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AN EXPERIMENTAL STUDY ON MECHANICAL PROPERTIES OF SELF CURING CONCRETE

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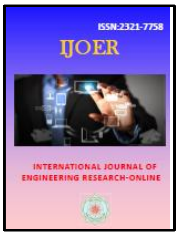


ABSTRACT

Concrete is recognised as a versatile construction material globally. As water is becoming a scarce material day-by-day, there is an urgent need to do research work pertaining to saving of water in making concrete and in constructions. Concrete is most widely used construction material due to its good compressive strength and durability. Depending upon the nature of work the cement, fine aggregate, coarse aggregate and water are mixed in specific proportions to produce plain concrete. Plain concrete needs congenial atmosphere by providing moisture for a minimum period of 28 days for good hydration and to attain desired strength. Any laxity in curing will badly affect the strength and durability of concrete. Self-curing concrete is one of the special concretes in mitigating insufficient curing due to human negligence paucity of water in arid areas, inaccessibility of structures in difficult terrains and in areas where the presence of fluorides in water will badly affect the characteristics of concrete.

The present study involves the use of shrinkage reducing admixture polyethylene glycol (PEG400) in concrete which helps in self curing and helps in better hydration and hence strength. In the present study, the effect of admixture (PEG400) on compressive strength, split tensile strength and modulus of rupture by varying the percentage of PEG by weight of cement from 0% to 2% were studied for M40. It was found that PEG400 could help in self curing by giving strength on par with conventional curing. It was also found that 1% of PEG400 by weight of cement was optimum for M40 grade concrete for achieving maximum strength without compromising workability.

Keywords: Compressive Strength, Durability, PEG-400, Self-Curing Concrete, Split Tensile Strength, Water Retention.

I. INTRODUCTION

Proper curing of concrete structures is important to meet performance and durability requirements. In conventional curing this is achieved by external curing applied after mixing, placing and finishing. Self-curing or internal curing is a technique that can be used to provide additional moisture in concrete for more effective hydration of cement and reduced self-desiccation.

The ACI-308 Code states that "internal curing refers to the process by which the hydration of cement occurs because of the availability of additional internal water that is not part of the mixing Water." Conventionally, curing concrete means creating conditions such that water is not lost from the surface i.e., curing is taken to happen 'from the outside to inside'. In contrast, 'internal curing' is allowing for curing 'from the inside to outside' through the internal reservoirs (in the form of saturated lightweight fine aggregates, super absorbent polymers, or saturated wood fibres) created. 'Internal curing' is often also referred as '**Self–curing**.'

When the mineral admixtures react completely in a blended cement system, their demand for curing water (external or internal) can be much greater than that in a conventional ordinary Portland cement concrete [10]. When this water is not readily available, due to depreciation of the capillary porosity, for example, significant autogenously deformation and (early-age) cracking may result.

Due to the chemical shrinkage occurring during cement hydration, empty pores are created within the cement paste, leading to a reduction in its internal relative humidity and also to shrinkage which may cause early-age cracking. This situation is intensified in HPC (compared to conventional concrete) due to its generally higher cement content, reduced water/cement (w/c) ratio and the pozzolanic mineral admixtures (fly ash, silica fume). The empty pores created during self-desiccation induce shrinkage stresses and also influence the kinetics of cement hydration process, limiting the final degree of hydration. The strength achieved by IC could be more than that possible under saturated curing conditions.

Often specially in HPC, it is not easily possible to provide curing water from the top surface at the rate required to satisfy the ongoing chemical shrinkage, due to the extremely low permeabilities often achieved.

II. BACKGROUND

Present-day self-curing concrete can be classified as an advanced construction material. As the name suggests, it does not require to be cured in water. This offers many benefits and advantages over conventional concrete. This includes an improved quality of concrete and reduction of autogenous shrinkage. The composition of Self Curing Concrete mixes includes substantial proportions of self curing agents and saturated recycled coarse aggregate and this gives possibilities for utilization of water inside concrete. The benefit from Self Curing Concrete can be expected when there is need for reduced construction time, quicker turnaround time in precast plants, lower maintenance cost, greater performance and predictability.The use of Self Curing Concrete ensures quality and durability of concrete. In the following, a summary of the articles and papers found in the literature, about the self compacting concrete and some of the projects carried out with this type of concrete, are presented.

