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Performance and Evaluation of Internal Curing Concrte by Adding Polyethylene Glycol-400

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Abstract— For a considerable amount of time to come, concrete will continue to be the most adaptable material utilized in construction. The mixture of cement, fine aggregate, coarse aggregate, and water that is known as conventional concrete it requires curing to obtain the appropriate strength. In order for the concrete to acquire the necessary rheological qualities for mixing, transporting, putting, and compacting, water must be added during the mixing process. One of the major considerations achieving the required properties is gaining control on water curing is the process of encouraging the cement to hydrate it involves regulating the temperature as well as the flow of moisture into and out of concrete.one of the most important aspects in curing is the need to maintain relative humidity of around 100% otherwise the improper curing causes shrinkage and crack in the concrete. Curing is mainly performed by water adding techniques and water retaining techniques. In internal curing hydration of cement occurs due to the availability of water not adding additional water. The function of Internal-curing agent is to reduce the water evaporation from concrete, and hence they increase the water retention capacity of concrete compared to the conventionally cured concrete. In the present study, Polyethylene glycol-400 used as the internal curing agent. The effect of adding 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 2.5% were studied for M25. It was found that PEG 400 could help in Internal-curing by giving strength on par with conventional curing.

Index Terms- Internal curing, Hydration, Polyethylene glycol-400, Compressive and Split tensile strength.

I. INTRODUCTION

Curing is the process of maintaining the correct moisture content, especially for 28 days, to promote optimal hydration of the cement immediately after application. Hardening plays an important role in the formation of concrete microstructure and pore structure. Good healing is almost impossible in most cases. Self-hardening concrete means that the concrete does not need external curing. Curing is the name given to methods used to promote cement hydration by controlling the movement of temperature and moisture from and to the concrete.

Hardening allows the cement to continue to hydrate and therefore increase in strength, when hardening stops the strength of the concrete also stops. Correct humidity conditions are critical, because cement hydration almost stops when the relative humidity in the capillaries drops below 80%.Proper hardening of concrete structures is important to meet performance and durability requirements. In traditional curing, this is achieved by external curing applied after mixing, setting and finishing. Self-healing, or internal healing, is a technique that can be used to add moisture to concrete for more effective cement hydration and less self-drying.

When concrete is in contact with the environment, water evaporation and moisture occur, which reduces the initial water-cement ratio, leading to incomplete hydration of the cement and thus deterioration of concrete quality.

Several factors such as wind speed, relative humidity, air temperature, water cement ratio of the mix and type of cement used in the mix. In the initial stage, evaporation leads to plastic shrinkage cracking and in the final stage of curing, drying shrinkage cracking. Cure temperature is one of the most important factors affecting the rate of strength development. At high temperatures, ordinary concrete loses its strength due to the formation of cracks between the two thermally incompatible ingredients, cement paste and aggregates.

Concrete is the most widely used building material. It has the characteristic of being formed into desired shape most conveniently. It is an artificial material consisting of ingredients such as cement, fine aggregates, coarse aggregates and water. Aggregates are the major ingredients of concrete.

Ordinary concrete has very low tensile strength, limited ductility and low cracking resistance. Concrete naturally has internal microcracks and its poor tensile strength is due to the propagation of such microcracks, which eventually leads to brittle failure of the concrete.

The most commonly accepted remedy for this flexural weakness of concrete is conventional reinforcement with high-strength steel. Also, RCC reinforcement and effective compaction are very difficult when the workability of the concrete is low, especially for concrete.

Structural cracks (microcracks) occur in ordinary concrete and similar brittle materials even before loading, mainly due to shrinkage or other causes of volume changes. Curing of concrete is important to meet performance and durability requirements.

Internal Curing (IC) is a very promising technique that can provide additional moisture in concrete for a more effective hydration of the cement. During hydration of cement, empty pores are created within the cement paste, leading to a reduction in its internal relative humidity and cause cracks to develop at the early-age.

II. LITRATURE REVIEW

Swamy (1990): Presented a simple method to obtain a 50 MPa 28-day strength concrete having 50 and 65 percent by weight cement replacement with slag having a relatively low specific surface. The compressive and flexural strengths and the elastic modulus of these two concretes as affected by curing conditions are then presented. Without any water curing, concrete with 50 percent slag replacement reached nearly 90 percent of its target strength of 50 MPa at 28 days 14 and continued to show modest strength improvement up to 6 months.

Dhir (1996): Worked on Internal-curing concrete using two computer models, at low dosages, good strength and improved permeability characteristics were observed. At high dosages it appears that the admixture has a detrimental effect on the concrete‘s compressive strength.

