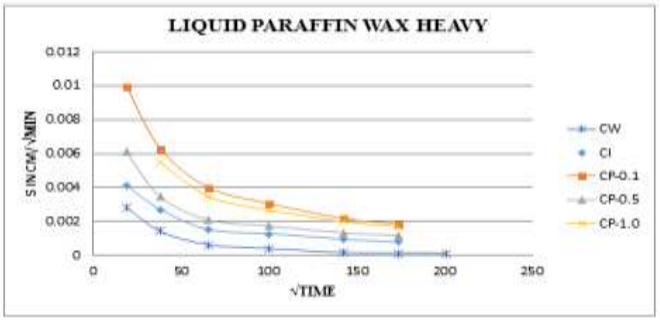
Sorptivity Coefficient Vs time$^{0.5}$ for PEG 4000 of mix C



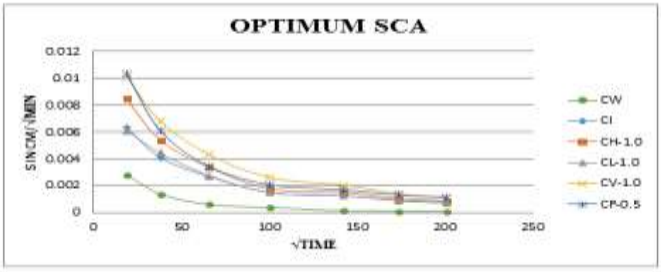
Sorptivity Coefficient Vs time$^{0.5}$ for PEG 200 of mix C



Sorptivity Coefficient Vs time$^{0.5}$ for LPWL of mix C



Sorptivity Coefficient and time$^{0.5}$ for LPWH of mix C



optimum dosage of self-curing compounds for mix C

CONCLUSION

Based on the experimental and analytical investigations, the following conclusions have been drawn:

1. There is a decrease in compressive strength of self-curing SCC with the increase in percentage of curing compounds for higher grade.
2. Higher dosage of curing compound is required for lower grades of self-curing SCC.
3. Resistance against acid attack decreased with increase in percentage dosage of self-curing compounds irrespective of grades.
4. 0.5% is optimum dosage to get better resistance against acid attack for all curing compounds.
5. Sorptivity decreased with decrease in dosage of PEG in both low and high molecular weights of PEG.
6. Sorptivity is lowest in higher grades of concrete and it is true for every percentage replacement of all the curing compounds.

This is true in case of general curing also.

7. In case of higher grades of concrete even in case of water cured specimens sorptivity is lowest.
8. 0.1% is optimum dosage for mix A considering all the factors viz., compressive strength, acid attack and sorptivity.
9. 0.1% of liquid paraffin wax is optimum for mix B.
10. 0.5% of Liquid paraffin wax heavy is optimum for mix C.

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