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Comparative Performance of Few Self-Curing Agents on Workability and Strength of Self-Curing Concrete

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Abstract - Self-curing concrete is a new generation concrete which does not need external curing. Since it does not need water for curing, self-curing concrete will be suitable in places where there is water scarcity and shortage of water. Many self-curing agents are reported in literature for the internal curing of concrete elements. An experimental study has been carried out to find the effectiveness of few self-curing agents namely Polyethylene glycol, Sodium Polyacrylate, Perlite, Propylene glycol and Vermiculite on the strength of concrete. Different dosages of 0.2%, 0.4%, 0.6% and 0.8% of these self-curing agents were added to M_{30} concrete mix. Workability, Split tensile strength and Compressive strength of mixes with and without the self-curing agents were found.

It is found that 0.8%, 0.2%, 0.8%, 0.8% and 0.4% are the optimal dosages of Polyethylene glycol, Sodium polyacrylate, Perlite, Propylene glycol and Vermiculite respectively. Polyethylene glycol and Propylene glycol are identified as the best self-curing agents.With regard to the compressive strength and split tensile strength, propylene glycol exhibited maximum strength at a dosage of 0.8% by weight of concrete.

Keywords:

Self-curing concrete, Self-curing agents, Workability, Compressive Strength and Split tensile strength.

INTRODUCTION

Concrete is a type of construction material comprising of cement, fine aggregate and coarse aggregate which are mixed with water and hardens over time. It is extensively used in the construction field. When compared with wood and steel, concrete is found to have higher resistance to temperature. To achieve excellent performance and durability of concrete, curing of concrete is indispensable. By curing, the concrete is shielded from the loss of moisture which is needed for hydration and the temperature range of the concrete is kept under control. Curing assists in improving the strength of the concrete and decreases the permeability of the concrete in hardened state. It is known that construction requires huge amount of water for curing. Water availability maybe deficit in some areas which makes external curing almost impossible. So, self- curing can come as an alternative method to overcome this problem. Self-curing can be carried out by using different self-curing agents such as PolyethyleneGlycol, Propylene Glycol, Sodium Poly-acrylate, Perlite, Vermiculite etc. It also contributes to the sustainability development of the environment. The optional dosage and the best self curing agent were identified through this study.

LITERATURE REVIEW

Self-curing is the process of hydrating the cement in concrete internally without external curing. Many chemicals function as self-curing agents.

Paraffin wax [1], Polyethylene glycol [2], Superabsorbent polymers [3] are some of the self-curing agents used for the internal curing of concrete. Vermiculite was used as an internal curing agent and was reported that 1.5% dosage of ground expanded vermiculite gives maximum strength [4]. Different dosages of 0.5%, 1%, 1.5% and 2% of Polyethylene Glycol (PEG) were mixed as the self-curing agent. The grade of cement used was 43 during the investigation. The compressive strength, split tensile strength and the flexural strength of concrete were found. Upto a dosage of 1% of PEG-400, an increase in the mechanical properties were noted and beyond the dosage of 1%, the mechanical properties decreased. The flexural strength was found to increase with the addition of 0.5% of PEG-400 and the strength decreased beyond the dosage of 0.5% of PEG [5]. The workability, strength and durability of self-consolidating concrete due to the addition of Super Absorbent Polymer (SAP) was investigated [6]. Workability of SCC mixes was found to decrease by 1-2% due to the initial absorption of water from the mix by the dry SAP particles. However, these values were in the permissible limits. Slump flow time and V-funnel time exhibited the same pattern and both werefound to have a perfect correlation with R^2 value of 0.95. An increase of 15-25% in the compressive strength was noticed at 7 days under air curing. The increase was 10-19% at 28 days. The best dosage was 0.1%. Electrical resistivity values were found to increase by 16-53% under air curing. Self-cured SCC mixtures with a dosage of 0.1% SAP and above were found to have good resistance to corrosion.