Hans W. Reinhardt (1998): They demonstrated on Internal-cured high Performance concrete that a partial replacement of normal weight aggregates by prewetted lightweight aggregates leads to an internal water supply for continuous hydration of cement. Despite water loss by evaporation there is continuous strength gain up to 25% more strength after 1 year compared to standard compressive testing after 28 days

Gowripalan (2001): The mechanism of Internal-curing can be explained as follows: The polymer 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. This reduces the rate of evaporation from the surface Internal-Curing concrete is the newly emerging trend in the construction industry.

C.Selvamony (2010): Investigated on Internal-compacted Internal-curing Concrete using limestone powder and clinkers. In this study, the effect of replacing the cement, coarse aggregate and fine aggregate by limestone powder (LP) with silica fume (SF), quarry dust (QD) and clinkers respectively and their combinations of various proportions on the properties of SCC has been compared.

Ravi Kumar M.S. (2011): An experimental investigation was conducted to make a comparative study on the properties of High Performance Concrete with kiln ash (25% and 50% replacement) and without kiln ash (control concrete) in normal and aggressive environment using Internal-curing instead of water curing

Raghavendra (2012): Using Membrane curing and Internal-Curing methods one can achieve 90% of efficiency as compared to Conventional Curing method. Membrane curing compounds are most practical and widely used method it is most suitable in water scarce area.

Vilas (2012): Carried out an experimental study to investigate the use of water soluble polyvinyl alcohol as a Internal-cutting agent. He concluded that Concrete mixes incorporating Internal-curing agent has higher water retention and better hydration with time as compared to conventional concrete.

III. SCOPE AND OBJECTIVE

1. The aim of this investigation is to evaluate the use of water soluble polymeric glycol as internal curing agents.
2. The benefit of internal curing admixtures is more significant in water Scarcity areas and the places difficult to curing the Structure.
3. Scope of the Study is to identify the effect of PEG-400 on strength characteristics of internal curing concrete and also evaluate influence of PEG on Mechanical properties which are experimentally investigated.

IV. SELF CURING

Internal hydration refers to the process by which cement hydration occurs due to the presence of other internal fluids that are not part of the mixing fluid. Internal medicine benefits include increased hydration and strength, reduced shrinkage and autogenous damage, reduced permeability, and increased strength In contrast, self-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. Self-curing is often also referred as Internal–curing.

A. Potential Materials For Self Curing:
1. Lightweight Aggregate (natural and synthetic, expanded shale),
2. LWS Sand (Water absorption =17 %)
3. LWA 19mm Coarse (Water absorption = 20%)
4. Super-absorbent Polymers (SAP) (60-300 mm size)
5. SRA (Shrinkage Reducing Admixture) (propylene glycol type i.e. polyethylene-glycol) Wood powder

B. 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.

C. Reason For Chemical Shrinkage:
Chemical shrinkage is an internal volume reduction due to the absolute volume of the hydration Products being less than that of the reactants (cement and water). For example: Hydration of tricalcium silicate:
$C_3S + 5.3H > C1.7SH_4 + 1.3CH$.

D. Improvements To Concrete Due To Self Curing:
1. Reduces autogenous cracking
2. Reduces permeability
3. Protects reinforcing steel
4. Increases mortar strength
5. Provides greater durability
6. Higher early age flexural strength
7. Higher early age compressive strength
8. Higher modulus of elasticity

E. Mechanism And Significance Of Self Curing Concrete:
1. 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

V. MATERIALS

A. Poly Ethylene Glycol-400:
Polyethylene Glycol (PEG) is family of water-soluble linear polymers formed by the additional reaction of Ethylene Oxide (EO) with Monoethylene Glycols (MEG) or Ethylene Glycol. The generalized formula for polyethylene glycol is: $H-(O-CH2-CH2)\ n-OH$. It is a polyether compound with many applications from industrial manufacturing to medicine. PEG is

also known as Polyethylene Oxide (PEO) or Polyoxy Ethylene (POE), depending on its molecular weight.

There are many grades of PEGs that represents them by their average molecular weight. For example PEG 4000 consists of a distribution of polymers of varying molecular weight with an average of 4000.

Polyethylene glycols are available in average molecular weight ranging from 200 to 8000 this wide range of products provides flexibility in choosing properties to meet the requirements of many different applications.

One common feature of PEG appears to be the water soluble nature. Poly ethylene glycol is non-toxic , odorless , neutral, lubricating , non- volatile, non – irritating and is used in a variety of pharmaceuticals.