Currently, there are two major methods available for internal curing of concrete. The first method uses saturated porous lightweight aggregate (LWA) in order to supply an internal source of water, which can replace the water consumed by chemical shrinkage during cement hydration. The second method uses poly-ethylene glycol (PEG) which reduces the evaporation of water from the surface of concrete and also helps in water retention. 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 polymers 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, thus reducing the rate of evaporation from the surface.

III. NEEDS AND ADVANTAGES

a. Internal curing (IC) is a method to provide the water to hydrate all the cement, accomplishing what the mixing water alone cannot do. In low w/c ratio mixes (under 0.43 and increasingly those below 0.40) absorptive lightweight aggregate, replacing some of the coarse aggregates, provides water that is desorbed into the mortar fraction (paste) to be used as additional curing water. The cement, not hydrated by low amount of mixing water, will have more water available to it.

b. IC provides water to keep the relative humidity (RH) high, keeping self-desiccation from occurring.

c. IC eliminates largely autogenous shrinkage.

d. IC maintains the strengths of mortar/concrete at the early age (12 to 72 hrs.) above the level where internally &

externally induced strains can cause cracking.

e. IC can make up for some of the deficiencies of external curing, both human related (critical period when curing is required in the first 12 to 72 hours) and hydration related (because hydration products clog the passageways needed for the fluid curing water to travel to the cement particles thirsting for water). Following factors establish the dynamics of water movement to the unhydrated cement particles:

 a. Thirst for water by the hydrating cement particles is very intense,
 b. Capillary action of the pores in the concrete is very strong

IV. LITERATURE REVIEW

Ole and Hansen described a new concept for the prevention of self-desiccation in hardening cement-based materials using fine, superabsorbent polymer (SAP)particles as a concrete admixture. The SAP will absorb water and form macro inclusions and this leads to water entrainment, i.e. the formation of water-filled macro pore inclusions in the fresh concrete. Consequently, the pore structure is actively designed to control self-desiccation. In this work, self-desiccation and water entrainment are described and discussed.

Roland Tak Yong Liang, Robert Keith Sun carried work on internal curing composition for concrete which includes a glycol and a wax. The invention provides for the first time an internal curing composition which, when added to concrete or other cementitious mixes meets the required standards of curing as per Australian Standard AS3799.

Wen-Chen Jau stated that self curing concrete is provided to absorb water from moisture from air to achieve better hydration of cement in concrete. It solves the problem when the degree of cement hydration is lowered due to no curing or improper curing by using self curing agent like poly-acrylic acid which has strong capability of absorbing moisture from atmosphere and providing water required for curing concrete.

A.S.El-Dieb investigated water retention of concrete using water-soluble polymeric glycol as self-curing agent. Concrete weight loss and internal relative humidity measurements with time were carried out, in order to evaluate the water retention of self-curing concrete.Water transport through concrete is evaluated by measuring absorption %, permeable voids %, water sorptivity and water permeability. The water transport through self-curing concrete is evaluated with age. The effect of the concrete mix proportions on the performance of self- curing concrete were investigated, such as, cement content and water/cement ratio.

PietroLura The main aim of his study was to reach a better comprehension of autogenous shrinkage in order to be able to modify and possibly reduce it. Once the important role of self-desiccation shrinkage in autogenous shrinkage is shown, the benefits of avoiding self-desiccation through internal curing become apparent.

V. METHODOLOGY

The methodology adopted to achieve the required objectives is presented below. In the present work the methodology adopted is as follows:

A. Characterization of materials
B. Scheme of experiments
C. Experimental procedure

A. Characterization of materials: The main constituents of the present investigation are Cement, Coarse aggregate, Water and Polyethylene Glycol-400 are used in present investigation.

