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Self-Curing of Concrete by Polyethylene Glycol and Epoxy Resin

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Abstract : Curing of concrete means maintaining optimum moisture content in concrete during its early stages in order to attain the desired characteristic properties. Proper curing is not possible in many cases due to human negligence, inaccessibility of structures and in areas where fluoride presence is more in water. The self-curing method reduces the water evaporation and helps the concrete to attain its strength and durability. Therefore water remains in the concrete when compared to conventional concrete. Water resources are getting valuable nowadays $1m^3$ of concrete needs $3m^3$ of water especially for the curing process. The benefit of self-curing admixture is very significant in water scarce areas where water is insufficient. The admixture is a water soluble polymer. The heat of hydration is slowed down by the epoxy resin. In this study, the mechanical properties of polymer added (2 percentage by the weight of cement) with the normal conventional concrete.
Index Terms : self-curing concrete; water retention; Hydration; polyethylene Glycol; Epoxy resin.

1.0 Introduction

Curing is used for promoting the hydration of the cement and controls the temperature, moisture movement from and into the concrete. Curing allows continuous hydration of cement and promotes continuous gain in the strength, once curing stops, strength gain of the concrete also stops. Proper curing of concrete structures is important to meet performance and durability requirements. In conventional curing process, this is achieved by external curing applied after mixing, placing and finishing.

Self-curing is a technique that can be used to provide additional moisture in concrete for effective hydration of cement and reduced self-desiccation. When concrete is exposed to the environment vapourization of water takes place[1]. The moisture loss will reduce the water cement ratio initially which will result in the incomplete hydration of the cement and hence lowering the quality of the concrete. In the initial stage hydration leads to plastic shrinkage cracking and at the final stage it leads to drying shrinkage cracking. Curing temperature is one of the major factors that affect the strength development rate.

1.1 Need for Self- Curing

Curing water is very much essential, when the complete reaction of mineral admixture in a blended cement system. During the hydration of cement, chemical shrinkage occurs and empty pores are created within the cement paste and lead to a reduction in internal relative humidity which may cause early age cracking[2]. The empty pores created during self-desiccation induce shrinkage stresses and also influence the cement hydration process, limiting the final degree of hydration.

1.2 Mechanism of Self-Curing

The difference in the chemical potentials (free energy) between the vapour and liquid phases cause continuous evaporation of moisture from an exposed surface. The reduction in the chemical potential of the water molecules, vapor pressure reduction in the rate of evaporation from the surface are due to the polymers added in the mix thus it forms hydrogen bonds with water molecules[3,4].

1.3 Materials for Self-Curing

The following materials are used

- Coarse Aggregate (natural 20 mm)
- SRA (Shrinkage Reducing Admixture) (propylene glycol type i.e. polyethylene-glycol)
- epoxy resin (polymer)

1.4 Advantages of Self-Curing

- Self-curing (SC) is a method to provide the water to hydrate all the cement, accomplishing what the mixing water alone cannot do.
- It provides water to keep the relative humidity (RH) high,
- It keeps self-desiccation from occurring.
- Eliminates largely autogenous shrinkage.
- Self-curing reduces labour cost on site.
- Suitable for the areas where water is scarce.

1.5 Polyethylene Glycol

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 oxyethylene group. Polyethylene glycols (PEG), also known as Polyethylene Oxide (PEO) or Polyethylene (POE), are the most commercially important Polyether's used as self-curing agents. PEG, PEO or POE refers to an Oligomer or polymer of ethylene Oxide[5]. The three names chemically synonymous, but historically PEG has tended to refer to Oligmers and Polymers with a molecular mass below 20,000 g/mol, PEO refers to polymers with a molecular mass below above 20,000 g/mol and POE refers to polymers of any molecular mass PEG and PEO are prepared by polymerisation of Ethylene Oxide and are commercially available over a wide range of molecular weights from 300 g/mol to 10,000,000 g/mol.PEG of different molecular weights find using different applications and have different physical properties (e.g. viscosity) due to chain length effects, their chemical properties are nearby identical. Different forms of PEG are also available dependent on the initiator used for the polymerisation process. PEGs are also available with the different geometries[6]. PEGs have 3 to 10 PEG chains emanating from a central core group. Star PEGs have 10 -100 PEG chains emanating from a central core group. Comb PEGs have multiple PEG chains conventionally grafted to a Polymer backbone. Their melting points vary depending on the formula weight of the polymer. PEG 400 has shown in fig 1.