B. Physical Properties:

Depend on molecular weight the wide range of the physical property such as solubility, hygroscopic, vapour pressure, melting or freezing point and viscosity are variable:

- Solubility
- Hygroscopic
- Viscosity
- Stability

C. Chemical Properties:

Table I: PEG Chemical Properties

SL.NO	DESCRIPTION	PROPERTIES
1	Molecular weight	400
2	Ph	6
3	Appearance	Clear Fluid
4	Moisture	0.2
5	Specific Gravity	1.12

D.Cement:

Cement is the main component of concrete. The grade of the cement, the form of the cement, the colour, the fineness of the cement, the heat of hydration, and the alkali content of the cement are all important factors to consider when selecting a cement. Ordinary Portland cement, available in grades 33, 43, and 53, is the most commonly used type of cement. The grade results indicate the compressive strength of the cement. The initial Setting time of cement is 35mins.

Table II: Cement Compositions

S.NO	COMPOSITION	PERCENTAGE
1	Al_2O_3	6.6
2	SiO_2	21.8
3	Fe_2O_3	4.1

E. Fine Aggregate:

River sand and crusher sand are used to make fine aggregate. Fine aggregate should be carefully sieved using a 2.36mm sieve before use. Fine aggregate is graded into zones I through IV based on the sieve scale. The fine aggregates' properties were tested using the IS 393-1970 codal provision. In general, zone II aggregate is used for concrete, with sizes ranging from 4.75 to 2.36 mm. The Specific gravity of the fine aggregate is 2.65.

F. Coarse Aggregate:

The coarse aggregate has a significant impact on the consistency of concrete. It is the least porous and more chemically resistant material. As coarse aggregate is used, drying shrinkage and other dimensional differences in concrete are minimized. The properties of coarse aggregate were evaluated using the IS 393-1970 codal provision. The coarse aggregate should have a height of 20mm. The Specific gravity varies between 2.67 and Finess modulus is 3.64.The water Absorption percentile is 0.206

VI. METHODOLOGY

In this work, it was proposed to study the effect of polyethylene glycol (PEG 400) on strength characteristics of self-curing concrete by adding PEG by weight of cement for M_{20} grade of concrete.

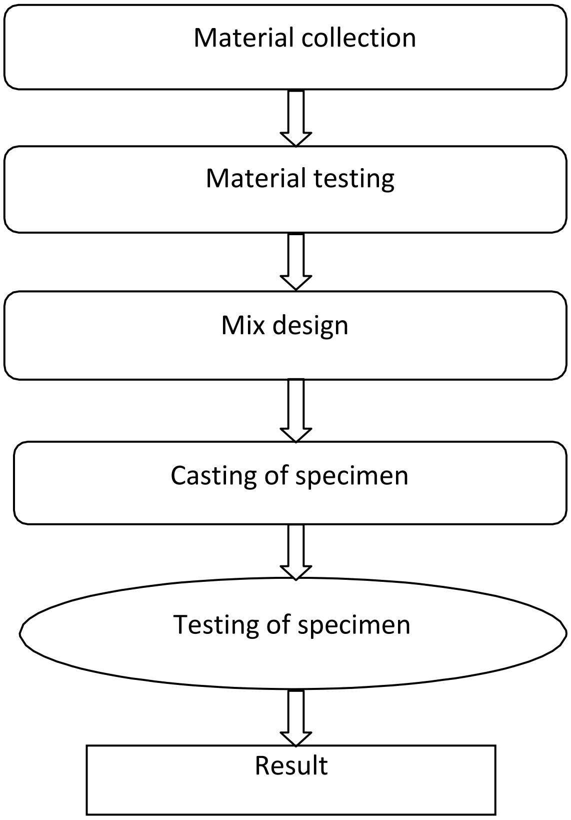

Fig I : Methodology

VII. CONCRETE MIX DESIGN

Grade of Concrete	Unit of Batch	Water (l)	Cement (Kg)	Fine Aggregate (Kg)	Coarse Aggregate (Kg)
M25	Content	197	350	638	1173
	Ratio	0.56	1	1.8	3.34

Table III: Mix Ratio

VIII. TESTS AND RESULTS

A. Compressive Strength:
This metric determines the compressive strength of reinforced concrete. The compressive strength of concrete is shown by the compressive test in optimal circumstances. The compressive strength of concrete is an indicator of its strength once it has hardened. Testing should be carried out with care.

The test was carried out at a standardized stress of 140 kg/cm2/minute after the specimen was centered in the measurement unit. Loading continued until the dial gauge needle simply reversed its movement. The needle's path has been redirected, meaning that the specimen failed.

The test specimen is cubical in shape and measures 150mmx150mmx150mm. If the highest normal dimension of the aggregate is less than 20mm, 10mm cubes would be used instead. Compressive strength checks are conducted on specimens of proven age, ideally from different batches made for each age of processing.

All of the cubes were tested in a saturated condition after the surface moisture was removed. At 7 days and 28 days of Internal-curing, each trail mix mixture three cube was tested using a compression measuring machine with a capacity of 2000KN according to IS 516-1959.

