

Self Curing Concrete with Partial Replacement of Course Aggregates With Fly Ash Pellets

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ABSTRACT: As water is becoming a scarce material day-by-day, there is an urgent need to do research work in saving of water for making concrete. Curing of concrete is very important for maintaining satisfactory moisture content in concrete during its early stages in order to develop the desired properties. Good curing is not always practical in many cases. Curing of concrete plays a major role in developing the concrete microstructure and pore structure and hence improves its durability and performance. Weight of concrete leads to more weight on structure. Design of heavy load structures are not economical. Keeping importance to this, an attempt has been made to develop self-curing concrete by using water-soluble Polyethylene Glycol (PEG 400) as self-curing agent and partial replacement of coarse aggregates with fly ash pellets. The main aim of this investigation is to study the strength properties of concrete using water-soluble Polyethylene Glycol (PEG 400) as self-curing agent and find the optimum dosage required for maximum strength. The function of self-curing agent is to reduce the water evaporation from concrete, and hence they increase the water retention capacity of concrete and it will absorb the water from the atmosphere. The use of self-curing agent is very important from the point of view that saving of water is a necessity everyday (each one cubic meter 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, flexural strength of concrete containing self-curing agent is investigated and compared with those of conventionally cured concrete.

KEYWORDS: Self Curing Concrete, Light Weight Aggregates, PEG-400

I. INTRODUCTION

From the last two decades, concrete technology 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. 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 to solve those water problems and saving of water. Therefore, several researchers are attracted towards identifying the self-curing agent. One of the self-curing agent is Polyethylene-glycol which decreases the surface tension of the water and minimizes the water evaporation from concrete 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 agent in concrete. In the new millennium, concrete incorporating self-curing agents will represent a new trend in the concrete construction.

Internal curing was originally defined by the American Concrete Institute (ACI) as “supplying water throughout a freshly placed cementitious mixture using reservoirs, via pre-wetted lightweight aggregates, that readily release water as needed for hydration or to replace moisture lost through evaporation or self-desiccation.”

In this study optimum dosage of PEG-400 required to get strength properties without adding any mineral or chemical admixtures and how the effect of self-curing agent in concrete were investigated.

SELF CURING:

The ACI-308 code states that “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.” “Internal curing” is often also referred as Self-curing. Self-Curing Concrete can be achieved by adding self-curing agents. The concept of self-curing agents is to reduce the water evaporation from concrete and hence increase the water retention capacity of the concrete. It was found that water soluble polymers can be used as self-curing agents in concrete. Curing of concrete plays a major role in developing the concrete microstructure and pore structure and hence improves its durability and performance. Currently, there are two major methods available for internal curing of concrete.

1. By using saturated porous LWA to supply internal source of water for hydration of cement

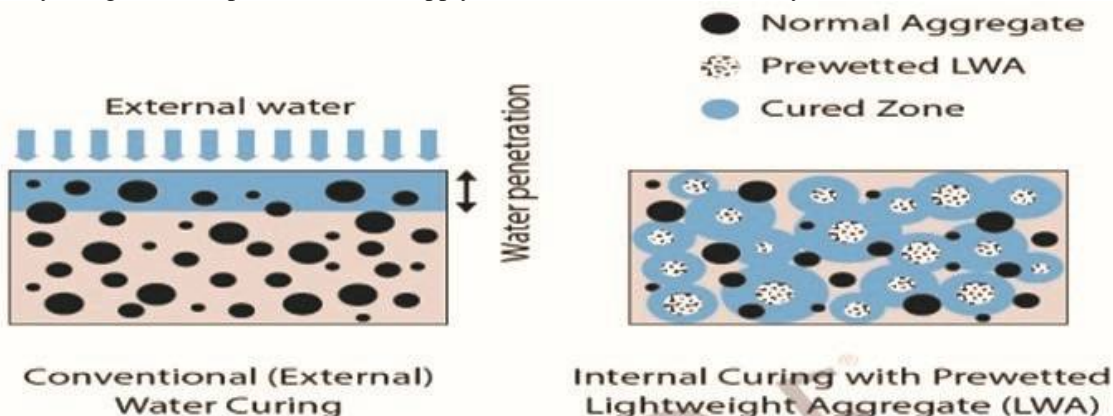


Fig. 1 Conventional curing versus Internal Curing

Using Self curing Agents: The concept of self-curing agent is to reduce the water evaporation from the concrete and hence increase the water retention capacity of the concrete and also absorbs the moisture from air and then releases it into the concrete. Polyethyleneglycol, Paraffin Wax, SAP, Polyvinyl alcohol are some of the materials available in market.

Significance and Objectives

As water is becoming a scarce material day-by-day, there is an urgent need to do research work in saving of water for making concrete. Curing of concrete is very important for maintaining satisfactory moisture content in concrete during its early stages in order to develop the desired properties. Good curing is not always practical in many cases. Curing of concrete plays a major role in developing the concrete microstructure and pore structure and hence improves its durability and performance. Weight of concrete leads to more weight on structure. Design of heavy load structures are not economical. Keeping importance to this, an attempt has been made to develop self-curing concrete by using water-soluble Polyethylene Glycol (PEG 400) as self-curing agent and partial replacement of coarse aggregates with fly ash pellets.

