Experimental investigation on eco-friendly self-curing concrete incorporated with polyethylene glycol

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ABSTRACT	The aim of this investigation is to study the strength and durability properties of concrete using water-soluble Polyethylene Glycol as self-curing agent. The function of self-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. The use of self-curing admixtures is very important from the point of view that saving of water is a necessity everyday (each one cubic metre of concrete requires 3m3 of water in a construction, most of which is used for curing). In this study, compressive strength and split tensile strength of concrete containing self-curing agent is investigated and compared with those of conventionally cured concrete. It is found through this experimental study that concrete cast with Polyethylene Glycol as self-curing agent is stronger than that obtained by sprinkler curing as well as by immersion curing.
KEY WORDS:	Self-curing concrete - Water retention - Polyethylene Glycol - Immersion curing - Sprinkler curing

Introduction

During the last two decades, concrete technology has been undergoing rapid improvement in the field of construction. In the past few decades, internal curing of concrete has gained popularity and is steadily progressing from laboratory to field of practice and curing of concrete is maintaining satisfactory moisture content in concrete during its early ages in order to develop the desired properties. Curing of concrete plays a major role in developing the strength and hardness of concrete, which leads to its improvement in durability and performance. Practically good curing is not at all achievable in many cases due to the non-availability of good quality water and also due to practical difficulties. Many researches are concerned to identify effective self-curing agent.

Materials and Methods

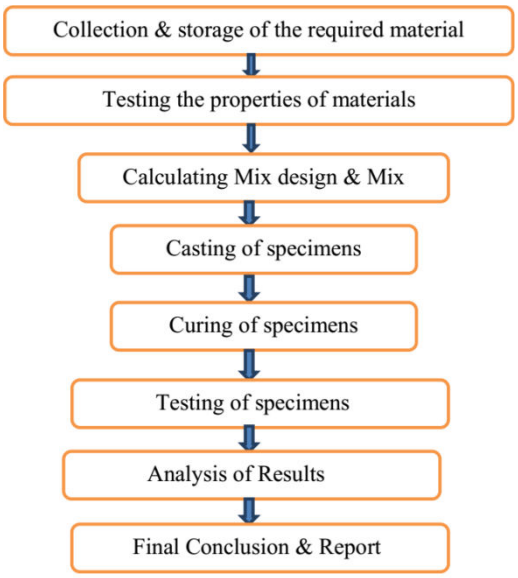
Materials required for preparing concrete are

1. Cement
2. Fine Aggregate
3. Coarse Aggregate
4. Metakoilin
5. Polyethylene Glycol (PEG 400)
6. Silica fume
7. Water

OPC of 53 Grade confirming to IS 12269-1987 was used in the investigation. The specific gravity of cement was 3.15. Cement is a amorphous form of Calcium silicates (Ca2SiO4) and other Calcium compound. The foremost important compound that makes cement (Bogue's Compounds) are Tri-calcium silicates (C3S), Di-calcium silicates (C2S), Tri-calcium aluminates (C3A), Tetra-calcium alumino ferrites (C4AF) where C stands for Calcium-oxide,S stands for Silicon-oxide, A stands for Aluminium oxide and FF for Ferric oxide.Tri-Calcium silicate and di-calcium silicate gives strength to cement and mutually contributes about 70% of cement mixture.

Two concrete mixes have been adopted with the similar w/c ratio. Self-curing agent was added to one mix and the other mix was without any curing agent. The slump value and compacting factor value based on workability tests for conventional concrete and self-curing concrete The self-curing agent used in this study was water-soluble polymers (i.e; Polyethylene Glycol) conforming to molecular weight 400. The dosage of self-curing agent was kept at 0.5, 1, 1.5 and 2% by weight of cement. Concretes of grade M20 have been chosen for this experimental work.

Methodology



Flowchart Representing Methodology

DIFFERENT METHODS USED FOR CURING OF CONCRETE

There are various method of curing. The adoption of a particular method will depend upon the nature of work and the climatic conditions. The following methods of curing of concrete are generally adopted :

- Shading concrete work.
- Covering surfaces with hessian or gunny.
- Sprinkling of water.
- Ponding method.
- Membrane curing.
- Steam curing.

The destructive tests tests on the hardened concrete are :

1. Compressive strength test.
2. Tensile strength test.
3. Flexure strength test.

1. Compressive strength test:

The cubical mould of size (150mm x 150mm x 150mm). The concrete is poured in the mould and tempered properly so as not to have any voids.
The compressive strength is calculated using the following formula :

Compressive strength (fc) = P/A

Where, P = Load at failure.