Characteristics of Cement: Cement used in the investigation was 53grade ordinary Portland cement confirming IS 12269:1987.standards has been procured and various tests have been carried out according IS: 8112-1989 from them it is found that

a) Specific Gravity of Cement is 3.15
b) Initial and Final setting times of Cement are 50min and 480 min respectively
c) Fineness of cement is 6.0%

Characteristics of Coarse Aggregate: Crushed granite and RCA was used as coarse aggregate. The coarse aggregate according to IS: 383-1970 was used. Maximum coarse aggregate size used 20 mm. The details of particle size distribution and grading are given in table 1.

Table 1 Proportions of different size fractions of coarse aggregates

Sieve size (mm)	Weight retained (gm)	%Weight retained (%)	Cumulative % weight retained	% Passing	%passing Recommended By IS:383-1970
40	-	-	-	100	100
20	-	-	-	100	95-100
16	1.428	28.56	28.56	71.44	75-90
12.5	1.545	30.90	59.46	40.54	60-75
10	1.323	26.46	85.92	14.08	25-55
4.75	0.668	13.36	99.28	0.72	0-10

Crushed granite was used as coarse aggregate. The coarse aggregate according to IS:383-1970 was used. Maximum coarse aggregate size used is 20 mm.

Characteristics of Fine Aggregate: The fine aggregate conforming to zone III according to IS: 383-1970 was used. The fine aggregate used was obtained from a near river source. The specific gravity of the sand used was 3.00. The sand obtained was sieved as per IS sieves (i.e. 475, 2.36, 1.18, 600, 300, and 150µ). The details of particle size distribution and grading are given in table 2.

Table 2 Proportions of different size fractions of sand

Sieve size (mm)	Weight retained (gm)	%Weight retained (%)	Cumulative % weight Retained	% Passing	%passing Recommended By IS:383-1970
4.75	7	1.4	1.4	98.60	90-100
2.36	12	2.4	3.8	96.20	75-100
1.18	20	4.0	7.8	92.20	55-90
0.60	65	13.0	20.8	79.00	35-59
0.30	292	58.4	79.2	30.00	8-30
0.15	90	18.0	97.20	2.80	0-10

The fine aggregate used was obtained from a nearby river source. The fine aggregate conforming to zone III according to IS:383-1970 was used.

Characteristics of Water: Water used for mixing concrete should be free from impurities that could adversely affect the process of hydration and, consequently, the properties of concrete. BS EN 1008 specifies requirements for the water and gives procedures for checking its suitability for use in concrete. Drinking water is suitable, and it's usually simply to obtain from local water utility. Some recycled water is being increasing by used in the interest of reducing the environment impact of the concrete production. Some organic matter can cause retardation, while chloride may not only accelerate the stiffening process but also cause embedded steel.

Characteristics of Polyethylene Glycol-400: Polyethylene glycol is a condensation polymer of ethylene oxide and water with the general formula $H(OCH_2CH_2)_nOH$, where n is the average number of repeating oxy-ethylene 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. The PEG-400 used in the investigation have Molecular Weight400, Appearance Clear liquid, pH5-7, Specific Gravity1.126

B. Scheme of experiments: The detailed scheme of experiments, formulated to meet the objectives stated in the Chapter-1 is presented in this section

C. Experimental Procedure

Procedure for Slump Cone test

1. Dampen the slump test mold and place it on a flat, moist, nonabsorbent, rigid surface, like a steel plate.
2. Fill the mold to 1/3 full by volume (about 2 1/2 inches), and rod the bottom layer with 25 evenly spaced strokes.

3. Fill the mold to 2/3 full (about 6 inches), and rod the second layer with 25 strokes penetrating the top of the bottom layer.
4. Heap the concrete on top of the mold, and rod the top layer with 25 strokes penetrating the top of the second layer.
5. Strike off the top surface of the concrete even to the top of the mold.
6. Remove the mold carefully in the vertical direction (take about five seconds).
7. Immediately invert and place the mold beside the slumped concrete and place the rod horizontally across the mold, and measure the slump, in inches, to the nearest 1/4 inch.

Compressive Strength Test

Compressive strength of pervious concrete is usually found to be lower than conventional concrete due to its high porosity. Compressive strengths are in the range of 500 psi to 4000 psi (3.5-28 MPa).For each series of tests, a set of standard size cube were made. The size ofcube 150×150×150 mm was made for compressive strength measurement as shown in Figure. The cube were tested in different curing days (3, 14, 28& 56 -days) in accordance with thetest procedures given in the Indian Standard IS: 516-1959.