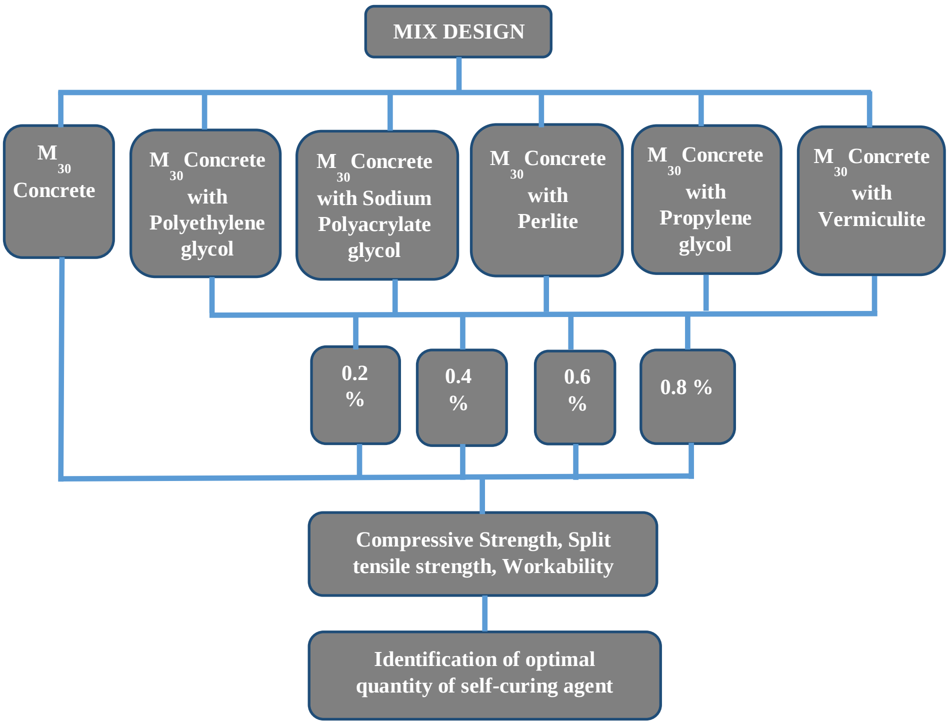
The shrinkage and mechanical properties of Lightweight Foamed Concrete (LFC) with different number of layer(s) of woven Fiber Glass Mesh (FGM) were explored [7]. The mechanical properties of low density, medium density and high density specimens having 1, 2 and 3 layers were determined. The higher drying shrinkage was obtained at the low density of LFC and vice versa, which was correlated to the volume of foam added. The utilization of FGM significantly reduced the drying shrinkage issue in LFC. At 600kg/m^3 density of LFC confined with 1-layer FGM, the during shrinkage was restricted to 48%, while for LFC density of 1100kg/m^3 and 1600kg/m^3 the drying shrinkage was limited to 57% and 43% when compared to the unconfined specimens at 56th day. When the number of layer(s) of FGM was increased to 2-layers and 3-layers, the drying shrinkage decreased by 52% to 77% than the unconfined/ control specimens.

A parametric study conducted on Geopolymer Concrete revealed that the optimum mix achieved 165mm slump and a compressive strength of 68.37 MPa at 28 days. The highest slump of 205mm was achieved by the mix with 20% of slice fume [8]. It was mentioned that polymers or porous aggregates absorb a large quantity of water and supply the water at the time of hydration[9]. An investigation on the shrinkage of self-cured concrete having 10% of silica and 25% of leca revealed that shrinkage can be completely eliminated [10].

To evaluate the relative performance of Polyethylene-glycol (PEG 400), Sodium Polyacrylate, Perlite, Propylene glycol and Vermiculite as self-curing agents, an experimental investigation was attempted.

METHODOLOGY

The methodology consists of mix design, casting of specimens and adding self-curing agents in different percentages varying from 0.2 to 0.8 in the mix. It was followed by tests on fresh and hardness concrete to find out the best dosage of the self-curing chemical. The methodology adopted is shown in Figure I.



FIGUREI. METHODOLOGY ADOPTED

MIX DESIGN

Concrete mix design is the procedure for finding the right quantities of cement, sand and aggregate and other admixtures to achieve the target strength, desired workability and durability. Accurate concrete mix design makes the construction economical. In this study, mix design was done for M30 grade concrete as per IS 10262:2009. The following are the material requirement for M30.

- Weight of Cement = 428.26 kgs
- Weight of Fine aggregate = 721.44 kgs
- Weight of Coarse aggregate = 1162.32 kgs
- Quantity of Water = $197/m^3$
- Water cement ratio = 0.46

MATERIAL USED

OPC of grade 53 conforming to IS:12269-1987 was employed for the experimental study.

The fine aggregate used was M-sand having a specific gravity of 2.3 and conforming to zone III.

Broken granite stones of size 20mm having a specific gravity of 2.7 was used as course aggregate.Portable Water conforming to the specifications of IS 456-2000 was adopted.