The following are the objectives of the study

- To study the strength properties of concrete using water soluble Polyethylene Glycol as self-curing agent.
- To find the optimum dosage of PEG-400 required for maximum strength of concrete.
- To study the strength properties of self-curing concrete with partial replacement of CA by fly ash pellets 25%.
- Comparison the self-curing concrete results with conventional concrete results.

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II. LITERATURE REVIEW

Wen-Chen Jaustated that “self-curing concrete is provided to absorb water from moisture from air to achieve better hydration of cement in concrete. It solves the problem when the degree of cement hydration is lowered due to no curing or improper curing by using a self-curing agent like poly-acrylic acid which has strong capability of absorbing moisture from the atmosphere and providing water required for curing concrete”.

AielsteinRozario, Dr.C.Freeda Christy, M.HannahAngelin(2013), “Experimental studies on effects of sulphate resistance on self.curing concrete”the main investigation in this study is variation of water soluble polymer dosage of 0.05% and 0.1%. The concrete produced by the addition of fly ash as a partial replacement of cement. The percentage of weight loss and of concrete was studied. The test result indicates that use of water soluble polymers in concrete has improved performance of concrete.

A.S. El-Dieb (2007), “Self-curing concrete: Water retention, hydration and moisture transport” investigated water retention of concrete using water-soluble polymeric glycol as self-curing agent. Concrete weight loss and internal relative humidity measurements with time were carried out, in order to evaluate the water retention of self-curing concrete. Water transport through concrete is evaluated by measuring absorption%, permeable voids%, water Sorptivity and water permeability.

Magda I. Mousa, Mohamed G. Mahdy, Ahmed H. Abdel-Reheem, Akram Z. Yehia (2014), “Mechanical properties of self-curing concrete” carried out to compare among concretes without or with silica fume (SF) along with chemical type of shrinkage reducing admixture, polyethylene-glycol (Ch), and leca as self-curing agents for water retention even at elevated temperature (50⁰C) and their durability. The cement content of 400 kg/m³, silica fume of 15% by weight of cement, polyethylene-glycol of 2% by weight of cement, pre-saturated lightweight aggregate (leca) 15% by volume of sand and water with Ch/ binder ratio of 0.4 were selected in this study. Some of the physical and mechanical properties were determined periodically up to 28 days in case of exposure to air curing in temperature of (25 C) and (50⁰C) while up to 6 months of exposure to 5% of carbon dioxide and wet/dry cycles in 8% of sodium chloride for durability study. The concrete mass loss and the volumetric water absorption were measured, to evaluate the water retention of the investigated concretes. Silica fume concrete either without or with Ch gave the best results under all curing regimes; significant water retention and good durability properties.

Mateusz Wyrzykowski, PietroLura, Francesco Pesavento and DariuszGawin (2012), “Modeling of Water Migration during Internal Curing with Super absorbent Polymers”, they carried A mechanistic-type numerical model of cementitious materials is applied for the analysis of water migration kinetics from internal curing agents [superabsorbent polymers (SAP)] into hydrating cement pastes with a low water-to-cement ratio. It is shown that the release of curing water at early age (i.e., during approximately the first day of hydration) allows for a uniform and practically instantaneous distribution of water within the whole volume of cured paste, even if the distances for water migration are as high as 2–3 mm. The evolution of permeability as a result of the hydration process is shown to have a major impact on the mobility of water in the cement paste. The depercolation of capillary porosity may substantially inhibit the water transport. The analysis shows that a part of the water first received by the paste in the proximity of the SAP can be later redistributed to a large volume of hardening paste, even after the permeability has become very low.

Sri Rama Chand Madduru ,Swamy Naga RatnaGiriPallapothu , Rathish Kumar Pancharathi Rajesh Kumar Garje, RaveenaChakilam (2016),

“Effect of self-curing chemicals in self-compacting mortars”In the presentwork, two self-compacting mortars 1:1 with w/c = 0.34 and 1:3 with w/c = 0.5 are investigated with twoself-curing agents (Polyethylene Glycol 4000 and 200). A comparison was made considering three curingconditions namely wet curing, self-curing and no curing. Different dosages, i.e. 0%, 0.1%, 0.5% and 1.0%mass of PEGs were attempted with the above two curing agents. Mini-slump flow and V funnel tests weredone to confirm flow properties required as per the specifications. Water retention, compressive strength,sorptivity and acid durability tests were carried out on SCM specimens.

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III. MATERIALS

The properties of the materials used in the experimental work are presented in this chapter. The material specifications for cement, fine aggregate, coarse aggregate, fly ash pellets and PEG-400 are discussed. The physical properties of locally available materials were determined in the laboratory.