Split tensile strength

i. Take mix proportion as 1:0.9:2.25 with water cement ratio of 0.375. Mix them thoroughly until uniform colour is obtained. This material will be sufficient for casting three cylinders of the size 150mm diameter X 300mm length.
ii. In mixing by hand cement and fine aggregate be first mixed dry to uniform colour and then coarse aggregate is added and mixed until coarse aggregate is uniformly distributed throughout the batch. Now the water shall be added and the ingredients are mixed until resulting concrete is uniform in colour. Mix at least for two minutes.
iii. Pour concrete in moulds oiled with medium viscosity oil. Fill the cylinder mould in four layers each of approximately 75 mm and ram each layer more than 35 times with evenly distributed strokes.
iv. Remove the surplus concrete from the top of the moulds with the help of the trowel.
v. Cover the moulds with wet mats and put the identification mark after about 3 to 4 hours. Remove the specimens from the mould after 24 hours and immerse them in water for the final curing. The test are usually conducted at the age of 7-28 days. The time age shall be calculated from the time of addition of water to the dry ingredients.
vi. Test at least three specimens for each age of test as follows
   a) Draw diametrical lines on two ends of the specimen so that they are in the same axial plane.
   b) Determine the diameter of specimen to the nearest 0.2 mm by averaging the diameters of the specimen lying in the plane of premarked lines measured near the ends and the middle of the specimen. The length of specimen also shall be taken be nearest 0.2 mm by averaging the two lengths measured in the plane containing pre marked lines.
   c) Centre one of the plywood strips along the center of the lower platen. Place the specimen on the plywood strip and align it so that the lines marked on the end of the specimen are vertical and centered over the plywood strip. The second plywood strip is placed length wise on the cylinder centered on the lines marked on the ends of the cylinder.
   d) The assembly is positioned to ensure that lines marked on the end of specimen are vertical and the projection of the plane passing through these two lines interest the center of the platen.
   e) Apply the load without shock and increase it continuously at the rate to produce a split tensile stress of approximately 1.4to 2.1 $N/mm^2/min$, until no greater load can be sustained. Record the maximum load applied to specimen.
   f) Note the appearance of concrete and any unusual feature in the type of failure.

g) Compute the split tensile strength of the specimen to the nearest 0.25 N/mm^2.

The cylinder specimens were tested on compression testing machine of capacity 3000KN.The bearing surface of machine was wiped off clean and looses other sand or other material removed from the surface of the specimen. 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 specimen was recorded.

fsplit=2 P/πDL, where P=load, D = diameter of cylinder, L= length of the cylinder

Modulus of Rupture

1. The arrangement for flexural strength test is shown in Figure-1.
2. Automatic universal testing machine was used for this test according to BS1881-118 [12].
3. Beam samples measuring 700×150×150mm were moulded and stored in water for 28days before test for normal concrete and self-curing concrete cubes placed in shade for 28days before test flexural strength.
4. Three similar samples were prepared for mix proportion. The casting was made by filling each mould with freshly mixed concrete in three layers.
5. Each layer was compacted manually using a 25mm diameter steel tamping rod to give 150 strokes on a layer.
6. The hardened beam was placed on the universal testing machine simply supported over a span 3times the beam depth on a pair of supporting rollers.
7. Two additional loading rollers were placed on top the beam as shown in Figure-1. The load was applied without shock at a rate of 200m/s.

VI. RESULTS AND DISCUSSIONS

Slump and Compaction factor test: The results of the Slump & Compaction factor test were represented inTable5.The graphical representation of the Slump & Compaction factor results is shown in Fig4 respectively. As the % of PEG400 is increased the slump and compaction factor is found to increase.

