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An Experimental Investigation of 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 $3m^3$ 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.

Keywords: Self-curing concrete - Water retention - Polyethylene Glycol - Immersion curing - Sprinkler curing

I. INTRODUCTION

During the last two decades, concrete technology has been undergoing rapid improvement. In the past few decades, internal curing of concrete has gained popularity and is steadily progressing from laboratory to field of practice [3], [16] and [17]. Curing of concrete is maintaining satisfactory moisture content in concrete during its early ages in order to develop the desired properties [8]. 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. Therefore, several researchers are attracted towards identifying the self-curing agent. polyethylene-glycol which decreases the surface tension of the water and minimizes the water evaporation from concrete [5], [4] and [14] and hence increases the water retention capacity of the concrete. It has been found that water-soluble polymers (Polyethylene Glycol) can be used as self-curing agents in concrete. In the new millennium, concrete incorporating self-curing agents will represent a new trend in the concrete construction.

II. EXPERIMENTAL PROGRAM

A. Material

In this study the materials used are Portland Pozzolana Cement of brand name "SANKAR", conforming to IS:1489 (PT 1):1991 , fine aggregate obtained from Karur River bed are tested as per IS:383-1970, angular coarse aggregates of maximum size 20mm are tested as per IS:383-1970. The following Tables shows the concrete mix used in this investigation.

TABLE 1
CONCRETE MIXES INVOLVING SELF-CURING AGENTFOR ONE CUBE OF SIZE 150 X 150 mm

Grade of concrete	Cement (kg)	Sand (kg)	Coarse aggregate (kg)	Water (lt)	PEG (ml)
M20	2.2	3.14	7.47	1.09	6.60
M30	2.9	2.89	7.27	1.23	8.70
M40	3.7	3.0	6.5	1.32	11.1

TABLE 2
CONCRETE MIXES INVOLVING SELF-CURING AGENT FOR ONE CYLINDER OF SIZE 150X300 mm

Grade of concrete	Cement (kg)	Sand (kg)	Coarse aggregate (kg)	Water (ml)	PEG (ml)
M20	1.4	2	4.76	690	4.20
M30	1.85	1.84	4.63	790	5.55
M40	2.36	1.91	4.14	843	7.08

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 are given in Table 3.

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 0.3% by weight of cement. Concretes of grade M20, M30, and M40 have been chosen for this experimental work.

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TABLE 3
SLUMP AND COMPACTING FACTOR TESTS RESULTS

Grade of concrete	Designation	w/c	Slump (mm)	Compacting factor
M_{20}	Conventional concrete	0.5	130	0.94
	Self-curing concrete	0.5	180	0.97
M_{30}	Conventional concrete	0.43	75	0.92
	Self-curing concrete	0.43	90	0.94
M_{40}	Conventional concrete	0.36	15	0.85
	Self-curing concrete	0.36	25	0.9

B. Non-destructive test

Schmidt rebound hammer test was done to find out the compressive strength of concrete as per IS: 13311 (Part 2) – 1992. Keeping rebound hammer in vertical position on 150mm cube specimen the test was conducted.

C. Compression and split tensile strengths

Cubes of size 150mm X 150mm and cylinder of size 150mm diameter and 300mm height of both conventional and self-curing concretes were casted. Each layer was compacted with 25 blows using steel tamping rod of 16mm diameter and 600mm length. The specimens that are cured conventionally were allowed to get dry for 24 hours after casting. For conventional concrete involving sprinkler curing, water was sprinkled on the cubes and cylinders periodically.

Fig1.Compressive strength of concrete

Self-cured specimens were kept as such without the application of any external curing after their removal from moulds. The strength related tests were carried out for hardened conventional concrete and self-cured concrete at the age of 3 days, 7 days and 28 days to ascertain the strength related properties such as cube compressive strength, cylinder compressive strength and cylinder split tensile strength.

D. Water absorption test

The 100mm dia, 50mm height cylinder after casting were immersed in water for 90 days-curing time. These specimens were then oven dried for 24 hours at the temperature 110^{o}C until the mass becomes constant and again weighed, which was noted as the dry weight (W1) of the cylinder. Then it was kept in hot water at 85^{o}C for 3.5 hours and its weight was taken as the wet weight (W2) of the cylinder [2].

$$Percentage\,water\,absorption = \frac{(W2 - W1)}{W1} X\ 100$$

E. Durability test (water sorpitivity test)

To measure the rate of water absorption, water sorptivity test was carried out. The cylinders of size 50mm diameter and 100mm height were used for both the conventional and the self-curing concrete. The specimens were oven dried at 110 ˚C for 24 hours and then the specimens were left to cool in dry condition for further 24 hours. As per ASTM C 1585 – O4e1, the test was carried out by placing one circular surface of the specimen to be in contact with water at 5mm depth as shown in Fig 2.