1. *Polyethylene Glycol (PEG 400):*

PEG 400 is a low molecular weight Polyethylene glycol. It is a clear, colourless, viscous liquid. Due to its low toxicity, PEG 400 is widely used in a variety of pharmaceutical formulations.It is dissolvable in acetone, water, benzene, glycerine, glycols and aromatic hydrocarbons and is dissolvable in aliphatic hydrocarbons to some extent.

The chemical formula for PEG 400 is $2nH_{4n+2}O_{n+1,}$ Density is $1.28g/cm^3$ and the melting point is4 to 8ºC (39 to 46ºF; 277K to 281K).Molecular weight: 380-420, Hydroxyl value: 265-295, Specific-gravity: 1.12-1.13.

PEG when added to concrete, it forms a thin cover over the water particles encompassing the water particles. The thickness of the cover layer is around 2 nm. Since a thin layer surrounds the water particles,evaporation of water particles is prevented and hence water is available for hydration. Due to continuous internal curing, early shrinkage cracks are prevented. Since external curing is not required, a large amount of water can be saved.

2. *Propylene Glycol:*

It is a viscous, colourless liquid, which is nearly odourless but possesses a faintly sweet taste. Its chemical formula is $CH_3CH(OH)CH_2OH$.

It is miscible with a broad range of solvents, including water, acetone, and chloroform. In general, glycols are non-irritating and have very low volatility.

Propylene glycol is used in architectural paintes to increase the dry time by reducing the evaporation rate compared to water. It enhances the mechanical properties especially in the early stages of hydration.

3. *Sodium Polyacrylate*

Sodium salt of poly-acrylic acid with the chemical formula $[-CH_2-CH(CO_2Na)-]_n$ is known as Sodium Polyacrylate.This Super-Absorbent Polymer (SAP) has the ability to absorb 100 to 1000 times its mass of water. When diffused in water, it forms a thick and translucent solution due to the ionic interactions of the molecules. Sodium poly-acrylate has many favourable mechanical properties. Some of these advantages include good mechanical stability, high resistance to heat, and good hydration.

Sodium poly-acrylate is considered as a thickening agent because it increases the viscosity of water-based compounds. When used as a super absorbent polymer in concrete, Sodium Polyacrylate has an encouraging potential to improve many properties of concrete including reduction in permeability. This property is very useful to prevent water leaks through the concrete mass making it a self-sealing concrete.

4. *Perlite:*

Perlite concrete provides better noise reduction and thermal insulating properties than the conventional concrete. Generally speaking, the lighter the weight, the greater will be the insulative properties.The use of perlite in concrete reduces the self-weight of concrete. Compared to normal concrete, 50% weight is often reduced. Perlite concrete as a finishing layer is widely used, due to the low weight and good workability.

5. *Vermiculite:*

Vermiculite being a hydrous phyloosilicate material, undergoes significant expansion when heated. When Vermiculate is heated in commercial furnace, exfoliation occurs.

It is non-structural construction product having a low density. It has both thermal and acoustical insulation properties and intrinsically fire resistant. Exfoliated vermiculite is used in concrete as the aggregate, with cement and water, along withadmixtures such as plasticisers as per the requirement.It is used as a core in fire doors, to build fire barriers, to encase or construct ductwork, and to protect steel building elements from the effect of fire.

PREPARATION OF SPECIMENS

As per IS 10262-2009 specification, M30 concrete mix was prepared. The required ingredients for different mixes were carefully weighed and mixed. Uniform mixing of the ingredients was guaranteed. The specimens were castin steel moulds. Cubes of size 150mm x 150mm x 150mm and cylinders of diameter 150mm and height 300mm were cast. The specimens were cast to determine the 28th day compressive and split tensile strengths. External curing was carried out for the specimens without curing agent. Curing agents were added in proportions of 0.2%, 0.4%, 0.6% and 0.8% by weight of cement.

EXPERIMENTAL INVESTIGATION

The details of the mixes cast are given in **TableI**.

