STRENGTH CHARACTERISTICS OF SELF-CURING CONCRETE USING POLYETHYLENE GLYCOL (PEG)

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ABSTRACT

Today 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 (PEG 400) in concrete which helps in self curing and helps in better hydration and hence strength. In the present study, the affect of admixture (PEG 400) 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 both for M20 and M40 mixes. It was found that PEG 400 could help in self curing by giving strength on par with conventional curing. It was also found that 1% of PEG 400 by weight of cement was optimum for M20, while 0.5 % was optimum for M40 grade concretes for achieving maximum strength without compromising workability.

Index Termss: Self-curing concrete; Water retention; Relative humidity; Hydration; Absorption; Permeable pores; Sorptivity; Water permeability

2. INTRODUCTION

Adequate curing is essential for concrete to obtain structural and durability properties and therefore is one of the most important requirements for optimum concrete performance. Curing of concrete is the process of maintaining the proper moisture conditions to promote optimum cement hydration immediately after placement. With insufficient water, the hydration will not proceed and the resulting concrete may not possess the desirable strength and impermeability. The near surface region of concrete is particularly affected, failing to provide a protective barrier against ingress of harmful agents. Proper curing of concrete structures is important to meet performance and durability requirements. Enough water needs to be present in a concrete mix for the hydration of cement to take place. However, even mix contains enough water, any loss of moisture from the concrete will reduce the initial water cement ratio and result in incomplete hydration of cement especially with the mixes having low water cement ratio. This results in very poor quality of concrete.

Proper curing of concrete structures is impotant to meet performance and durability requirements.inconventional 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

2.1 Methods of Conventional Curing

Methods of curing concrete fall broadly into the following categories:

- Ponding or spraying
- By using covering of wet hessian.
- Reducing the rate of evaporation of water from concrete surface by covering with a relatively impermeable membrane.
- Delaying the removal of formwork can also be used to retain some water.
- Steam curing.

2.2 Difficulties in conventional curing methods

- For the vertical member it is not possible to keep the surface moist as in case of the flat surfaces.
- In the places where there is scarcity of water.
- In the places where manual curing is not possible.
- A human error may lead to the formation of crack in the member and hence affects strength and durability.

3. Self-curing

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, superabsorbent polymers, or saturated wood fibers) Created. 'Internal curing' is often also referred as 'Self–curing.

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 concept of self-curing agents is to reduce the water evaporation from concrete, and hence increase the water retention capacity of the concrete compared to conventional concrete. It was found that water soluble polymers can be used as self-curing agents in concrete. Curing of concrete plays a major role in developing the concrete microstructure and pore structure and hence improves its durability and performance.

3.1 Methods of self curing

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.

3.2 Mechanism of Internal Curing

According to R.T.Y Liang and R.K Sun, 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.

3.3 Need for 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. When this water is not readily available, significant autogenous 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).

3.4 Potential Materials for Internal Curing (IC)

The following materials can provide internal water reservoirs:

- Lightweight Aggregate (natural and synthetic, expanded shale)
- Super-absorbent Polymers (SAP) (60-300 nm size)
- SRA (Shrinkage Reducing Admixture)
- Wood powder.

3.5 Benefit of self-curing

- Internal curing (IC) is a method to provide the water to hydrate all the cement, accomplishing what the mixing water alone cannot do.
- Provides water to keep the relative humidity (RH) high, keeping self-desiccation from occurring.
- Eliminates largely autogenous shrinkage.
- 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.
- Can make up for some of the deficiencies of external curing, both human related and hydration related.

3.6 Chemicals to Achieve Self–curing

Some specific water-soluble chemicals added during the mixing can reduce water evaporation from and within the set concrete, making it 'self-curing.' The chemicals should have abilities to reduce evaporation from solution and to improve water retention in ordinary Portland cement matrix. Followings are some of the chemicals which are hydrophilic in nature.

i. Polyvalent alcohol
ii.Polyethylene glycol (PEG)
iii.Poly-acrylic acid
iv.Xylitol, sorbitol
v.Glycerine
vi.Phytosterols
vii. Hyaluronic acid
viii Polyxyelhylene (POE)
ix Stearyl alcohol
x Cetyl alcohol
xi Urethanes
xii Sodium pyrrolidone carboxylate (PCA- Na)

4. SCOPE AND OBJECTIVE

1. The scope of the paper is to study the effect of polyethylene glycol 400 on strength characteristics of Self-curing concrete.
2. The objective is to study the mechanical characterstics of concrete such as compressive strength,, split tensile strength and modulus of rupture by varying the percentage of PEG from 0.1% to 2% by weight of cement for both M20 and M40 grades of concrete.