Table .3. Results of Workability

Sl. No	PEG400	Slump (mm)	Compaction factor
1	Plain	80	0.88
2	0.50%	112	0.91
3	1.00%	120	0.92
4	1.50%	140	0.93

Compressive Strength

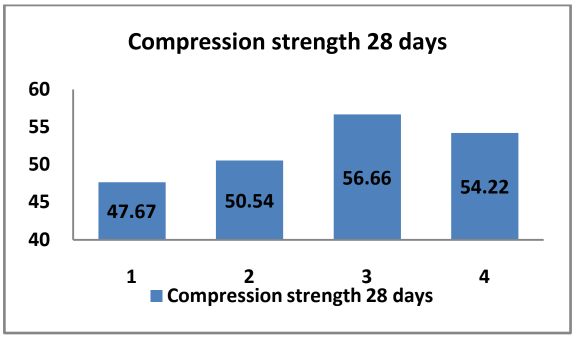
The results of compressive strength are represented increase upto 0.5 % PEG400 and then decreased for M40 grade

In our project, we are considering the following coding.

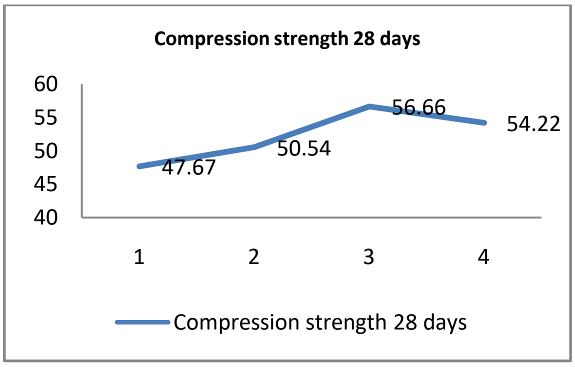
C - Conventional concrete
S1 - Combination of 0.5% PEG400
S2 - Combination of 1% PEG 400
S3 - Combination of 1.5% PEG 400

Table .4. Results of Compression strength test

Codings	Compressive strength for 3 days(MPa)				Compressive strength for 7 days(MPa)				Compressive strength for 28 days(MPa)			
	Cube no				Cube no				Cube no			
	1	2	3	Avg	1	2	3	Avg	1	2	3	Avg
C	38.88	37.55	39.56	38.66	42.33	43.44	42.15	42.64	48.77	47.08	47.15	47.67
S1	41.88	42.11	40.18	41.39	43.78	44.33	43.65	43.92	49.88	50.12	51.62	50.54
S2	43.64	44.55	43.2	43.8	47.33	46.18	48.1	47.2	55.27	56.62	57.78	56.66
S3	40.64	41.55	42.2	41.46	44.33	43.18	44.1	43.87	52.27	54.62	55.78	54.22



Graph 1 : Bar chart showing different admixtures M40 mix compressive strength



Graph2:Graph sheet showing different admixtures M40 mix(compressive strength)

Split Tensile Strength:

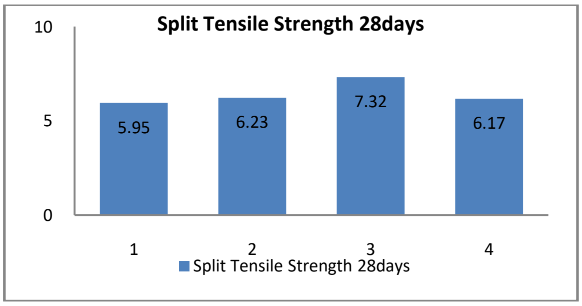
The results of split tensile strength are represented o increase upto 0.5% PEG400 and then decreased for M40 grade

In our project, we are considering the following coding.

C - Conventional concrete
S1 - Combination of 0.5% PEG400
S2 - Combination of 1% PEG 400
S3 - Combination of 1.5% PEG 400

Table .5. Results of Compression strength test

Codings	Tensile strength for 3 days(MPa)				Tensile strength for 7 days(MPa)				Tensile strength for 28 days(MPa)			
	Cylinder no				Cylinder no				Cylinder no			
	1	2	3	Avg	1	2	3	Avg	1	2	3	Avg
C	3.06	2.96	3.18	3.07	3.94	4.12	4.26	4.11	5.68	6.04	6.12	5.95
S1	3.69	4.1	4.62	4.14	5.02	5.26	5.48	5.25	6.24	6.36	6.08	6.23
S2	4.94	5.14	5.26	5.11	6.25	6.36	6.87	6.49	7.02	7.25	7.68	7.32
S3	4.12	4.06	4.22	4.13	4.98	5.01	5.14	5.04	6.1	6.04	6.36	6.17