TABLE I

DETAILS OF THE MIXES

S.No.	Mix	Chemical
1	Mix 1	No chemical
2	Mix 2	PEG 400-0.2
3	Mix 3	PEG 400-0.4
4	Mix 4	PEG 400-0.6
5	Mix 5	PEG 400-0.8
6	Mix 6	Sodium polyacrylate-0.2
7	Mix 7	Sodium polyacrylate-0.4
8	Mix 8	Sodium polyacrylate-0.6
9	Mix 9	Sodium polyacrylate-0.8
10	Mix 10	Perlite-0.2
11	Mix 11	Perlite-0.4
12	Mix 12	Perlite-0.6
13	Mix 13	Perlite-0.8
14	Mix 14	Propylene glycol-0.2
15	Mix 15	Propylene glycol-0.4
16	Mix 16	Propylene glycol-0.6
17	Mix 17	Propylene glycol-0.8
18	Mix 18	Vermiculite-0.2
19	Mix 19	Vermiculite-0.4
20	Mix 20	Vermiculite-0.6
21	Mix 21	Vermiculite-0.8

Workability

The workability of fresh concrete was found using the slump cone apparatus as per the specifications of IS 7320-1974. The internal surface of the slump cone was cleaned and was filled with concrete in four layers. Each layer was tamped 25 times by the rod. The mouldwas cautiously removed vertically after striking off the excess concrete from the top layer with a trowel. The height of the slump was measured in mm.

Compressive Strength Test

It is an investigation to find the ability of the concrete to withstand specific compressive stress. Cubes of size 150mm x 150mm x 150mm were used as specimen for this test. The28th day compressive strength was determined using the compression testing machine.Compressive forces were applied slowly at the rate of 14 N/sq mm/min till the specimens fail. Compressive strength of concrete can be found by dividing the failure load by the area of the specimen.

Split Tensile Strength

It is an indirect method of finding the tensile strength of concrete by applying a compressive force across the longitudinal axis of the specimens. Cylinders of diameter 150mm and height 300mm were used as specimens to find the split tensile strength.Loads were applied at the rate of 1.2MPa/min to 2.4MPa/min. The loads at which the specimens failed were noted. The Split Tensile strength was found using the formula,

$$T = 2P/\Pi DL$$

Where, P=maximum applied load or load at which the specimen breaks.

D=diameter of the specimen in mm

L=length of the specimen in mm

RESULTS AND DISCUSSION

Table II gives the details of the workability, compressive and tensile strengths of specimens with various proportions of PEG 400.

TABLE II

STRENGTH AND WORKABILITY OF CONCRETE WITH POLYETHYLENE GLYCOL 400

Polyethylene Glycol%	Compressive strength(N/mm^2)	Tensile strength (N/mm^2)	Workability (mm)
0	29.20	2.75	10
0.2	36.91	2.64	10
0.4	35.18	3.05	25
0.6	28.27	2.28	15
0.8	38.04	3.05	20

It can be seen from Table II that a dosage of 0.8% of PEG gives maximum compressive and split tensile strength. The compressive and split tensile strengths of the mix with 0.8% of PEG are 30.3% and 10.9% more than those of the mix without PEG.

Table III gives the details of the workability, compressive and tensile strengths of specimens with various proportions of sodium polyacrylate.

TABLE III

STRENGTH AND WORKABILITY OF CONCRETE WITH SODIUM POLYACRYLATE

Sodium Polyacrylate%	Compressive strength (N/mm^2)	Tensile strength (N/mm^2)	Workability (mm)
0	29.20	2.75	10
0.2	29.11	2.35	25
0.4	15.40	1.32	168
0.6	14.71	1.17	175
0.8	13.38	1.47	180

It can be seen from Table III that a dosage of 0.2% of sodium polyacrylate gives maximum compressive and split tensile strength. The mix with 0.2% of sodium polyacrylate and the mix without sodium polyacrylate were found to have almost the same compressive strength. However the split tensile strength of the mix with 0.2% of sodium polyacrylate is found to be 14.5 % less than that of the mix without sodium polyacrylate.The workability of the mix increases as the percentage of sodium polyacrylate increases.

Table IV gives the details of the workability, compressive and tensile strengths of specimens with various proportions of perlite.

TABLE IV

STRENGTH AND WORKABILITY OF CONCRETE WITH PERLITE

Perlite %	Compressive strength (N/mm^2)	Tensile strength (N/mm^2)	Workability (mm)
0	29.20	2.75	10
0.2	24.64	2.32	15
0.4	32.16	1.82	20
0.6	30.89	2.38	35
0.8	32.60	2.31	45

From Table IV, it can be seen that at a dosage of 0.8% of perlite, maximum compressive strength is achieved. The compressive strength at this dosage is found to be 11.6% higher than the mix without perlite. The workability at this dosage is found to be 4.5 times more than the workability of the mix without perlite. However there is a reduction of 16% in the in the split tensile strength.

The details of the workability, compressive and tensile strengths of specimens with various proportions of propylene glycol are prescribed in Table V.