5. Materials Used

The different materialsused in this investigation are

i. Cement

The cement used in the investigation was 53-grade Ordinary Portland Cement and Portland Pozzolana Cement conforming to IS:12269-1987and IS:1489-1991 respectively.

ii. Fine Aggregate

The fine aggregateused wasobtained froma nearby river course. The fineaggregate conforming tozone-II according to IS 383-1970 was used. The sand was sievedthrougha set ofsieves (i.**e.** 2.36mm,1.18mm, 600µ, 300µ and150µ). Sand retained on each sievewas filled in different bags and stacked separately. To obtain zone- II sand correctly, sand retained on each sieve is mixed in appropriate proportion. The physical properties of fine aggregate and proportionin whicheach size fraction is mixed is shown in table 1 & 2 respectively.

Table 1 Physical Properties of fine aggregate

Fineness modulus	2.80
Bulk density	1.39gm/cc
Specific gravity	2.6

Table 2 Proportions of different size fractions of sand obtain zone-II sand

Sieve size (mm)	% Passing Recommended by IS:383	Adopted Grading.	Cumulative (%) weight Retained	%Weight Retained	Weight Retained in (gm)
10	100	100	-	-	-
4.75	90-100	100	-	-	-
2.36	75-100	85	15	15	150
1.18	55-90	70	30	15	150
600µ	35-59	45	55	25	250
300µ	8-30	10	90	35	350
150µ	0-10	0	100	10	100

iii. Coarse Aggregates:

The coarse aggregate used is from a local crushing unit having 20mm nominal size. 20mm well-graded aggregate according to IS-383 is used in this investigation. The coarse aggregate procured from quarry was sieved through all the sieves (i.e. 20mm, 16mm, 12.5mm. 10mm and 4.75mm). The material retained on each sieve was filled in bags and stacked separately. To obtain 20mm well-graded aggregate, coarse aggregate retained on each sieve is mixed in appropriate proportions. The physical properties and proportions in each fraction are shown in table 3&4 respectively.

Table 3 Physical properties of coarse aggregate

Fineness modulus	7.35
Bulk density	1.59gm/cc
Specific gravity	2.67

Table 4 Proportions of different size fraction of coarse aggregate to obtain 20mm well-graded aggregate

Sieve size (mm)	% Passing Recommended by IS-383	Adopted Grading	Cumulative (%)Weight Retained	% Weight Retained	Weight Retained In(gm)
40	100	100	-	-	-
20	95-100	100	-	-	-
16	67-82	70	30	30	3000
12	42-66	45	55	25	2500
10	25-55	30	70	15	1500
4.75	0-10	0	100	30	3000

iv. Polyethylene glycol (PEG)

Polyethylene glycol is a condensation polymers of ethylene oxide and water with the general formula $H(OCH_2CH_2)_nOH$, where n is the average number of repeating oxyethylene groups typically from 4 to about 180. The low molecular weight members from n=2 to n=4 are diethylene glycol, triethylene glycol and tetraethylene glycol respectively, which are produced as pure compounds. The low molecular weight compounds up to 700 are colourless, odourless viscous liquids with a freezing point from 10 °C (diethylene glycols), while polymerized compounds with higher molecular weight than 1,000 are wax like solids with melting point up to 67 °C for n 180. The abbreviation (PEG) is termed in combination with a numeric suffix which indicates the average molecular weights. One common feature of PEG appears to be water-soluble. The specifications of PEG 200 & PEG 4000 are shown in table 5.

It is also soluble in many organic solvents including aromatic hydrocarbons (not aliphatic). They are used to make emulsifying agents and detergents, and as plasticizers, humectants, and water-soluble textile lubricants.

Polyethylene glycol is non-toxic, odourless, neutral, lubricating, non-volatile and no irritating and is used in a variety of pharmaceuticals and in medications as a solvent, dispensing agent, ointment and suppository bases, vehicle, and tablet excipient. The chemical structure of PEG is shown below.

Polyethylene glycol is produced by the interaction of ethylene oxide with water, ethylene glycol or ethylene glycol oligomers.

6. EXPERIMENTAL PROGRAMME

The experimental program was designed to investigate the strength of self curing concrete by adding poly ethylene glycol PEG400 @ 0.5%, 1%, 1.5% and 2% by weight of cement to the concrete. The experimental program was aimed to study the workability, compressive strength, split tensile strength and modulus of rupture. To study the above properties mixes M20 and M40 were considered. The scheme of experimental program is given in Table No.1

SL. No	Nature	M20			M40		
		Cube *	Cylinder #	Prism$	Cube	Cylinder	Prism
1	Plain	3	3	3	3	3	3
2	0.5%	3	3	3	3	3	3
3	1%	3	3	3	3	3	3
4	1.5%	3	3	3	3	3	3
5	2%	3	3	3	3	3	3

*The size of each cube is 150 x150 x150 mm. # The size of each cylinder is 150 mm in dia and 300 mm in height. $ The size of each prism is 100 x100 x400 mm **Table 1:** Details of specimens cast.