Graph2:Graph Bar chart showing different admixtures M40 mix Split Tensile strength

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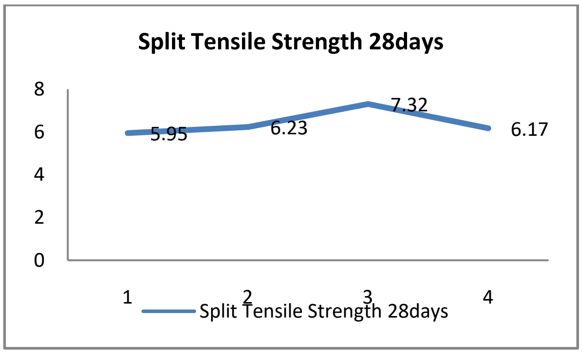


Graph 4: Graph sheet showing different admixtures M40 mix(Split Tensile strength)

Flexural Strength

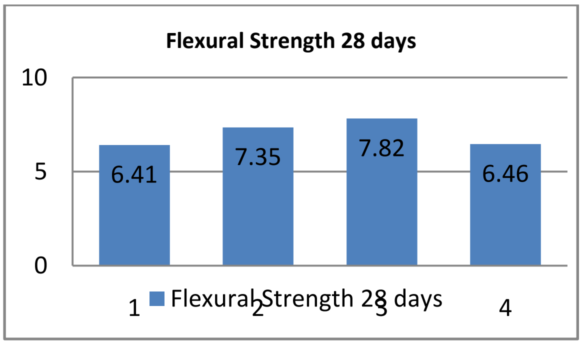
The results of Flexural strength are represented The increase upto 0.5% PEG400 and then decreased for M40 grade .

In our project, we are considering the following coding.

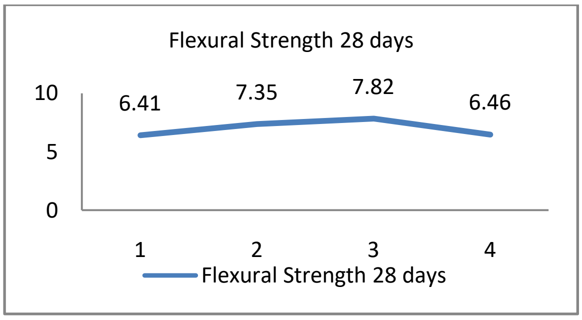
C - Conventional concrete
S1 - Combination of 0.5% PEG400
S2 - Combination of 1% PEG 400
S3 - Combination of 1.5% PEG 400

Table .6. Results of Compression strength test

Codings	Tensile strength for 3 days(MPa)				Tensile strength for 7 days(MPa)				Tensile strength for 28 days(MPa)			
	Beam No				Beam No				Beam No			
	1	2	3	Avg	1	2	3	Avg	1	2	3	Avg
C	3.76	3.96	3.48	3.73	4.01	4.72	4.96	4.56	5.98	6.64	6.36	6.41
S1	4.1	4.26	4.98	4.45	5.84	5.98	6.21	6.01	6.98	7.08	7.28	7.35
S2	5.02	5.64	5.36	5.34	6.65	6.76	7.02	6.87	7.22	7.65	8.06	7.82
S3	4.02	4.18	4.56	4.25	5.24	5.56	5.06	5.47	6.26	6.38	6.74	6.46



Graph 5: Graph Bar chart showing different admixtures M40 mix Flexural strength



Graph 6: Graph sheet showing different admixtures M40 mix(Flexural strength)

VII. CONCLUSION

1. The optimum dosage of PEG400 for maximum strengths (compressive, tensile and modulus of rupture) was found to be 1% for M40.
2. As percentage of PEG400 increased slump increased for M0 grade of concrete.
3. Strength of self curing concrete is on par with conventional concrete.
4. Self curing concrete is the answer to many problems faced due to lack of proper curing.

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