Experimental Examination of Self-curing Concrete Combined with Polyethylene glycol-400 as a Self-curing agent

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Abstract - Concrete, the world's second most used building material, is known for its great compressive, tensile, and flexural strength. Self-curing concrete is an alternative to immersion that avoids water limitations. This study investigates the effects of adding polyethylene glycol-400 to an M-30 grade concrete mix during internal curing. This approach is utilized when outdoor curing is not an option, such as in places with restricted water supply or human access. Self-curing is critical for developing concrete's pore structure and microstructure, whereas water curing is required to prevent unwanted qualities. The study's goal is to discover the best amount of polyethylene glycol-400 as a 0%, 0.5%, 1%, and 1.5% for self-curing, resulting in high-quality curing.

Keywords: *Slump cone test, PEG-400 self-curing agent, compares the compressive, tensile, and flexural strength self-curing concrete, regular concrete.*

1. INTRODUCTION

Concrete constructions require adequate curing to meet performance and durability standards. Conventional curing requires exterior curing after mixing, putting, and finishing, whereas self-curing or internal curing adds moisture for effective cement hydration. Concrete is the most extensively used building material due to its low cost, strength, and durability. It is suitable for bridges, highways, and infrastructure. Concrete's versatility and strength make it ideal for a variety of construction applications. New admixtures can increase the workability and strength of concrete.

1.1 Curing: the process of controlling moisture transfer from concrete during cement hydration. It can be done during the production process or after the concrete has been laid. Curing time is critical for concrete strength and durability since it takes days or weeks to hydrate. Temperature management is also important in curing because it affects the cement's hydration rate. The basic purpose of curing is to keep the moisture content of the concrete constant while reinforcing it.

1.2 Self-curing and its necessity: Self-curing is a way of increasing concrete's water capacity while decreasing water loss as compared to normal concrete. PEG-400 is utilized to do this since it minimizes water loss while increasing water capacity. Self-curing compounds can be created from water-soluble polymers, unlike conventional concrete, which requires external curing for strength. The polymers establish hydrogen bonds with water molecules, lowering their chemical potential and vapor pressure, so slowing evaporation from the surface. Proper hydration is critical for meeting durability requirements in cement concrete projects.

1.3 Process and Mechanism of self-curing or internal curing: The process of releasing water from an exposed surface due to the presence of hydrogen and oxygen is known as self-curing or internal curing. This method slows the chemical reaction and reduces the pace of concrete evaporation. The oxygen in the atmosphere combines with the hydrogen to make water. Moisture evaporates from an exposed surface due to chemical changes, resulting in cement hydration and shrinkage. This leaves empty holes and reduces relative humidity, allowing the cement paste to self-desiccate and form microcracks and capillary pores. Self-curing inhibits self-desiccation while maintaining relative humidity. Maintaining the moisture content is critical because cement hydration becomes ineffective when relative humidity goes below 80%.

2.0 LITRATURE REVIEW:

- **Singh G et al. (2021)** discovered that increasing the dose of the self-curing chemical PEG-400 increases the workability and performance of M30 grade concrete, resulting in greater compressive, split tensile, and flexural strengths.
- **Azhagarsamy and Sundaraman's 2016** study on the strength and durability of M20 grade concrete using water-soluble polyethylene glycol (PEG 400) as a self-curing agent discovered that self-curing concrete had an average increase of 12.73% in compressive strength and 13.31% in split tensile strength, indicating superior performance over conventional concrete.
- **Tyagi's 2015** study looked at the usage of PEG-400 in concrete at various quantities (0.5-2%). The study examined M25 and M40 grades of OPC cement in accordance with IS 12269-1987. The optimum values for M40 grade were 0.5% and 1% for M25 grade PEG-400, enhancing concrete strength and durability.

3.0 AIM AND OBJECTIVE:

- M-30-grade concrete contains 1% PEG-400 as an optimum dosage for self-curing concrete by the weight of cement to provide strength without compromising workability.
- To examine the impact of PEG-400, the curing agent, on the strength properties of the concrete.
- Analyze the concrete's compressive, tensile and flexural strengths. Based on the information, draw conclusions regarding the compressive, tensile, and flexural strengths of conventional and self-curing concrete.
- Our project's primary goal is to produce concrete with less water while maintaining its simplicity of use and strength-boosting properties.

4.0 MATERIAL AND METHDOLOGY:

4.1 Polyethylene glycol (PEG)-400: Polyethylene glycol (PEG) is a condensation polymer that serves as a non-irritating, lubricating, non-volatile, odorless, and non-toxic additive in concrete. It dissolves quickly in a variety of solvents and is widely utilized in sanitary applications. PEG-n, a combination of ethylene oxide and water, retains water particles in concrete by producing a thin shell around them. This helps to preserve water by lowering evaporation rates and minimizing the requirement for external curing. Additionally, it minimizes shrinkage in concrete. PEG is benign, with a density of 1.13 g/cm3 and a slight odor.