6.1 CASTING PROGRAMME:

Casting of the specimens were done as per IS:10086-1982, preparation of materials, weighing of materials and casting of cubes, cylinders, beams.

The mixing, compacting and curing of concrete are done according to IS 516: 1959. The plain samples of cubes, cylinders and prisms were cured for 28 days in water pond and the specimens with PEG400 were cured for 28 days at room temperature by placing them in shade. The M20 and M40 grades of concrete are designed and the material required per cubic meter of concrete is shown in Table 2.

SL. No	Mix	Cement (kg)	Fine Aggregate (kg)	Coarse Aggregate (kg)	Water (kg)
1	M20	340	610	1300	187
2	M40	440	520	1220	154

Table 2: Materials required per cubic meter of concrete

6.2 TESTING

6.2.1 Slump Test & Compaction Factor.

Slump test is the most commonly used method of measuring consistency of concrete which can be employed either in laboratory or at site of work. It does not measure all factors contributing to workability. However, it is used conveniently as a control test and gives an indication of the uniformity of concrete from batch to batch. The compacting factor test is designed primarily for use in the laboratory but it can also be used in the field. It is more precise and sensitive than the slump test and particularly useful for concrete mixes of very low workability as are normally used when concrete is to be compacted by vibration. Such dry concretes are insensitive to slump test.

6.2.2 Compressive strength:

The cube specimens were tested on compression testing machine of capacity 3000KN.The bearing surface of machine was wiped off clean and sand or other material removed from the surface of the specimen. The specimen was placed in machine in such a manner that the load was applied to opposite sides of the cubes as casted that is, not top and bottom. The axis of the specimen was carefully aligned at the centre of 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 specimen was recorded. fc = P/A , where, P is load & A is area

6.2.3 Split tensile strength:

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

7.4 Modulus of rupture:

$f_{rup.} = (3Wa)/(bd^2)$, where W = load at failure,
L = length of specimen (400mm)
b = width of specimen (10mm),
d=depth of specimen (100mm)

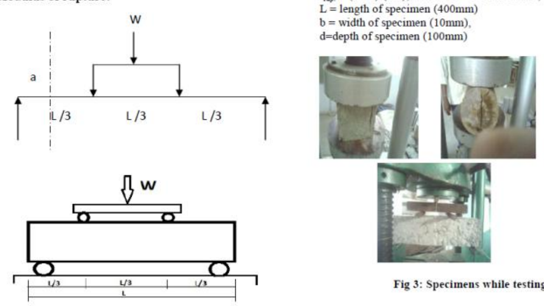

Fig 3: Specimens while testing

The beam specimens were tested on universal testing machine for two-point loading to create a pure bending. The bearing surface of machine was wiped off clean and sand or other material is removed from the surface of the specimen. The two point bending load applied was increased continuously at a constant rate until the specimen breaks down and no longer can be sustained. The maximum load applied on specimen was recorded. The test set–up is shown in Fig. 2. The modulus of rupture depends on where the specimen breaks along the span. The specimens while testing compressive strength, split tenslie & Modulus of ruptrure is shown in Fig 3.

7. RESULTS & DISCUSSION

7.1 Slump and Compaction factor test:

The results of the Slump & Compaction factor test were represented in Table 3. The graphical representation of the Slump & Compaction factor results is shown in Fig 4 and Fig 5 respectively. As the % of PEG400 is increased the slump and compaction factor is found to increase. But, the rate of increase of slump & compaction factor for M40 concrete is less than that of M20 plain concrete

Sl. No	PEG 400	Slump (mm)		Compaction Factor	
		M20	M40	M20	M40
1	Plain	80	45	0.88	0.85
2	0.50%	92	65	0.90	0.87
3	1.00%	112	95	0.91	0.90
4	1.50%	140	130	0.93	0.91
5	2.00%	175	160	0.96	0.94