CEMENT

“Coromandel” brand Ordinary Portland Cement of grade 43 was used in this present investigation. The cement was tested for various physical properties according to IS: 12269-1987 (revised 2004). It is observed that all the values are within the IS specified limits. The specific gravity of cement used in this study is tabulated in Table 1

Table 01: Specific Gravity of Cement

Sl. No.	Observations	Trial 1	Trial 2	Trial 3
1.	Weight of the specific gravity bottle(W_1), g	77.10	77.10	77.10
2.	Weight of bottle + 1/3 rd filled cement(W_2), g	110.9	109.8	109.5
3.	Weight of bottle + 1/3 rd filled cement + kerosene(W_3), g	184	183	183
4.	Weight of bottle + kerosene (W_4), g	155.1	155.1	155.1
5.	Specific gravity	3.15	3.08	3.14

Average specific gravity of cement = 3.12

FINE AGGREGATE

Locally available river sand was used in this study as fine aggregate, conforming to grading zone-II as per IS: 383-1970. The sand was screened at site to remove deleterious material. Sieve analysis was performed and the analysis results are tabulated in Table 2. The specific gravity of sand is tabulated in Table 3. Weight of sample taken = 1000 gms

Table 02: Sieve Analysis of Fine Aggregate

Sieve size (mm)	Weight Retained (g)	Cumulative Weight retained (g)	% Cumulative Retained	% passing
4.75	12	12	1.2	98.80
2.36	16	28	2.8	97.20
1.18	223	251	25.1	74.90
0.6	178	429	42.9	57.10
0.3	428	857	85.7	14.3
0.15	128	985	98.5	1.5
Pan	14	999	99.90	0.10

Fineness modulus of fine aggregate = 2.6

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Table 03: Specific Gravity of Fine Aggregate

Sl. No.	Observations	Trial 1	Trial 2	Trial 3
1.	Weight of the specific gravity bottle, (W_1), g	25	25	25
2.	Weight of the bottle + 1/3 rd filled aggregate, (W_2), g	54	53.8	53.5
3.	W_2 + water, (W_3), g	93.6	93.5	93.4
4.	Weight of bottle + water, (W_4), g	75	75	75
5.	Specific Gravity	2.52	2.45	2.82

Average specific gravity of fine aggregate = 2.6

COARSEAGGREGATE

In the present study a locally available coarse aggregates (60%-20 mm and 40%-12.5mm) was used. Sieve analysis was performed and the analysis results are tabulated in Table 4. The specific gravity of coarse aggregate is tabulated in Table 5. Weight of sample taken = 5000 gms.

Table 04: Sieve Analysis of Coarse Aggregate

Sieve size (mm)	Weight Retained (kg)	Cumulative Weight retained (kg)	%Cumulative Retained	% passing
40	0.00	0.00	0.00	100.00
20	1.20	1.20	24.00	76.00
10	3.00	4.20	84.00	26.00
4.75	0.799	4.999	99.98	0.02
2.36	0.001	5	100.00	0.00
1.18	0.00	0	100.00	0.00
0.6	0.00	0	100.00	0.00
0.3	0.00	0	100.00	0.00
0.15	0.00	0	100.00	0.00

Fineness modulus of coarse aggregate= 7.07

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Table 05: Specific Gravity of Coarse Aggregate

Sl. No.	Observations	Trial 1	Trial 2	Trial 3
1.	Weight of the specific gravity pycnometer (W_1), g	619.50	619.50	619.50
2.	Weight of pycnometer + 1/3 rd filled aggregate (W_2), g	1110	1120	1115
3.	Weight of pycnometer + 1/3 rd filled aggregate + water (W_3), g	1756	1759	1753
4.	Weight of pycnometer + water (W_4), g	1444	1448	1445
5.	Specific gravity	2.75	2.87	2.77

Average specific gravity of coarse aggregate = 2.80

3.5 FLY ASH PELLETS:

Fly ash pellets was used to reduce the weight of concrete. Coarse aggregates are replaced by fly ash pellets with 25%. Table 06 shows the specific gravity of FAP and Table 7 shows the water absorption of FAP.

Table 06: Specific Gravity of Fly ash pellets

Sl. No.	Observations	Trial 1	Trial 2	Trial 3
1.	Weight of the specific gravity pycnometer (W_1), g	640	640	640
2.	$W_1 + 1/3^{\text{rd}}$ filled aggregate, (W_2), g	1011	1025	1008
3.	$W_2 + \text{water}$ (W_3), g	1693	1702	1689
4.	Weight of pycnometer + water (W_4), g	1497	1497	1497
5.	Specific gravity	2.12	2.10	2.14

Average specific gravity of coarse fly ash pellets = 2.12

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Table 07: Water absorption of Fly ash pellets

Sl. No.	Observations	Trial 1	Trial 2	Trial 3
1.	Empty weight of container	127	127	127
2.	Empty weight of container + 500 gms of FAP	627	627	627
3.	Empty weight of container + 500 gms of FAP + with moisture	699	693	705
4.	Water absorption	14.40	13.20	15.6

Average water absorption of Fly ash pellets = 14.40%

POLYETHYLENE GLYCOL-400

Polyethylene glycol is a condensation polymer of ethylene oxide and water with the general formula $H(OCH_2CH_2)_nOH$, where n is the average number of repeating oxyethylene groups typically from 4 to about 180. PEG is termed in combination with a numeric suffix which indicates the average molecular weights. One common feature of PEG appears to be the water-soluble nature. Polyethylene glycol is non-toxic, odourless, neutral, lubricating, non-volatile and non-irritating and is used in a variety of pharmaceuticals. For PEG-400 the value of n varies from 8.2 to 9.1 and specific gravity is 1.12.