Table IV: Compressive Strength

S.NO	% OF PEG	7 Days (N/mm^2)	28 Days (N/mm^2)
1.	Conventional Concrete	19.2	32.7
2.	1	22.9	32
3.	1.5	24.5	33.4
4.	2.5	21.6	30.3

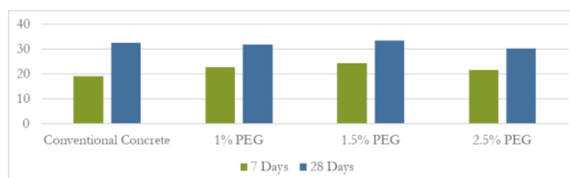

Fig II: Compressive Strength Graph

B. Split Tensile Strength:
Tensile strength is one of the most basic and essential properties of concrete. Concrete is typically supposed to survive direct stress due to its low tensile strength and translucent appearance. On the other side, the load at which the concrete members will fail. Aside from the flexural measure, there are two techniques for calculating concrete tensile strength: (a) direct method and (b) indirect method. The direct solution has a number of advantages, including holding the specimen properly in the measurement machine without inducing tension accumulation and adding a free-of-

eccentricity uniaxial tensile load to the specimen. The cylinder measures 150 mm in diameter and 300 mm in height. Splitting tests, also known as break tensile strength of concrete, are well-known indirect tests for determining concrete performance. According to an elastic analysis, compression loading produces tensile strength that is almost uniform around the entire filled diameter. The estimate establishes the degree of tensile stress (IS 5816-1970).

Table V: Split Tensile Strength

S.NO	% OF PEG	7 Days (N/mm^2)	28 Days (N/mm^2)
1.	Conventional Concrete	2.03	3.67
2.	1	1.8	2.81
3.	1.5	2.5	3.1
4.	2.5	2.1	2.8

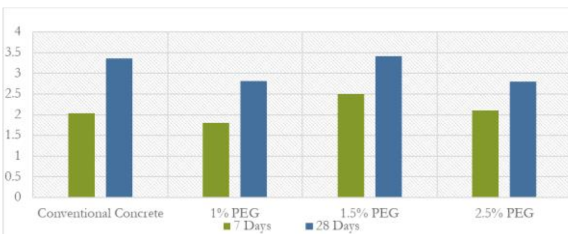

Fig III: Split Tensile Strength Graph

C. Flexural Strength:

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.

$F_{Rup}=WL/bd^2$

Where,

W = load at failure

L = length of specimen (700mm)

b = width of specimen (150mm)

d = depth of specimen (150mm)

when ‘a ’is greater than 20.0cm for 15.0 cm specimen ,in cm ,or greater than 13.3 cm for a 10.0 cm specimen Or when ‘a’ is less than 20.0 but greater than 17.0 cm for 15.0 specimen or less than 13.3 cm but greater than 11.0cm for a 10.0cm. Following graph shows the variation in flexural strength with addition of PEG.

Table VI: Flexural Strength-Prism

S.No	% of PEG	7 Days (N/mm^2)	28Days (N/mm^2)
1.	Conventional Concrete	2.03	2.67
2.	1	1.8	2.81
3.	1.5	2.5	3.1
4.	2.5	2.1	2.8

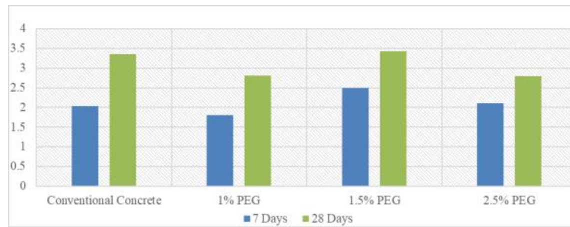

Fig IV: Flexural Strength Graph

CONCLUSION

1. The use of self-curing agent in concrete blends increases the strength characteristics of concrete under an air curing system that can be ascribed to better retention of water and causes continuing hydration of cement paste resulting in reduced voids and pores.
2. It has been observed that 2.5% PEG provides a lower compressive, split tensile and flexural strength compared to 1.5% PEG, so it is found that adding PEG at a high dose of over 1.5% of cement would not produce expected strength and would not be practically applicable,
3. Compared to standard curing concrete, setting time of self-compacting self-curing concrete is slow when percentage of PEG increases.
4. In this experiment 1.5% percent PEG gives better result when compared to 0.5%, 1%, 2.5% of PEG as a self curing agent.
5. Resistance to Chloride Ingress of Concrete Slightly improves by Addition of Polyethylene Glycol. RCPT values decreased with proportion of PEG Value Increases.
6. When Quantity of PEG-400 increases the molecular weight also increases due to change in temperature and additives the crystalline structure of PEG-400 disintegrates so strength reduces in

high quantity. It can be qualitatively assessed and confirmed using Powder X-ray diffraction

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