Mechanical properties of self curing concrete incorporating polyethylene glycol-600

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Abstract - *Curing of concrete is defined as a process of providing satisfactory moisture content in concrete during its early ages in order to develop the desired properties of concrete. In conventional curing this is achieved by external supply of water after mixing, placing and finishing of concrete. In practice conventional type of curing is difficult to perform as it shall need a large amount of water, meanwhile scarcity of potable water increases day by day, hence arises the concept of self curing concrete. Self curing concrete relays on supplying water throughout a freshly placed cementitious mixture using reservoirs, that readily release water as needed for hydration or to replace moisture lost through evaporation or self-desiccation (American Concrete Institute 2010). The paper aims to study the properties of self curing concrete obtained by the addition of self curing agent polyethylene glycol-600. In this experimental investigation the strength characteristics of concrete, cast with the self-curing agent has been studied and compared with the corresponding conventionally cured concrete. IS method of mix design was adopted. Properties of the concrete such as compressive strength, split tensile strength, flexural strength and modulus of elasticity were studied. From the results optimum percentage of PEG addition was obtained.*

***Key Words*: Self curing concrete, Poly ethylene glycol, Compressive strength, Split tensile strength, Flexural strength, Modulus of elasticity**

1. INTRODUCTION

Concrete is the widely used construction material due to its ability to cast into required shape and size. The most important aspect in usage of concrete is the development of desired strength which mainly depends on hydration of cement mortar. Curing allows continuous hydration of cement and consequently continuous gain in the strength [2]. Curing of concrete can be done in several methods, among them external and internal curing has gained popularity so far. Self-curing or internal curing is a technique that can be employed to provide additional moisture in concrete for more effective hydration of cement and reduced self-desiccation. According to the ACI 308 committee, ''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'' [7].

It was found that water soluble polymers can be used as self-curing agents in concrete. Concrete incorporating self-curing agents will represent a new trend in concrete construction in the new millennium. M.I.Mousa et al in 2014 studied the mechanical properties of concrete containing self-curing agents. Results proved that the concrete with polyethylene-glycol as self-curing agent, attained higher values of mechanical properties than with other type of curing agents [4].

1.1 Principal and Mechanism of Self Curing

An exposed surface suffers from continuous evaporation of moisture due to the difference in chemical potentials between the vapour and liquid phases. Also when the mineral admixtures react completely in a blended cement system, their demand for curing water can be much greater than that in a conventional ordinary portland cement concrete. When this water is not readily available, significant autogenous deformation and 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 [2].

It is not possible to provide curing by external supply of water from top surface at the rate required to satisfy the ongoing chemical shrinkage. 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 [5]. The usage of polyethylene-glycol reduces the evaporation of water from the surface of the concrete and thereby providing water retention.

1.2 Polyethylene-Glycol

Polyethylene glycol is also known as polyethylene oxide (PEO) or polyoxyethylene (POE), depending on its molecular weight. It is a condensation polymer of ethylene oxide and water. The structure of PEG is commonly expressed as $H(OCH_2CH_2)nOH$, where n is the average number of repeating oxyethylene groups typically from 4 to about 180. Polyethylene glycols are available in average molecular weight ranging from 200 to 8000.The low molecular weight compounds up to 700 are colourless, odorless and viscous compounds with a freezing point from -10^{o}C (di-ehylene glycol),while polymerized compounds with high molecular weight more than 1000 are wax like solids with melting point up to 67^{o}C. One common feature of PEG appears to be the water-soluble nature. Polyethylene glycol is non-toxic, odourless, neutral, lubricating, non-volatile and nonirritating and is used in a variety of pharmaceuticals.

2. MATERIALS

Cement

The Ordinary Portland Cement of 53 grade conforming to IS: 12269-2013 was used. Initial setting time, standard consistency, specific gravity test and fineness modulus test were performed to find the properties of cement.

Coarse Aggregate

20 mm coarse aggregate, conforming to IS: 383 -1970 was used. The properties of coarse aggregates such as specific gravity and water absorption were obtained.

Fine Aggregate

The fine aggregate used in the study was manufactured sand. It was screened to eliminate over size particles. As per IS:383-1970, the fine aggregate conforming to zone II was used.