These specimens are tested by compression testing machine after the 7, 14 and 28 days of the casting . And the load is applied at a gradual rate of 140kg/cm2 per minute till the specimen fails.

COMPRESSIVE STRENGTH TEST OF CONCRETE

2. Split Tensile Strength Test

The split tensile strength test on concrete cylinder is a method to determine the tensile strength of concrete.

The split tensile strength is calculated using the following formula :

Split tensile strength (fs) = 2P/IIDL

Where, P = Load at failure.
D = Diameter of cylinder.
L = Length of cylinder.

The tensile strength of the concrete is much lower than the compression strength. It has been estimated that the tensile strength of concrete equals roughly about 10% of the compression strength.

SPLIT TENSILE STRENGTH TEST

3. Flexural Strength Test

The beam specimen f size (100mm x 100mm x 500mm) is casted to determine the flexural strength of concrete with various percentage of polyethylene glycol 400. Apply the load at a rate that constantly increases the maximum stress until rupture occurs.
The flexural strength is calculated by using the simple bending equation

$$\sigma = Pl/bd2 \ (N/mm2)$$

The flexural strength is also known as the modulus of rupture or the bending strength or also known as the transverse rupture strength it is a material property, which is defined as the stress in a material just before it yields in a flexure test.

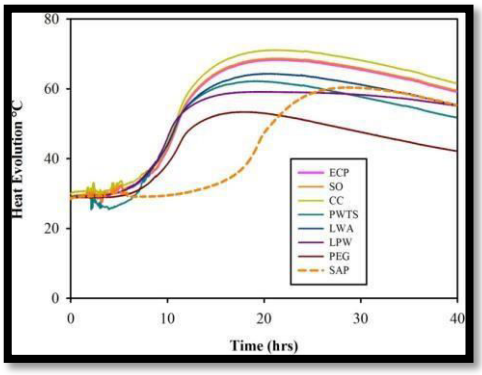
FLEXURAL STRENGTH TEST

DURABILITY PROPERTIES

1. Durability Studies on Water Retention Properties

The retention of water in the cement paste with and without curing agents is discussed in order to assay the nature of paste under fixed environmental conditions.

2. Heat of hydration

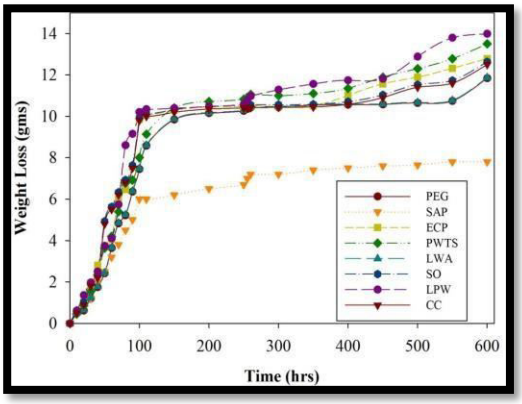


Heat of Hydration

it is observed that the cement paste with internal curing agents in the order PEG, SAP, ECP, PWTS, LWA, SO, LPW suffers less heat evolution than the cement paste without curing agent.

The sudden release of heat within a short span may lead to create more hair cracks at a plastic stage which further leads to create path to self- strain condition.

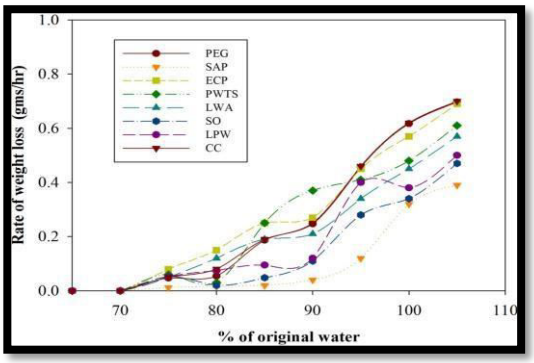
3. Weight loss vs. time



Weight loss vs Time

indicates the compiled weight loss vs. time graph which is analyzed for 28 days in terms of hours. The loss of mass (gms) in time interval (hrs) is studied for various curing agents in addition with conventional type of curing and the results indicate the reduction in mass loss.