Table 3: Results of Workability

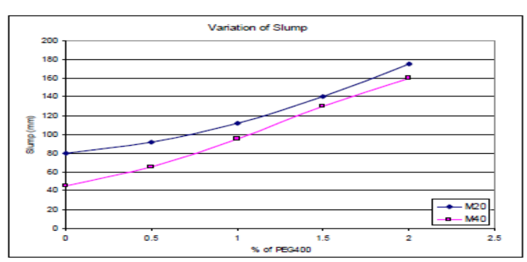

Fig 4. Variation of Slump

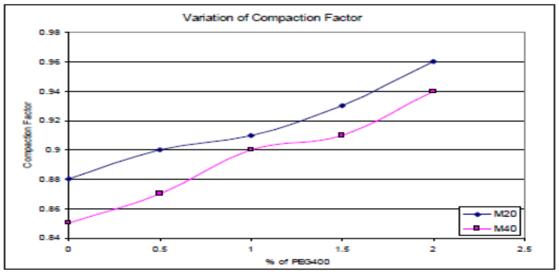

Fig 5. Variation of Compaction Factor

7.2 Compressive Strength:

The results of the compressive strength are represented in Table 4 and the graphical representation is shown in Fig 6. The compressive strength was found to increase up to 1% PEG400 and then decreased for M20 grade. In the case of M40 compressive strength increased up to 0.5% and then decreased. The increase in compressive strength was 7.23% at 1% of PEG 400 compared to conventional concrete for M20, while the increase is 1.24% at 0.5% of PEG400 in case of M40 grade of concrete.

Sl. No	PEG	f_c (N/mm²) M20	f_c (N/mm²) M40	f_{split} (N/mm²) M20	f_{split} (N/mm²) M40	f_{rup} (N/mm²) M20	f_{rup} (N/mm²) M40
1	Plain	26.60	46.65	1.81	2.42	3.50	4.62
2	0.50%	27.61	47.23	1.96	2.50	3.75	4.75
3	1.00%	28.49	45.93	2.02	2.45	3.80	4.64
4	1.50%	26.74	44.62	1.92	2.34	3.68	4.53
5	2.00%	25.03	42.44	1.83	2.25	3.55	4.46

Table 4: Mechanical Properties

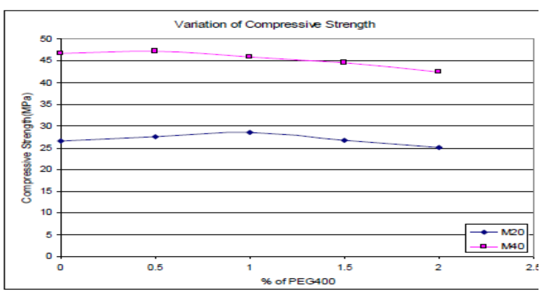

Fig 6. Variation of Compressive Strength

7.3 Split Tensile Strength:

The results of the split tensile strength are represented in Table 4 and the graphical representation is shown in Fig 7. The split tensile strength was found to increase up to 1% PEG400 and then decreased for M20 grade. In the case of M40 split tensile strength increased up to 0.5% and then decreased. The increase in split tensile strength was 11.60% at 1% of PEG400 compared to conventional concrete for M20, while the increase is 3.30% at 0.5% of PEG400 in case of M40 grade of concrete.

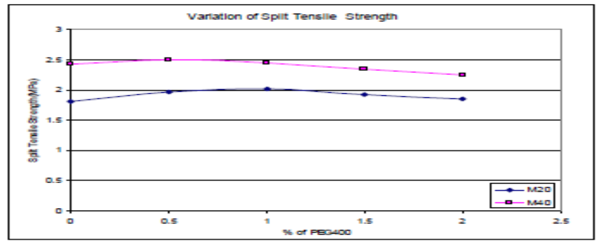

Fig 7. Variation of Split Tensile Strength

7.4 Modulus of rupture:

The results of the modulus of rupture are represented in Table 4 and the graphical representation is shown in Fig 8. The modulus of rupture was found to increase up to 1% PEG400 and then decreased for M20 grade. In the case of M40 modulus of rupture increased up to 0.5% and then decreased. The increase in modulus of rupture was 8.57% at 1% of PEG 400 compared to conventional concrete for M20, while the increase is 2.81% at 0.5% of PEG400 in case of M40 grade of concrete.

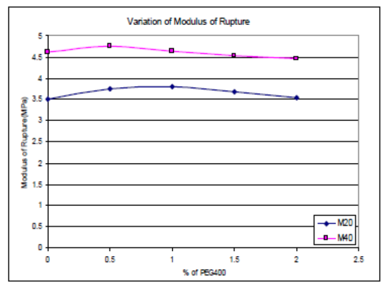

Fig 8. Variation of Modulus of Rupture

8.CONCLUSIONS:

1. The optimum dosage of PEG400 for maximum strengths (compressive, tensile and modulus of rupture) was found to be 1% for M20 and 0.5% for M40 grades of concrete.
2. As percentage of PEG400 increased slump increased for both M20 and M40 grades 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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