Fig.2. Depth of Penetration

The remaining portion of the specimen (other than 5mm) was coated with high quality water proofer (High Bond Polymers) in order to create unidirectional flow pattern through the concrete specimen.
The water sorptivity (by capillary suction) tests were carried out in hardened conventional concrete and self-cured concrete at the age of 28 days to ascertain the amount of absorption of water at the interval of 0.5 hour, 1 hour, 1.5 hours, 2 hours, 2.5 hours and 3 hours. The water sorptivity could be found by the formula,

$$\frac{W}{(A\ X\ \sqrt{t})} = k$$

where, W = weight of water

III.RESULTS AND DISCUSSIONS

The compressive strength of concrete at 3 days, 7 days and 28 days curing of cube and cylinderby Schmidt rebound hammerfor different grades of concretes are given in the Fig. 3 to 5. The results show that there is increase in compressive strength in case of self-cured concrete specimens when compared to other concrete specimens.

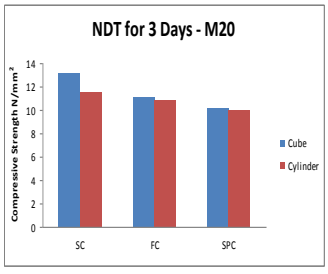

Fig. 3.a

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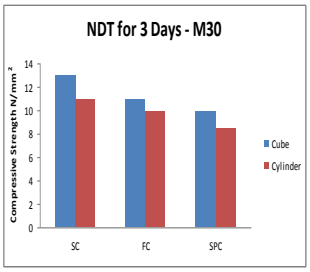

Fig. 3.b

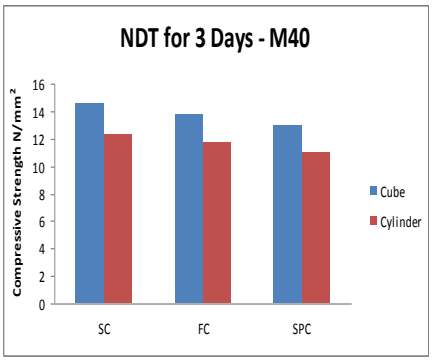

Fig. 3.c

Fig. 3 Comparison chart for conventional concrete (Fully cured/Sprinkler cured) with Self-cured concrete for 3 days using NDT (Schmidt Rebound Hammer)

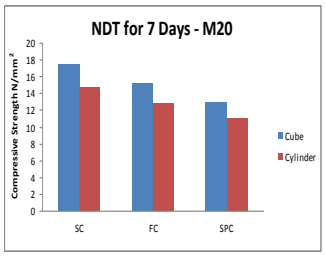

Fig. 4.a

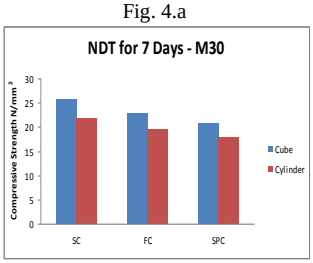

Fig. 4.b

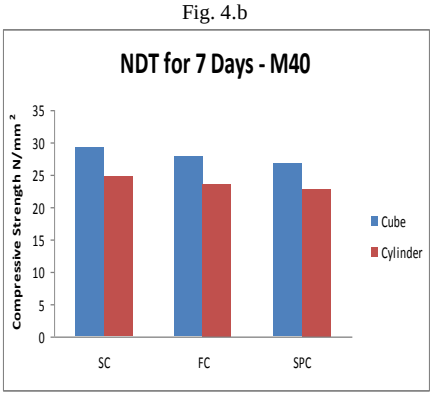

Fig. 4.c

Fig. 4 Comparison chart for conventional concrete (Fully cured/Sprinkler cured) with Self-cured concrete for 7 days using NDT (Schmidt Rebound Hammer)

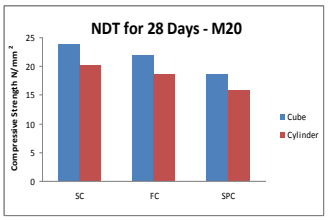

Fig. 5.a

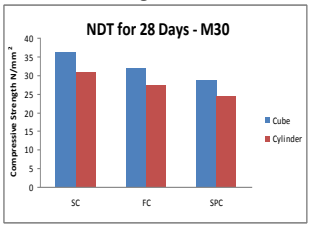

Fig. 5.b

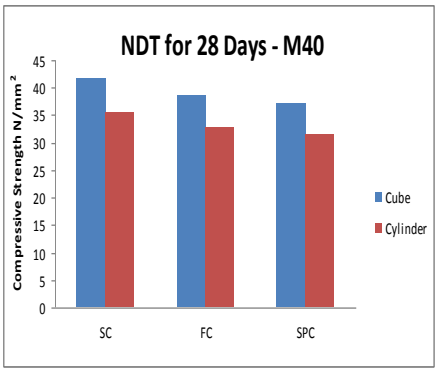

Fig. 5.c

Fig. 5 Comparison chart for conventional concrete (Fully cured/Sprinkler cured) with Self-cured concrete for 28 days using NDT (Schmidt Rebound Hammer)