4. Rate of weight loss vs. % of original water

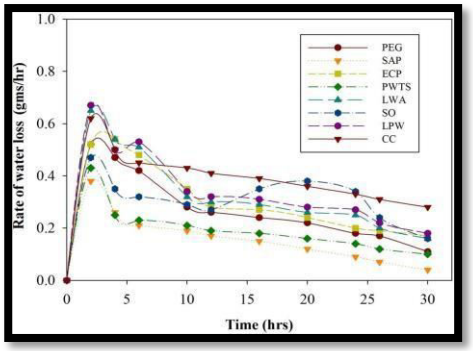


Weight loss rate vs. % of original water

It is clear that the matrix with PEG when compared with cement paste without curing agent shows 54.83% lesser rate of weight loss because of less heat evolution, results in notable pore reduction with denser matrix.

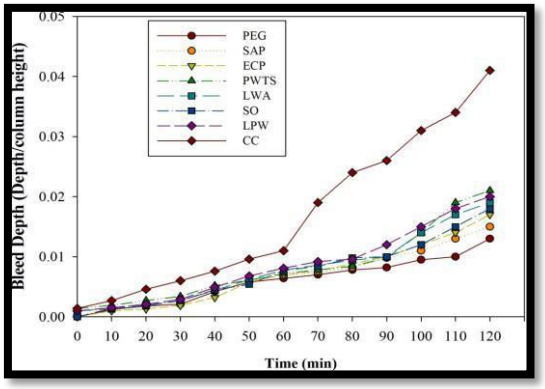
5. Rate of water loss vs. time

The observation is made for paste with and without curing agents for a period of 30 hours at an average interval of 3 hours is shown in Figure the presence of only self-compacting chemical with designed w/c ratio. In detail, it is found that the reduction in percentage of water loss were 66.66%. But the critical increase of water loss is found for PEG



Water loss rate vs. Time

6 Bleed depth analysis

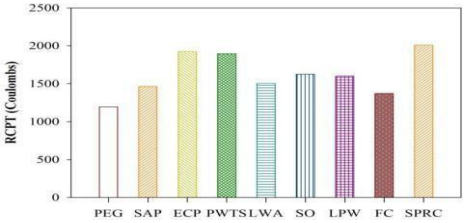


Bleed Characteristics

it is found that the reduction in bleed depth for PEG is 68.29% with FC, 13.33% with SAP, 23.53% with ECP, 38.09% with PWTS, 31.57% with LWA, 27.77% with SO and 35% with LPW. The reason is observed as excelled capillary pore volume reduction as the pore blockage will resist the upward movement of water as it prevents self-desiccation effect.

Durability studies on hardened concrete properties

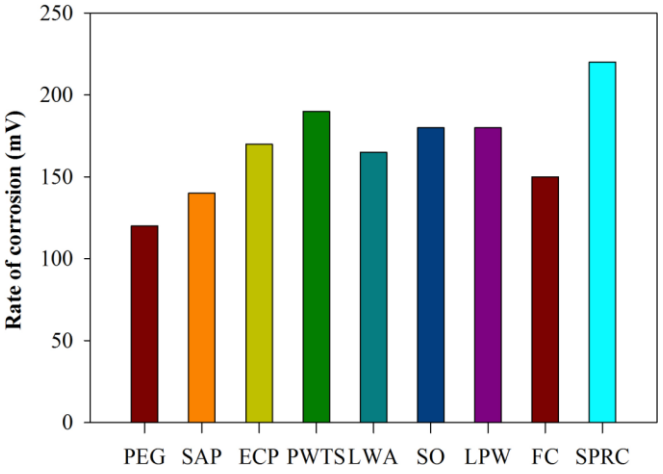
1. Rapid chloride permeability test



Curing agents vs. Charge passed

since the output falls between 2,000 to 4,000, it is categorized as „Moderate" because the presence of micro pores is found to be slight higher. So, it is not advisable for sprinkler curing technique during the construction activities.

2. Accelerated corrosion test

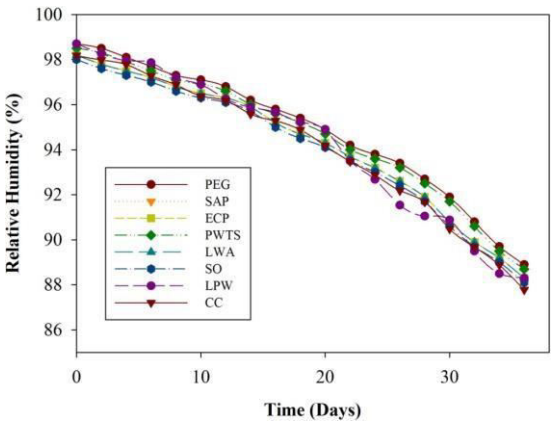


Curing agents vs. Rate of Corrosion

It is estimated that as the average corrosion rate for all types of curing is less than 200 mV, the presence of corrosion is observed as Nil.