Water

Potable water was used in the experimental work for mixing. The strength of cement concrete comes mainly from the binding action of the hydrated cement gel. The requirement of water should be reduced to that required for chemical reaction of unhydrated cement as the excess water would end up in only formation of undesirable voids in the hardened cement paste in concrete.

Polyethylene Glycol (PEG)-600

For the experimental programme PEG 600 was used. PEG 600 consists of a distribution of polymers of varying molecular weights with an average of 600.The appearance of PEG 600 is clear liquid. One common feature of PEG appears to be the water-soluble nature.

Ceraplast 300

Ceraplast 300 was used as superplasticizer for better performance, which was purchased from Cera Chem Pvt. Ltd. The dosage of Ceraplast 300 was fixed as 2.5 percentage by weight of cement after conducting many trials and measuring the flow. Properties of the materials chosen are shown in Table-1

Table -1: Material properties

Materials	Properties	Values
Cement	Specific gravity Standard consistency Initial setting time Fineness modulus	3.125 30% 120min 5%
Coarse Aggregate	Specific gravity Water absorption	2.74 0.8%
Fine Aggregate	Specific gravity Fineness modulus	2.605 2.8
PEG-600	Specific gravity	1.13
Ceraplast 300	Specific gravity	1.2

3. CASTING PROGRAMME

Casting programme consists of preparation of moulds as per IS 10086:1982, preparation of materials, weighing of materials and casting of cubes, beams and cylinders. Mixing, compacting and curing of concrete was done according to IS 516:1959. Concrete mix was prepared as per trial and error method and a suitable design mix was fixed. Specimens were cast for various test with following dimensions.

1. Cubes of size 150mm X 150mm X 150mm
2. Cylinder of size 150mm ϕ X 300mm length
3. Beams of size 100mm X 100mm X 500mm

The designed mix proportion and materials chosen for the mix are shown in Table-2. Specimen nomenclature chosen for identification is shown in Table-3

Table -2:Mix proportion of materials per m^3

Details of mix	Grade – M50
Designed mix proportion	1:1.28:2.45
Cement content	437.57kg/m^3
Fine aggregate content	613.26kg
Coarse aggregate content	1174kg
Water cement ratio	0.33
Amount of water	144.39ml

Table-3: Mix designation for specimen

Specimen	Description
N00	Specimen with external water curing
P05	Specimen with 0.5% PEG
P10	Specimen with 1.0% PEG
P15	Specimen with 1.5% PEG
P20	Specimen with 2.0% PEG

4. TESTING PROGRAMME

In order to find the properties of self-curing concrete obtained by the addition self curing agent polyethylene glycol-600, the following test were conducted.

Compressive Strength Test

The cube specimens of size 150mm X 150 mm X 150 mm were tested on compression testing machine. The bearing surface of machine was wiped off clean and sand or other materials were 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 i.e, not top and bottom. The applied load 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. Compressive strength is calculated by,

$$\sigma c = P/A$$

Where, P is the maximum load

A is the cross-sectional area

Split Tensile Strength Test

The cylinder specimens of size 150 mm diameter and 300 mm height were tested on universal testing machine and the load was applied until the failure of cylinder. The load was applied on the vertical diameter of the cylinder subjected to a horizontal stress and the split tensile strength was calculated using subsequent formulae,

$$f_{ct}=2P/\pi dl$$

Where P= maximum load in Newton applied to the specimen

l = length of the specimen (in mm),

d = cross sectional dimension of the specimen (in mm)

Flexural strength

The flexural strength test of concrete was held on beam of size 100 mm×100 mm×500 mm. Concrete beams were cast for each concrete mix proportions for 7 and 28 days. Test was held on four point flexural testing machine.

The flexural strength is given by

$$f_b = Pl/bd^2$$

Where b = width of specimen (mm)

l = supported length (mm)

d= failure point depth (mm)

P = maximum load (kg)

Modulus of Elasticity

Modulus of elasticity of the cylindrical specimens was found using compression testing machine and extensometer. Test was conducted in cylinder having 150 mmm diameter and 300 mm length at the age of 28 days. The average compressive strength of three specimens at the age of 28 days was recorded. The extensometer was attached at the ends and the load was applied continuously at a rate of 140kg/cm^2/min until an average stress of (C +0.5) kg/cm^2 was reached, where C is one-third of the average compressive strength of the cubes. The load was maintained at this stress for at least one minute and then it was reduced gradually. The load was applied a second and third time and extensometer readings was taken at approximately equal increments of stress up to an average stress of (C+ 0.15) kg/cm^2. Readings were taken at each stage of loading.