For M20 concrete, the percentage increase in compressive strength at 28 days of curing is about 15.8 and 26.3 respectively for fully cured and self-cured concrete compared with sprinkler cured concrete. For M30 concrete, the percentage increase in compressive strength at 28 days curing is 12.5 and 28.8 respectively for fully cured and self-cured concrete compared with sprinkler cured concrete. For M40 concrete, the percentage increase in compressive strength at 28 days curing is 7.4 and 14.7 for fully cured and self-cured concrete compared with sprinkler cured concrete.

From the fig. 3 to 5, it is clear that self-cured concrete gives more compressive strength based on NDT (Rebound Hammer) compared with cubes and cylinders subjected to the other two types of curing.

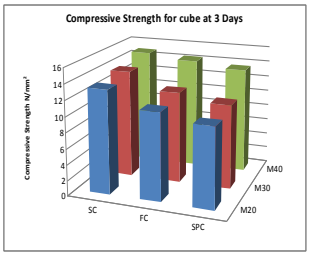

Fig. 6.a

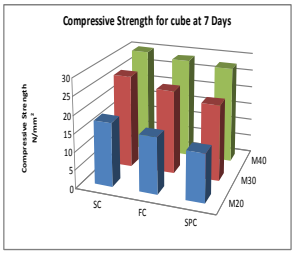

Fig. 6.b

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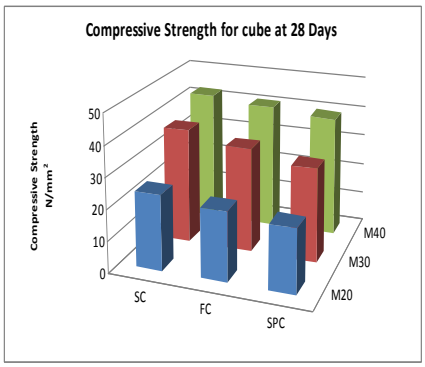

Fig. 6.c

Fig. 6 Comparison chart for conventional concrete (Fully cured/Sprinkler cured) with Self-cured concrete for 3 days, 7 days and 28 days using Compression testing machine

The Compressive strength of cube obtained by HEICO compression Testing machine for 3, 7 and 28 days specimen under different curing conditions are shown in Fig. 6. From which it is clear the compressive strength of self-cured concrete is more when compared with other types of curing. For M20 grade of concrete, the percentage increase in compressive strength at 28 days curing is 11.7 and 20.6 respectively for fully cured and self-cured concrete compared with sprinkler cured concrete. For M30 grade of concrete, the percentage increase in compressive strength at 28 days curing is 11.1 and 27.4 respectively for fully cured and self-cured concrete compared with sprinkler cured concrete. For M40 grade of concrete, the percentage increase in compressive strength at 28 days curing is 8.7 and 17.2 respectively for fully cured and self-cured concrete compared with sprinkler cured concrete.

The Split tensile strength for 3, 7 and 28 days specimen for cylinders cured under different types of curing is shown in Fig.7. From these figures, it is clear that self-cured concrete gives more Split Tensile strength compared to the other types of curing. For M20 concrete, the percentage increase in split tensile strength at 28 days curing is 7.5 and 12.7 respectively for fully cured and self-cured concrete compared with sprinkler cured concrete.

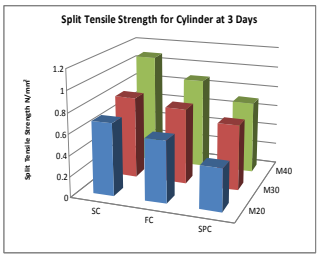

Fig. 7.a

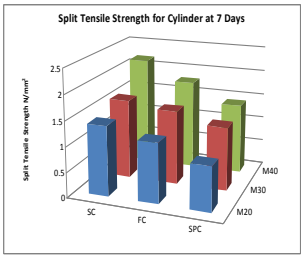

Fig. 7.b

For M30 concrete, the percentage increase in split tensile strength at 28 days curing is 9 and 30.1 respectively for fully cured and self-cured concrete compared with sprinkler cured concrete. For M40 concrete, the percentage increase in split tensile strength at 28 days curing is 8.3 and 24.7 respectively for fully cured and self-cured concrete compared with sprinkler cured concrete.