POTABLE WATER

Water is an essential component of concrete for mixing and curing. It should be free from harmful impurities, which may hinder the normal hardening process of concrete. Water found satisfactory for mixing is also suitable for curing to this investigation. Table 8 summarizes the properties of materials used in this study.

Table 08: Summarizes the Properties of Material

Sl. No	Material	Property	Value
1.	Cement	Type	OPC
		Grade	43 Grade
		Specific Gravity	3.12
		Fineness	3.43
		Consistency	32%
		Initial Setting Time	32 min
2.	Fine Aggregate	Specific Gravity	2.60

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		Fineness Modulus	2.6
		Dry Density	1706 kg/m ³
3.	Coarse Aggregate 20 mm size	Specific Gravity	2.80
		Fineness Modulus	7.07
		Dry Density	1659kg/m ³
4.	Fly ash pellets	Specific gravity	2.12
		Water absorption	14.4%
5.	PEG-400	Specific gravity	1.12

CONCRETE MIX DESIGN – AS PER IS 10262:2009

DESIGN STIPULATIONS:

- Design strength : 25 MPa
- Workability : 100-125 mm
- Maximum size of aggregate : 20 mm
- Cement content : 420 kg/m³
- Water cement ratio : 0.45

TEST DATA FOR MATERIALS:

- Cement type : OPC 43 grade
- Fineness modulus of fine aggregate : 2.56
- Specific gravity of cement : 3.15
- Specific gravity of fine aggregate : 2.60
- Specific gravity of coarse aggregate : 2.80
- Specific gravity of fly ash pellets : 2.12
- Water absorption of CA : 0.35%
- Water absorption of FA : 0.7%
- Water absorption of FAP : 14.4%

IV. EXPERIMENTAL INVESTIGATIONS

SPECIMEN CASTING

Mixing was carried out in a pan mixer machine. Initially Coarse aggregates, FAP, FA was added according to mix proportions. Cement was added and mixed in the dry condition. After some time water with self-curing agent was added to the mix, to get uniform mix and to avoid the balling effect. Figure shows the casting of specimens.

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Fig 2 casting of specimens

Workability of the mix was determined using slump cone test. The specimens were compacted for two minutes on the table vibrator. The self-curing of specimen was carried out for 28 days. The specimens were taken out from the laboratory allowed to surface dry before testing them.

The beam specimens of size 100mm × 100mm × 500mm, cube specimens of size 150mm and cylinder specimens of diameter 150mm and length 300mm for M25 grade self-curing concrete were casted according to mix proportion and water cement ratio of 0.45. A total of 30 cubes 30 cylinders and 30 beams were cast with different proportions of PEG-400.

TRIAL MIX FOR PARTIAL REPLACEMENT OF CA WITH FAP

Table 9 shows the trial mix for partial replacement of CA0 with FAP with different proportions.

Table 9 Trial mix results for FAP

FAP % of CA	Load (kN)	Compressive strength 7 days (N/mm ²)
10%	480	21.33
15%	484	21.51
20%	489	21.73
25%	496	22.04
30%	473	21.02

Replacement of CA by FAP with 25%

So replacement of CA by fly ash pellets with 25% by volume gives better results.

FRESH CONCRETE PROPERTIES

Workability Test

A concrete mix must be made of the right amount of cement, aggregates and water to make the concrete workable enough for easy compaction and placing and strong enough for good performance in resisting stresses after hardening. If the mix is too dry, then its compaction will be too difficult and if it is too wet, then the concrete is likely to be weak.

Slump test is the simplest test for workability and are most widely used on construction sites. In the slump test, the distance that a cone full of concrete slumps down is measured when the cone is lifted from around the concrete. The slump can vary from nil on dry mixes to complete collapse on very wet ones. One drawback with the test is that it is not helpful for very dry mixes. The slump values obtained after mixing are tabulated in table 5.2.