3. Relative Humidity Test

It is clear that all the specimens under different curing agents are found to have effective humidity than the concrete with sprinkler curing type. But it doesn"t affect the behaviour of concrete with age of time.

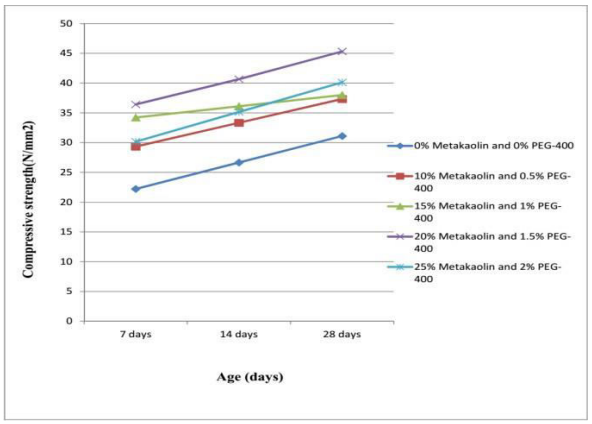


Relative Humidity Analysis

RESULTS AND DISCUSSION

1. COMPRESSION STRENGTH RESULTS

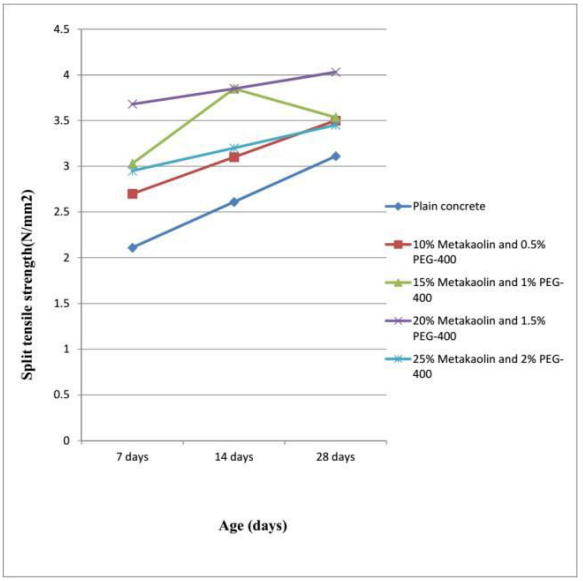
Details	Specimens (Cube)		
	7 days	14 days	28 days
For 0% Metakaolin and 0% PEG-400	22.22	26.66	31.11
10% Metakaolin and 0.5% PEG-400	29.33	33.33	37.33
15% Metakaolin and 1% PEG-400	34.22	36.11	38
20% Metakaolin and 1.5% PEG-400	36.42	40.66	45.33
25% Metakaolin and 2% PEG-400	30.17	35.15	40.13



Compressive strength

2. SPLIT TENSILE STRENGTH RESULTS

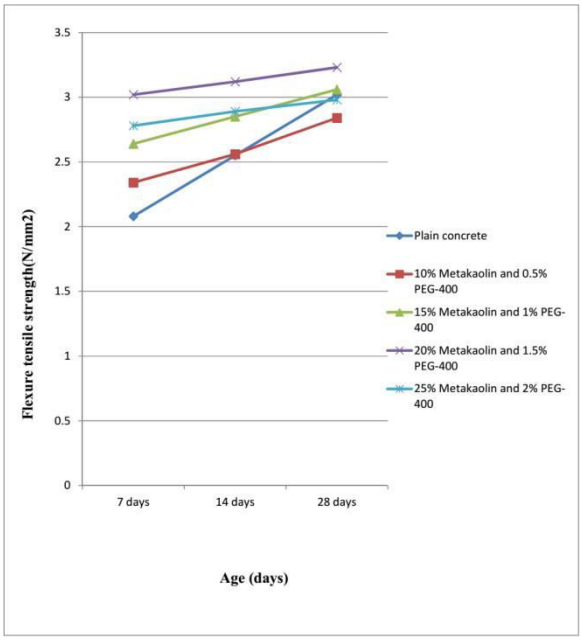
Details	Specimens (Cylinder)		
	7 days	14 days	28 days
Plain concrete	2.11	2.61	3.11
10% Metakaolin and 0.5% PEG-400	2.70	3.10	3.5
15% Metakaolin and 1% PEG-400	3.03	3.28	3.536
20% Metakaolin and 1.5% PEG-400	3.68	3.85	4.03
25% Metakaolin and 2% PEG-400	2.95	3.2	3.45