Fig 1. Polyethylene glycol

1.6 Epoxy Resin

Epoxy resins are a class of thermoset material used extensively in structural and specialty composite application because they offer a unique combination of properties that are unattainable with other thermoset resins available in a wide variety of physical forms from low viscosity liquids to high melting solids. Epoxy offer high strength, low shrinkage, excellent adhesion to the various substrate, effective electrical insulation, chemical and solvent resistance, low cost and low toxicity[7]. They are easily used without the evaluation of volatile or by-products by a broad range of chemical specie. Epoxy resin is chemically compatible with most substrates and tends to wet surfaces easily, making them especially well suited to composite applications.

2.0 Scope and Objective

• The scope of the paper is to study the effect of polyethylene glycol (PEG 400) on strength characteristics of Self-curing concrete.

• The objective is to study the mechanical properties of concrete such as compressive strength, split tensile strength by varying the percentage of PEG from 0% to 2% by weight of cement for M25 grade of concrete

3.0mix Proportion Designations

The method of expressing the proportions of ingredients of a concrete mix is in the terms of parts or ratios of cement, fine and coarse aggregates. For e.g., a concrete mix of proportions 1:1:2 means that cement, fine and coarse aggregate are in the ratio 1:1:2 or the mix contains one part of cement, one part of fine aggregate and two parts of coarse aggregate. The proportions are by volume or by mass [8]. The water-cement ratio is usually expressed in mass.

4.0 Experimental Programme

The investigation of the strength of self-curing concrete was done by adding polyethylene glycol (PEG400) at 2% by weight of cement and coating with epoxy resin to the concrete. The experimental program was performed to study the compressive strength, split tensile strength at 14^{th} day and 28^{th} day. To study the above properties M25 mixes were considered. The scheme of experimental program is given in Table.1

Table .1 Experimental program

Sl no	Nature	M25 grade concrete	
		Cube	Cylinder
1	Plain	4	4
2	2% PEG	4	4

- 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.

5.0 Materials Used

The different materials used in this experiment are

5.1 Cement: Cement used in the experiment was 53 grade ordinary Portland cement confirming IS: 12269: 1987.

5.2 Fine aggregate: 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.

5.3 Coarse aggregate: The coarse aggregate according to IS: 383-1970 was used. Maximum coarse aggregate size used is 20 mm.

5.4 Polyethylene Glycol-400: Polyethylene glycol is a condensation polymer of ethylene oxide and water with the general formula H (OCH2CH2) nOH, where n is the average number of repeating oxyethylenegroups typically from 4 to about 180. The abbreviation (PEG) is termed in combination witha 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 has Molecular Weight 400, Appearance Clear liquid, pH 5-7, Specific Gravity 1.126.

5.5 Epoxyresin: Epoxy resins are low molecular weight pre-polymers or higher molecular weight polymers which normally contain at least two epoxide groups. The epoxide group is also sometimes referred to as a glycidyl or oxirane group. A wide range of epoxy resins is produced industrially. The raw materials for epoxy resin production are today largely petroleum derived, although some plant derived sources are now becoming commercially available (e.g. plant derived glycerol used to make epichlorohydrin)

5.6 Water: Portable water was used in the experimental work for both mixing and curing purposes.

6.0 Casting Programme:

The Casting of the specimens was done as per IS10086-1982, 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 samples of cubes and cylinders were cured for 14days and 28 days in water pond and the specimens with PEG400 were cured for 14 days and 28 days at room temperature by placing them in shade. The M25 grades of concrete are designed and the material required per cubic meter of concrete is shown in Table 2.

Table 2: Materials required per cubic meter of concrete

Sl no	Mix	Fine Aggregate (Kg)	Coarse Aggregate (Kg)	Cement (Kg)	Water (Kg)
1	M25	600	1200	400	220

7.0 Testing

7.1 Slump Test & Compaction Factor

The slump test result is a measure of the behavior of a compacted inverted cone of concrete under the action of gravity[8,9]. It measures the consistency or the wetness of concrete. In a collapse slump the concrete collapses completely, a collapse slump will generally mean that the mix is too wet or that it is a high workability mix, for which slump test is not appropriate. In a shear slump the top portion of the concrete shears off and slips sideways. If the shear slump persists, as may the case with harsh mixes, this is an indication of lack of cohesion of the mix. In a true slump the concrete simply subsides, keeping more or less to shape. This is the only slump which is used in tests. Mixes of stiff consistence have a zero slump that in the rather dry range no variation can be detected between mixes of different workability.

7.2 Compressive strength

The compressive load is applied gradually at the rate of 13.73N/mm^2per minute till the specimen fails[10]. The bearing surface of the testing machine is cleaned. The specimen is placed in the machine and the load is applied to the opposite sides of the cube cast. The specimen is aligned centrally on the base plate of the machine. The movable portion is rotated gently by hand so that it touches the top surface of the specimen. The load is applied gradually without shock at the rate of 13.73 N/mm^2/minute till the specimen fails. The maximum load is recorded and any unusual features are noted in the type of failure.