5. RESULTS AND DISCUSSIONS

Compressive Strength

Fig-1 shows the experimental test set up for compressive strength of concrete cube. Table-4 shows the compressive strengths of self curing concrete with varying percentage of PEG addition. Chart-1 shows that the use of self curing agents in concrete mixes improves the compressive strength of concrete. 1.5% of polyethylene glycol represents the optimum dosage

Fig -1: Compressive strength testing of cube

Table-4: 7th and 28th day compressive strength of self curing concrete with varying percentage of PEG

Specimen PEG-600	7th day compressive strength (N/mm^2)	28th day compressive strength (N/mm^2)
N00	33.91	52.18
P05	36.59	54.19
P10	38.67	56.2
P15	42.97	59.03
P20	38.38	58.32

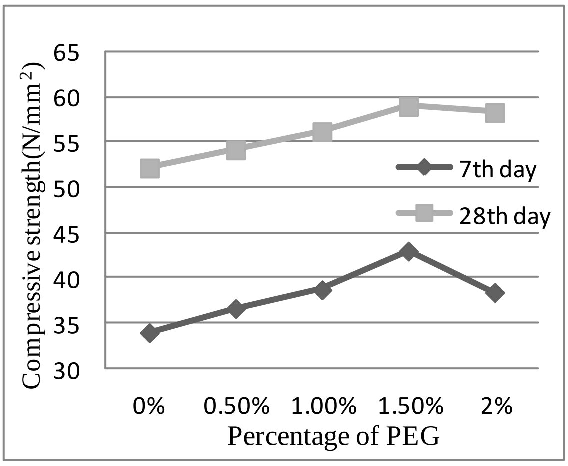

Chart-1: 7th and 28th day compressive strength of self curing concrete with varying percentage of PEG

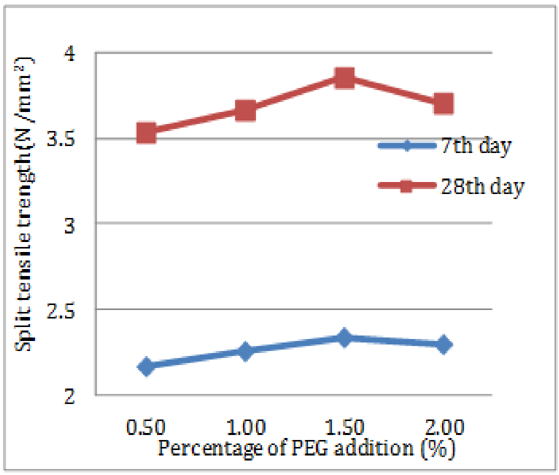

Chart-2: 7th and 28th day Split tensile strength of self curing concrete with varying percentage of PEG

Split Tensile Strength

Experimental test set up for split tensile strength of cylindrical specimen is shown in Fig-2. The results of the split tensile strength test are noted in Table 5 and the graphical representation is shown in the Chart-2. The use of polyethylene glycol has lead to improvement in the tensile strength of the concrete and an optimum percentage of PEG addition was found to be 1.5%.

Fig -2:Split tensile strength testing of cylinder

Table-5:Split tensile strength of self curing concrete with varying percentage of PEG addition tested on 7th and 28th day

Specimen PEG-600	7th day split tensile strength (N/mm²)	28th day split tensile strength (N/mm²)
P05	2.17	3.54
P10	2.26	3.67
P15	2.34	3.86
P20	2.3	3.71

Flexural strength

Flexural strength test set up is shown in Fig-3. Values obtained after testing concrete beams are noted in Table-6. Chart-3 confines that flexural strength of self curing concrete beams are increasing upto 1.5% and there after decreases, fixing 1.5% as the optimum.