Split tensile strength

3.FLEXURAL STRENGTH RESULTS

Details	Specimens (Beams)		
	Specimen 1 @ 7 days	Specimen 2 @ 14 days	Specimen 3 @ 28 days
Plain concrete	2.08	2.55	3.02
10% Metakaolin and 0.5% PEG-400	2.34	2.59	2.84
15% Metakaolin and 1% PEG-400	2.64	2.85	3.06
20% Metakaolin and 1.5% PEG-400	3.02	3.12	3.23
25% Metakaolin and 2% PEG-400	2.78	2.89	2.98



Flexural tensile strength

DISCUSSION

For 1.5% PEG 400, obtained compressive strength 36.42 N/mm2 is maximum and it is more than the reference mix (22.22 N/mm2) and the same is presented in the figure for the 7days. And for the same 1.5% PEG 400, the compressive strength obtained is 40.66 N/mm2 is maximum and more than the reference mix (26.66 N/mm2) as shown this is for 14 days. And finally for 28 days the maximum strength obtained for the same 1.5% PEG 400 is 45.33 N/mm2 which is more than the reference concrete (31.11 N/mm2).The final conclusion out of discussion on the result, is the absolute maximum compressive strength is obtained for 1.5% PEG 400 as shown in figure.

Using the self-curing agent such as PEG 400. For this the maximum split tensile strength obtained was 3.68 N/mm2 at 1.5% which is more than the reference mix (2.11 N/mm2) for the 7days . And for the 14days also at the 1.5% the maximum split tensile obtained is

N/mm2 which is more than the reference mix (2.61 N/mm2).And finally for the 28 days the maximum strength obtained at 1.5% is 4.03 N/mm2 which is more than the reference mix (3.11 N/mm2).The final conclusion out of discussion on the results is the absolute maximum split tensile strength is at 1.5% PEG as shown in figure.

For this the maximum split tensile strength obtained was 3.68 N/mm2 at 1.5% which is more than the reference mix (2.11 N/mm2) for the 7days . And for the 14days also at the 1.5% the maximum split tensile obtained is 3.85 N/mm2 which is more than the reference mix (2.61 N/mm2).And finally for the 28 days the maximum strength obtained at 1.5% is 4.03 N/mm2 which is more than the reference mix (3.11 N/mm2).The final conclusion out of discussion on the results is the absolute maximum split tensile strength is at 1.5% PEG as shown in figure.

CONCLUSION

- The workability parameters are satisfied for both type of curing as per the standards.
- There is no specific deviation has been observed in plastic stage of concrete by the addition of self-curing agents in conventional self-compacting concrete.
- The reason is observed that the influence of fixed dosage of water reducing and viscosity modifying admixture as a self curing agent maintained the deviation.
- But it has been noticed that the addition of different curing agents altered the mechanical, durability.
- It has been observed that at an initial age, the strength development of concrete is low due to the addition of fly ash.
- Addition of self-curing agents with respect to cement weight, the curing agents in the order 1.5% PEG shows better results.
- The outcome from self-curing agent is superior to conventional concrete curing by sprinkler type.

- The self-cured concrete strength is found to very slight reduction with conventional concrete by immersion curing but ultimately satisfied the target strength.
- So, it is confirmed that the concrete with self-curing agents show reliable strength with immersion curing and superior behaviour to sprinkler curing. So, it is advisable to prevent sprinkler curing..
- The humidity profile for SCC is better compare to conventional cement paste mix.
- Very negligible loss of weight is observed for SCC than conventional mix.
- Self-desiccation effect is highly reduced for SCC than conventional mix.
- The presence of bound water is superior for SCC than traditional mix, as the mass loss due to evaporation of pore water from the surface will be higher for conventional mix.
- SCC experienced negligible bleed water compare to normal mix.
- The diffusion co-efficient is lower for SCC because of trivial evaporation effect than ordinary mix.

The present investigation results would be helpful for many organizations as listed below:

- Construction companies seeking alternatives to water curing and compaction by labors.
- Academic institutions, which adopt the investigated results for their research and development.
- Government firms, those seeking for minimize and protection of water to meet demand in future.
- Environmental organizations for the understanding of interaction behavior of admixtures with the atmosphere.

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