Table 10 Slump values

% OF PEG	SLUMP VALUE IN mm
0.5%	90
0.7%	100
0.75%	105
0.8%	110
1%	120

Fig shows the variation of workability with different proportions of PEG-400

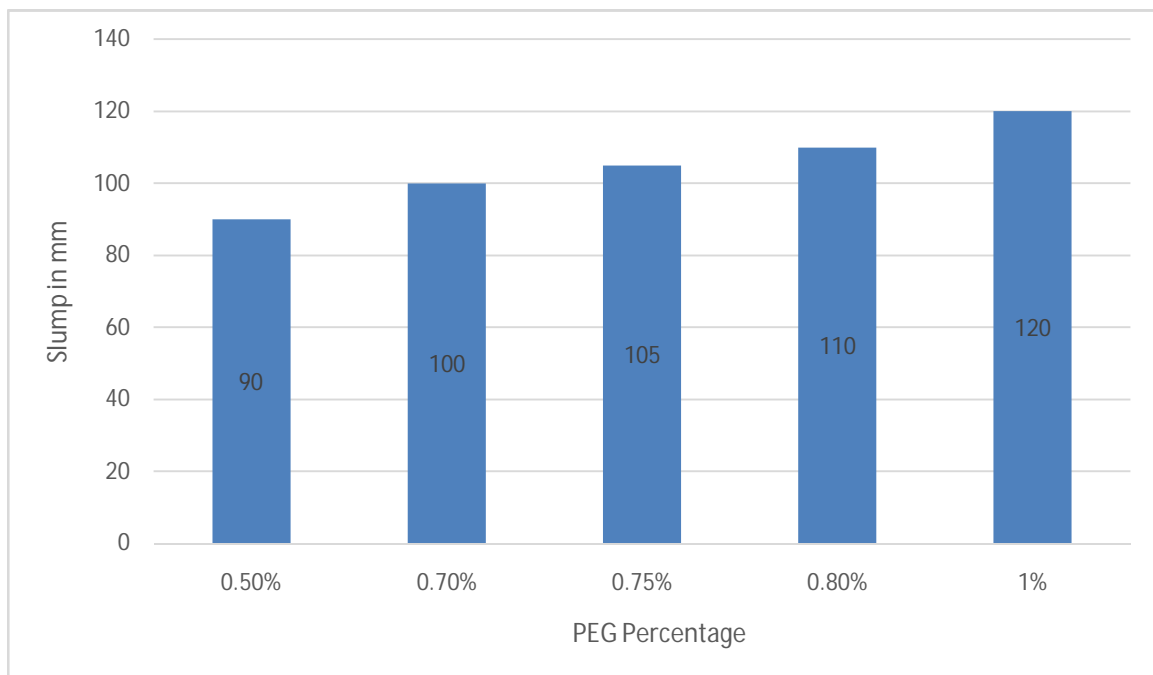


Fig3 Variation of the workability with % of PEG

V. RESULTS AND DISCUSSIONS

COMPRESSIVE STENGTH

Compressive strength of concrete specimens were determined after 7 days and 28 days. It was observed that as the PEG content increased the compressive strength increased up to 0.75% and then decreased. The maximum compressive strength was attained PEG at 0.75% by weight of cement.

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Fig 4 Testing of cube in compressive testing machine

Table 11 Compressive Strength at 7 and 28 day

PEG-400	Compressive strength (N/mm ²)	
	7 day	28 day
0.50%	23.89	34.37
0.70%	24.7	35.62
0.75%	25.2	35.95
0.80%	24.95	35.40
1.00%	22.3	34.80

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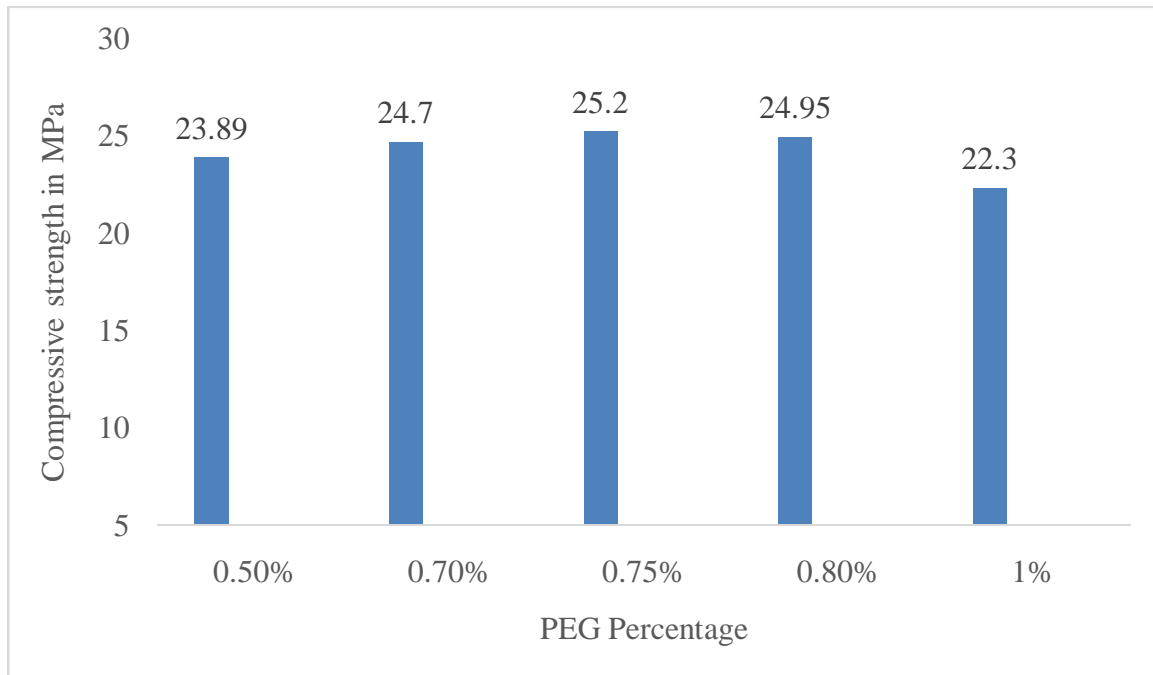