$fc= P/A$

where, P is load, A is area

Fig 2. Compression test

7.3 Split tensile strength

We know that the concrete is weak in tension and strong in compression. Tensile strength is one of the important properties of the concrete. Usually concrete is not expected to resist the direct tension because of its low tensile strength of concrete and brittle nature. The determination of tensile strength of concrete is necessary to determine the load at which the concrete members may crack. The cracking is a form of tension failure. The load at which the splitting of specimen takes place is recorded. The splitting tensile strength of cylinder is done in the compression testing machine.

fsplit=2 P/πDL,

Where,L=load, D= diameter of cylinder, L=length of the cylinder.

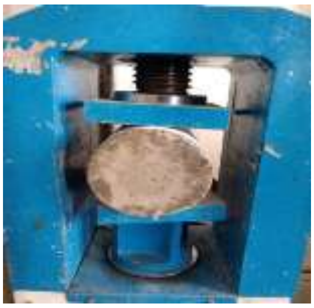

Fig 3. Split tensile test

8.0 Results & Discussion

8.1 Compressive Strength

The results of the compressive strength for 14^{th}day and 28th day are represented in Table 3 and 4 the graphical representation is shown in Fig 4& Fig 5. The compressive strength was found to increase up to 2% PEG400 and when coated with epoxy resin.

Table 3: compression strength for 14^{th} day

Sl no	Conventionalfc (N/mm2)	Polymer addedfc (N/mm2)
1	17.63	16.5

Table 4: compression strength for 28^{th} day

Sl no	Conventional fc (N/mm2)	Polymer added fc (N/mm2)
1	25	24.7

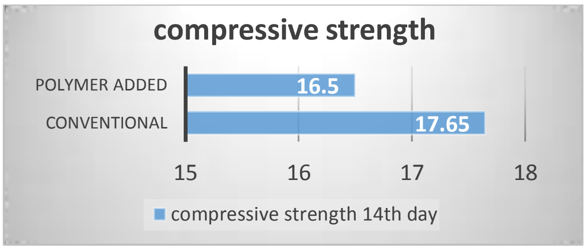

Fig 4: 14th day compressive strength of cube

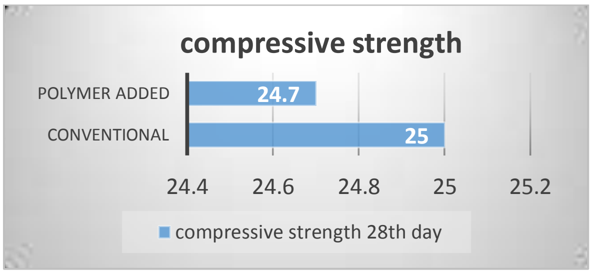

Fig 5: 28th day compressive strength of cube

8.2 Split Tensile Strength

The results of the split tensile strength are represented in Table 5 and the graphical representation is shown in Fig 6&7.

Table 5: split tensile strength for 14th day

Sno	Conventional fsplit (N/mm2)	Polymer added fsplit (N/mm2)
1	2.65	2.64

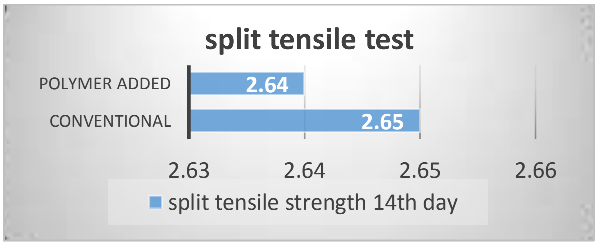

Fig 6: 14th day split tensile strength of cylinder

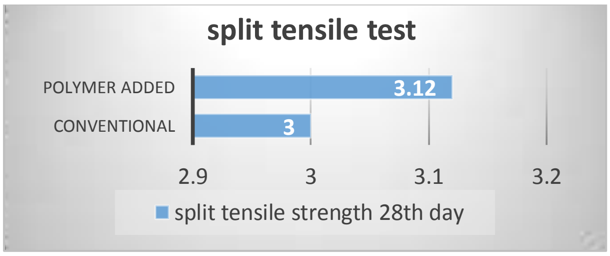

Fig 7: 28th day split tensile strength of cylinder

9.0 Conclusions

1. The optimum dosage of PEG400 for maximum strengths (compressive, tensile strength) was found to be 2% for M25grade of concrete when coated with epoxy resin.

2. Self-curing concrete is the answer to many problems faced due to improper curing.
3. Self-curing concrete is an alternative to conventional concrete in desert regions where scarcity of water is a major problem.
4. Asapercentage of PEG400 gets increased slump, as well as compaction factor also gets increased.
5. Epoxy resin slows down the hydration process.

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