TABLE V

STRENGTH AND WORKABILITY OF CONCRETE WITH PROPYLENE GLYCOL

Propylene glycol %	Compressive strength (N/mm^2)	Tensile strength (N/mm^2)	Workability (mm)
0	29.20	2.75	10
0.2	33.82	3.17	20
0.4	33.04	2.33	25
0.6	38.69	2.12	30
0.8	38.71	3.66	20

It can be noted from Table V that the compressive strength of the mixesincreases upto 0.8% dosage of propylene glycol. However beyond a dosage of 0.6%, the workability decreases. At the optimal dosage of 0.8%, the compressive strength and the split tensile strengths are 32.6% and 33.1% more than those of the mix without propylene glycol.

Table VI gives the details of the workability, compressive and tensile strengths of specimens with various proportions of vermiculite.

TABLE VI

STRENGTH AND WORKABILITY OF CONCRETE WITH VERMICULITE

Vermiculite %	Compressive strength (N/mm^2)	Tensile strength (N/mm^2)	Workability (mm)
0	29.20	2.75	10
0.2	32.91	2.73	30
0.4	39.60	2.43	35
0.6	34.51	2.7	5
0.8	31.30	2.6	5

It can be noted from Table VI that at the most favorable dosage of 0.4%, the compressive strength and the workability are the highest. The compressive strength is 35.6% more than that of the mix without vermiculite. At this dosage, the workability is 3.5 times that of the mix without vermiculite. The decrease in the split tensile strength is 11.6%.

Table VII gives the details of the optimal dosages of self-curing agents with regard to the compressive strength.

TABLE VII

OPTIMAL DOSAGES OF SELF-CURING AGENTS

S.No	**Self-curing Agent**	**Optimal Dosages %**	**Compressive Strength (N/mm^2)**	**Workability (mm)**	**Split Tensile (N/mm^2)**
1	-	-	29.20	10	2.75
2	PEG 400	0.8	38.04	20	3.05
3	Sodium Polyacrylate	0.2	29.11	25	2.35
4	Perlite	0.8	32.60	45	2.31
5	Propylene glycol	0.8	38.71	20	3.66
6	Vermiculite	0.4	39.60	35	2.43

From Table VI, it can be seen that all mixes with self curing agents exhibited higher compressive strength than that of the normally cured mix except for theone with sodium polyacrylate which hada strength of 29.11N/mm^2 which is 0.31% less thanthe conventionally cured concrete. The maximum strength of 39.6N/mm^2 is obtained for the concrete with vermiculite which is 35.6% more than the strength of the conventionally cured concrete. The workability of the concrete with perlite is maximum. The performance of propylene glycol is also good. Both the compressive and split tensile strengths of the mix with 0.8% of propylene glycol are excellent with values of 38.71N/mm^2 and 3.66N/mm^2.

CONCLUSIONS

- Compressive strength of all mixes with PEG 400 except one is found to be higher than that of the conventionally cured concrete.
- The best dosage of PEG 400 is found to be 0.8%.
- When the dosage of sodium polyacrylate was 0.2%, all mixes exhibited the same compressive strength as that of the conventionally cured concrete. At other dosages, the strength was lower than the strength of conventionally cured concrete. Hence the performance of polyacrylate as a self-curing agent is not satisfactory.
- The optimal dosage of perlite is found to be 0.8% and the compressive strength attained at this dosage is 32.6 N/mm^2 which is 11.6% more than that of the conventionally cured concrete.
- All mixes with propylene glycol exhibited higher strength than the conventionally cured concrete.
- The optimal dosage of propylene glycol was 0.8% and the compressive strength at this dosage is 38.71 N/mm^2 which is 32.6% higher than that of the conventionally cured concrete.

- All mixes with vermiculite exhibited higher compressive strength than the conventionally cured concrete. The optimal dosage of vermiculite is found to be 0.4% and the compressive strength at this dosage is found to be 39.6 N/ mm^2 which is 35.6% higher than that of the conventionally cured concrete.
- The split tensile strength of concrete with the optimal dosage of PEG 400 is 3.05N/mm^2 which is 10.91% higher than that of the conventionally cured concrete.
- The split tensile strength of concrete which had Sodium polyacrylate, perlite and vermiculite are found to be lower than that of the conventionally cured concrete.
- The split tensile strength of concrete with propylene glycol at the optimal dosage is 3.66 N/ mm^2 which is 33.09% higher than that of the conventionally cured concrete.
- PEG400 and Propylene glycol are identified as best self-curing agents.

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