Fig. 5 Variation of Compressive Strength after 7 days

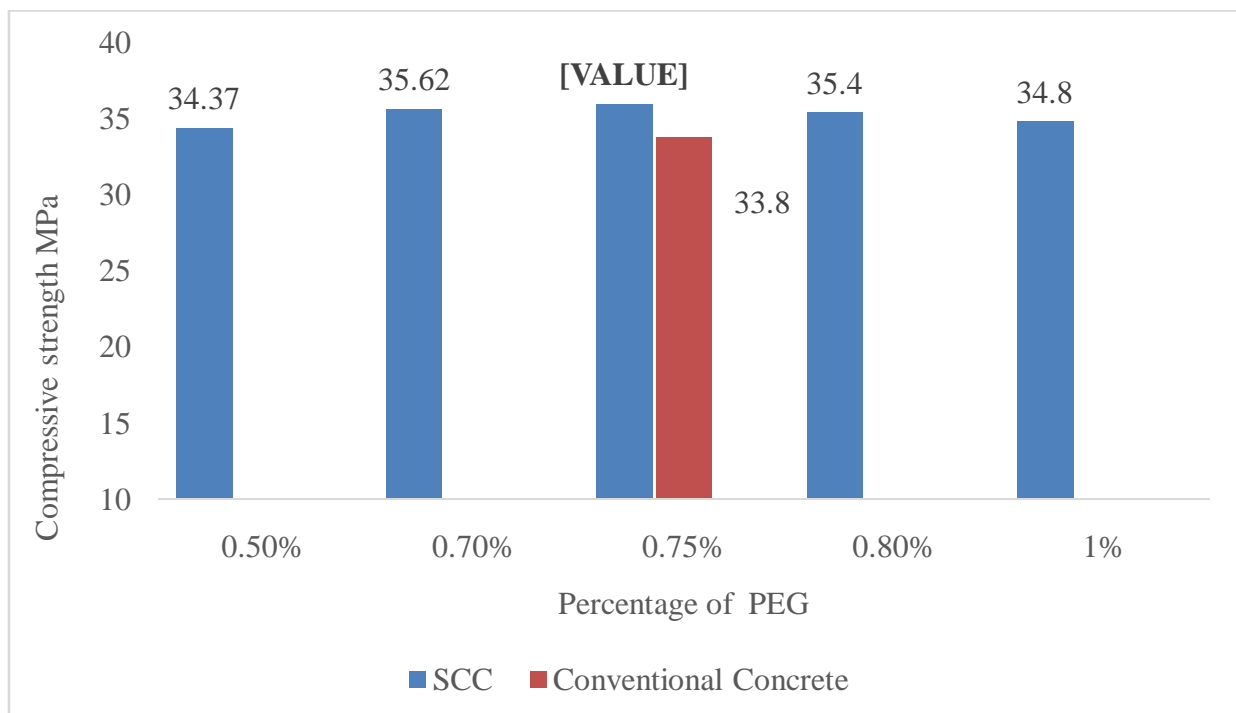


Fig. 6 Variation of Compressive Strength after 28 days

6.3 SPLIT TENSILE STENGTH



Fig 7 Testing of cylinder in compressive testing machine

Table 12 Split tensile Strength at 7 and 28 day

PEG-400	Split tensile strength (N/mm ²)	
	7 day	28 day
0.50%	1.78	2.15
0.70%	1.83	2.30
0.75%	1.87	2.45
0.80%	1.85	2.35
1.00%	1.76	2.20

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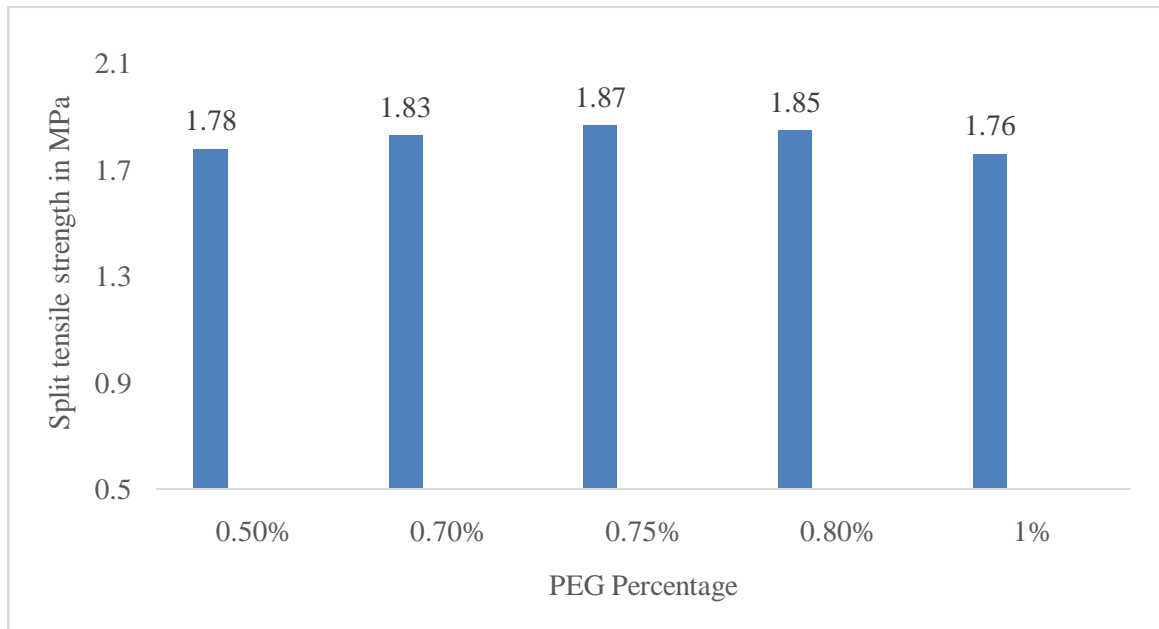