Fig -3:Flexural strength testing of beam

Table-6:7th and 28th day flexural strength of self curing concrete with varying percentage of PEG addition

Specimen PEG-600	7th day flexural Strength (N/mm²)	28th day flexural Strength (N/mm²)
P05	3.4	5.15
P10	3.41	5.24
P15	3.52	5.37
P20	3.47	5.34

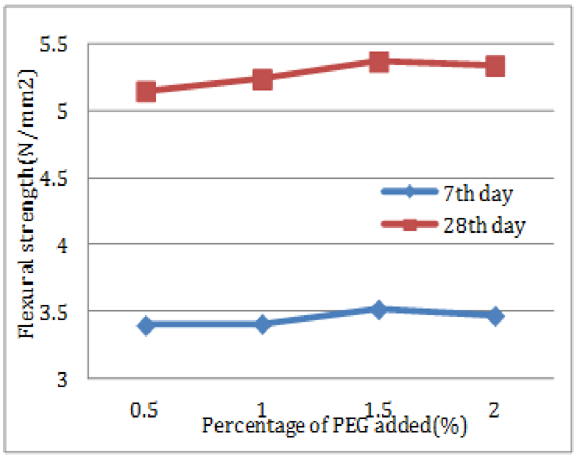

Chart-3: Flexural strength of self curing concrete with varying percentage of PEG tested on 7th and 28th day

Modulus of elasticity

Experimental test set up is shown in Fig-4. Results obtained from the modulus of elasticity test are tabulated in Table-6. Stress strain graph plotted is shown in Chart-4. Chart-5 gives the graphical representation of the values. Results proof that PEG addition by 1.5% weight of cement gives higher results than other percentages.

Fig -4: Modulus of elasticity testing of cylinder

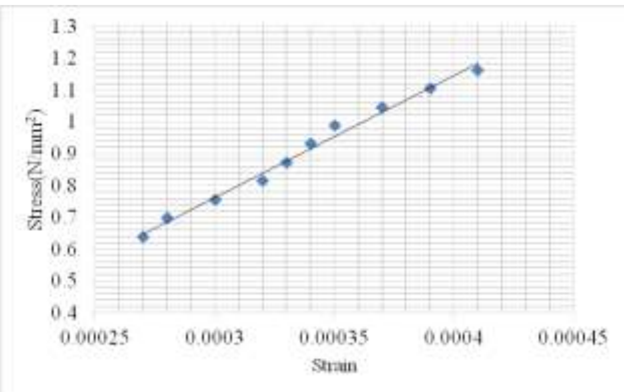

Chart-4: Stress-strain graph of 1.5% PEG added self curing concrete

Table 7:Modulus of easticity of self curing concrete tested on 28th day of air curing

Specimen PEG-600	Modulus of elasticity (28th day)
P05	36.57
P10	37.83
P15	38.54
P20	38.01

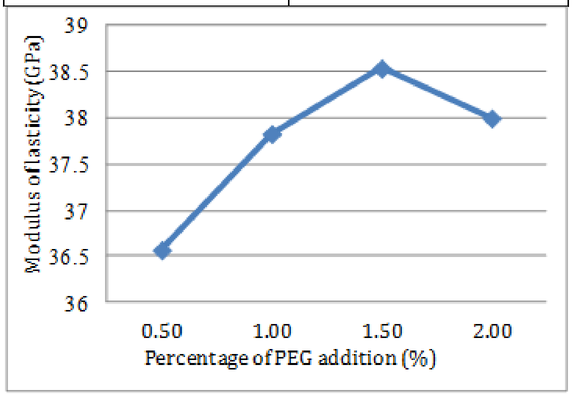

Chart-5: Modulus of elasticity of self curing concrete at 28th day with varying percentage of PEG

6. CONCLUSIONS

Concrete, which is a major component of construction industry needs to attain desired strength by 28 days. The deficiencies in conventional curing can be avoided by introducing the concept of self-curing. Self-cured concrete shows improvement in mechanical properties of concrete and ensure sustainable development. Addition of self curing agent Poly ethylene glycol(PEG-600) increases the mechanical properties of concrete. The following conclusions may be drawn from the experimental work conducted on self-curing concrete of grade M50 after 28 day of curing.

- The obtained value of compressive strength of self-cured concrete is more when compared to conventionally cured concrete. An optimum dosage of PEG-600 for maximum compressive strength was found to be 1.5% for M50 grade concrete.
- The percentage increase in compressive strength was found to be 13% compared to conventionally cured concrete.
- The obtained split tensile strength, flexural strength and modulus of elasticity of self-cured concrete showed a maximum split tensile strength at 1.5% for the M50 grade concrete

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