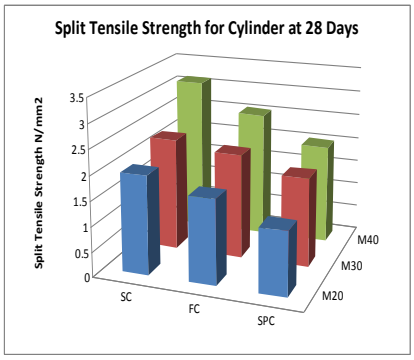

Fig. 7.c

Fig. 7 Comparison chart of Split tensile strength for conventional concrete (Fully cured/Sprinkler cured) with Self-cured concrete for 3 days, 7 days and 28 days using Compression testing machine

The results for water absorption and water sorptivity for the self-curing and conventional concrete at the age of 28 days are shown in Fig.8 and 9. From these figures, it is clear that there is a decrease in value of amount of water absorption and water sorptivity of self-curing concrete with fully curing and sprinkler curing concrete.

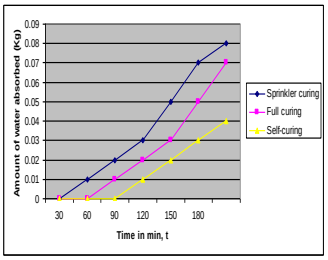

Fig. 8.a

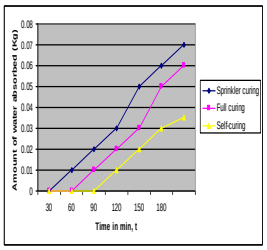

Fig. 8.b

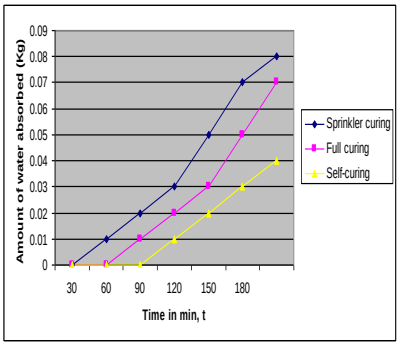

Fig. 8.c

Fig. 8 Water absorption chart for M20, M30 and M40

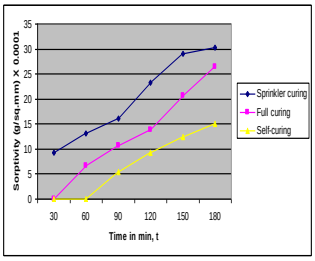

Fig. 9.a

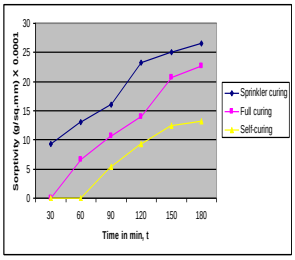

Fig. 9.b

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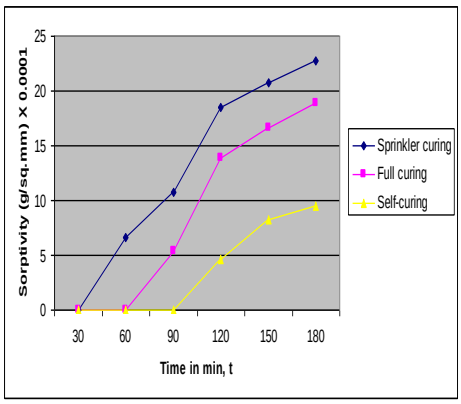

Fig. 9.c

Fig. 9 Water sorptivity chart for M20, M30 and M40

The results conveys that in all these grades of concrete the amount of absorption of water and water sorptivity for self-cured concrete is found to be lesser than that of fully cured and sprinkler cured concrete specimens showing that the amount of pores is in self-cured concrete is less compared to the other two types.

IV. CONCLUSION

From this experimental investigation the following conclusions are attained:

- The Compressive strength of cubes and cylinders by NDT (Rebound Hammer) for self-cured concrete is higher than that of conventional concrete cured by full curing and sprinkler curing.
- The Compressive strength of cubes by HEICO compression testing machine for self-cured concrete is higher than of concrete cured by full curing and sprinkler curing.
- The Split tensile strength of self-cured cylinder specimen is higher than that of conventionally cured specimen.
- Self-cured concrete is found to have less water absorption and water sorptivity values compared with concrete cured by other methods.
- Self-cured concrete thus has fewer amounts of pores.

The success of these initial studies highlights the promise of additional work. In planned studies, the mix design will be optimized for self-curing agent (polyethylene glycol) in concrete mix.

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