Fig. 8 Variation of Split tensile Strength after 7 days

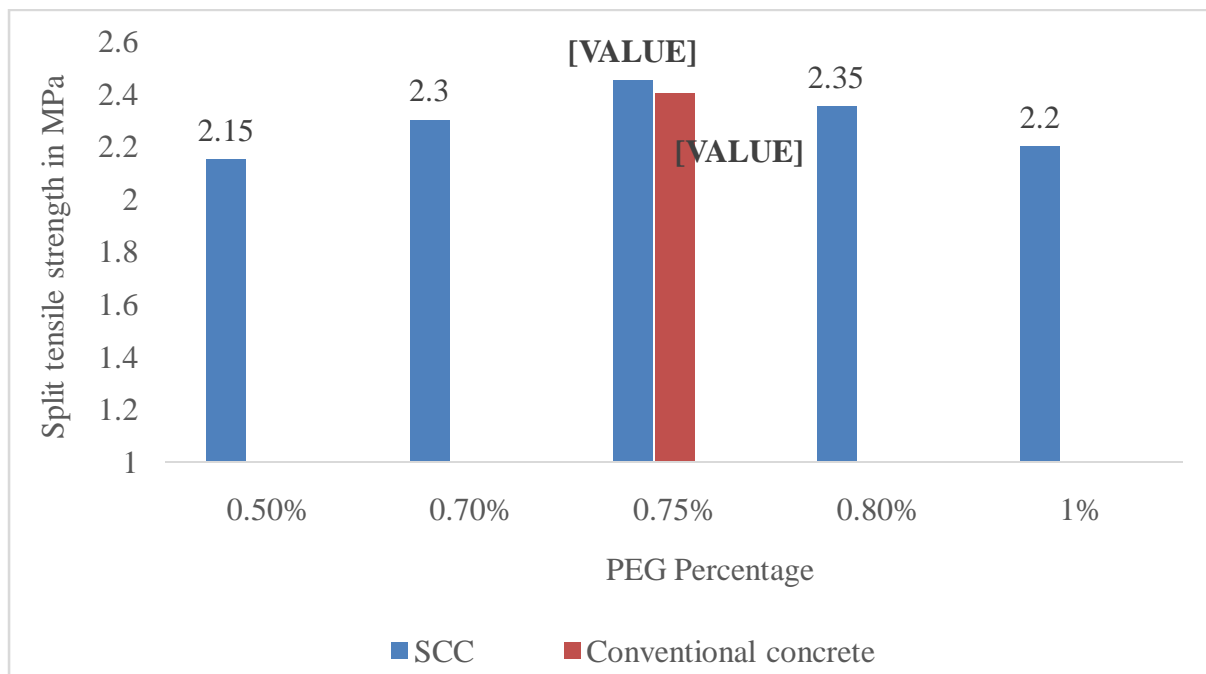


Fig. 9 Variation of Split tensile Strength after 28 days

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6.4 FLEXURAL STRENGTH

Table 13 Flexural Strength at 7 and 28 day

PEG-400	Flexural strength (N/mm ²)	
	7 day	28 day
0.50%	3.4	4.4
0.70%	4.2	4.8
0.75%	4.6	5.2
0.80%	4.4	5.0
1.00%	3.8	4.6

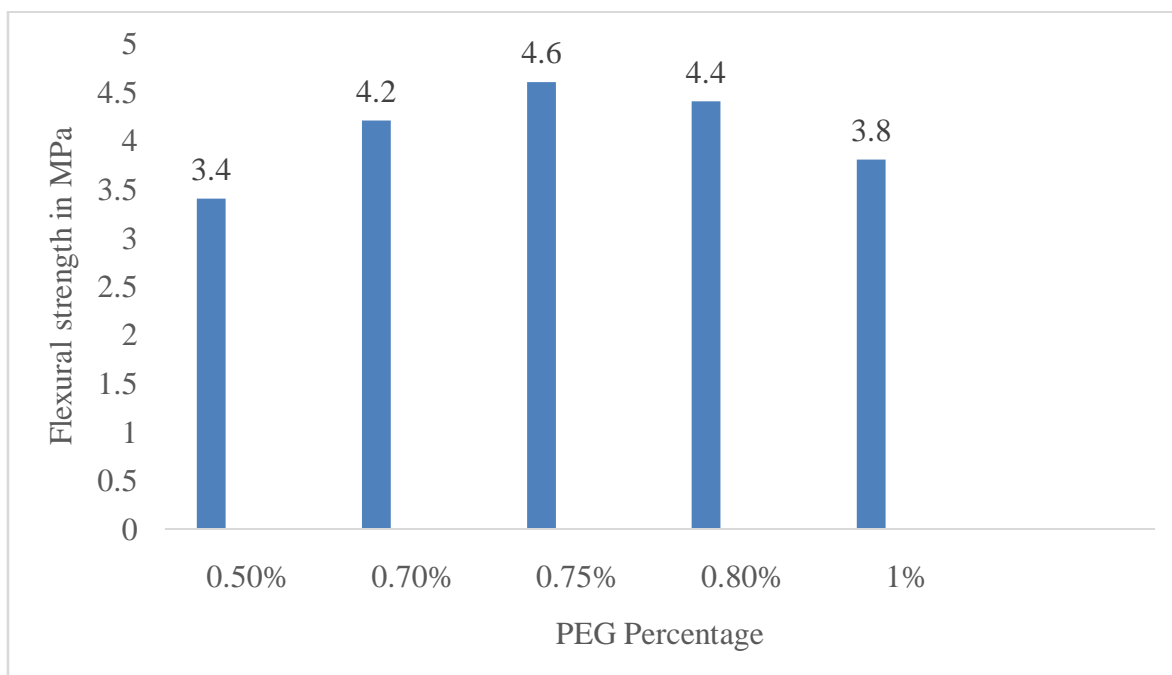


Fig. 10 Variation of Flexural Strength after 7 days

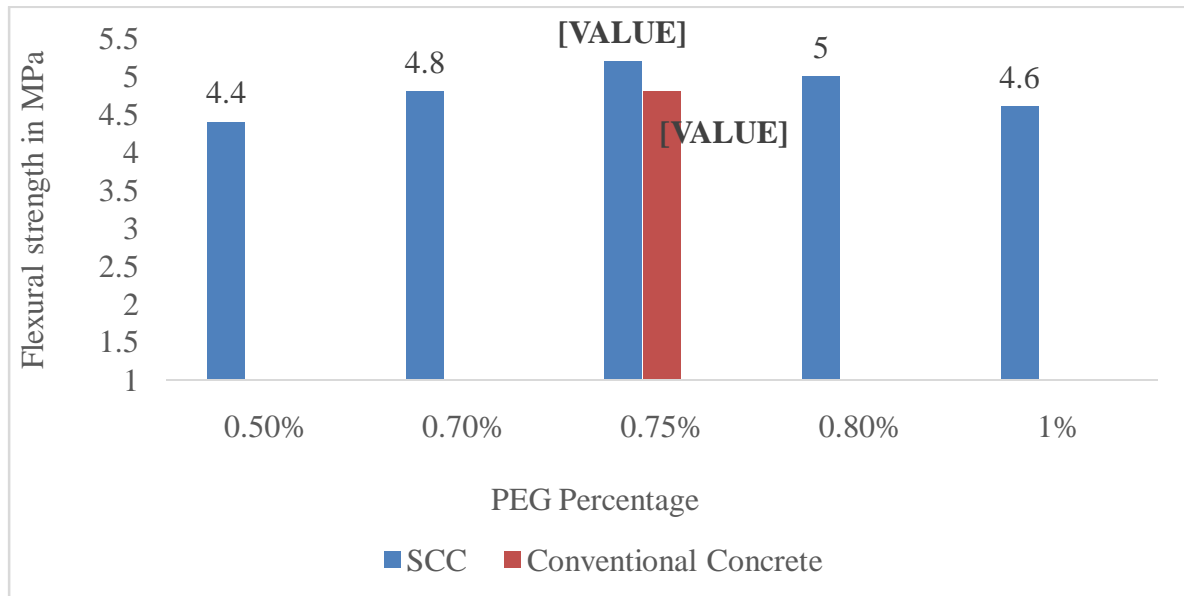


Fig. 11 Variation of Flexural Strength after 28 days

VI. CONCLUSIONS

- The optimum dosage of PEG-400 for maximum Compressive strength, split tensile strength and flexural strength was found to be 0.75% by weight of cement for M25 grade of concrete.
- Strength of self-curing concrete is better than conventional concrete.
- As percentage of PEG-400 increased slump of M25 grade of concrete increasing.
- Partial replacement of coarse aggregates with fly ash pellets leads to decrease the weight of concrete around 4.17%.
- When compared with conventional concrete, self-curing concrete resulted in better hydration with time under drying condition.
- Self-curing concrete is economical than conventional concrete.
- Self-curing concrete with light weight aggregates is the answer to many problems faced due to lack of proper curing, water scarcity and to reduce the weight of the concrete.

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