Table-1 Properties of PEG-400

Properties of (PEG-400)	Value
Weight	400gr/mol
pH	>6-7
formula	$H(OCH_2CH_2)_nOH$
Density	1.13gr/cm^3
Specific-gravity	1.12 at 27 _Ċ

4.2 Fine aggregate: The experiment employed natural river sand with a maximum size of 4.75 mm as fine aggregate. Sand zone II, which was accessible locally, had a specific gravity of 2.51, a fineness modulus of 2.7, and a water absorption of 1.19%, supporting I.S. 383-1970.

4.3 Coarse aggregate: A significant portion (30–40%) of coarse-particle concrete is void. crushed granite stone, 20 mm is the nominal size of the aggregate used in construction with a specific gravity of 2.65 and a fineness modulus of 2.7, as per I.S. 383-1970. In the construction process, this substance is essential.

4.4 Water: The hydration of concrete with water determines its strength and workability. It is critical to utilize water judiciously, as too much water might induce segregation. Water is required for concrete's chemical interaction with cement. An experimental operation employed portable water that met IS 456-2000 criteria for mixing and curing, ensuring that the pH level was maintained.

Test data of material:

- Specific gravity of cement = 3.130
- Specific gravity of coarse aggregate = 2.651
- Specific gravity of fine aggregate = 2.511
- Water absorption of coarse aggregate = 0.989
- Water absorption for fine aggregate = 1.191
- Initial setting time of cement = 32 min
- Final setting time = 420 min
- Consistency of cement = 32%
- Type of aggregate = uniformly graded aggregate.

Mix design for M-30 grade conventional concrete:
Mix design by (IS10262-2019)
(A)Design Required:
1.Grade of concrete - M30(as per IS Code 10262:2019)
2. Cement – OPC-53 Grade
3. Fine Aggregate - Zone II
4. Coarse Aggregate – 20mm Nominal size
5. Slump Value – 75mm (IS code 456:2000)
6. Condition of Exposure – Severe
7. Degree of site control = Good
8. Workability = 75 mm
9. Method of concrete placing = manual
10. Water cement ratio = 0.45
11. Water content = 191.58 kg/m^3
12. Minimum cement content = 320 kg/m^3

C) Target mean strength:
$f'_{ck} = f_{ck} + 1.65 x S$
$f'_{ck} = 30 + (1.65 \times 5)$
$f'_{ck} = 38.25$ N/mm^2
OR
$f'_{ck} = fck + X$
$f'_{ck} = 30+6.5$
$f'_{ck} = 36.50$ N/mm^2
where S= standard deviation (Table -8 IS Code 456:2000, Clause 9.2.4.2) X = factor based on grade of concrete. As per IS code 10262:2019

D) Approximate air Content: For 20 mm nominal maximum size of aggregate 1.0%. As per IS 10262:2019 Table 3 Clause 5.2

E) Cement Content = 425.73 kg/m^3

F) Calculation of Coarse and fine aggregate content:
As per IS Code 10262(2019), Table-5, Clause 5.5 Table- 4
Size of Coarse Aggregate = 20mm
Size of Fine aggregate = 4.75 mm
Volume of coarse aggregate = 0.62
Corrected proportion of volume of coarse aggregate = 0.01+0.62 = 0.63

Volume of fine aggregate = 1-0.63 = 0.37

G) Mix Design:

i. Volume of Concrete = 1m^3
ii. Volume of cement = 0.13601 m^3
iii. Volume of water = 0.19158 m^3
iv. Volume of all aggregate = 0.6625 m^3
v. Weight of coarse aggregate = 1106.04 kg
vi. Weight of fine aggregate = 615.26 kg

H) Site Correction:

(i) Absorption of fine aggregate = 1.191 %
= (1.191/100) × 615.26
= 7.327 lt.
(ii) Absorption of coarse aggregate = 0.989 %
= (0.989/100) × 1106.04
= 10.831 lt.
Total absorptions = 18.154 lt.
(iii) Actual amount of water to be used = 191.50+18.154
= 209.654 lt.
(iv) Actual weight of fine aggregate to be used = 615.26-7.32
= 607.94 kg.
(v) Actual weight of coarse aggregate = 1106.04-10.83
= 1095.21 kg

Table-02 mix proportion of conventional concrete after site correction

Cement (kg)	Sand (kg)	Aggregate (kg)	Water(kg)
421.75	606.82	1093.21	209.65
Or MIX Ratio			
1	**1.43**	**2.59**	**0.45**

I) Mix Design of concrete with PEG-400 as a self-curing concrete:

Adding 1% of PEG-400 Admixture by weight of cement:

- Cement = 425.73 kg/m^3
- Cement content = 425.73- 4.257 = 421.48 kg/m^3

Mix Design:

- Volume of cement = 0.134 m^3
- Volume of water = 0.19158 m^3
- Volume of PEG-400 = 0.0037 m^3
- Volume of total aggregate = 0.6613 m^3
- Weight of coarse aggregate = 1104.04kg
- Weight of fine aggregate = 614.149 kg

Site Correction:

- Absorption of fine aggregate = 7.32 lt.
- Absorption of coarse aggregate = 10.83 lt.
- Total absorptions = 18.15 lt.
- Actual amount of water to be used = 209.65 lt.
- Actual weight of fine aggregate to = 606.82 kg.
- Actual weight of coarse aggregate = 1093.21 kg

Table -03 Mix proportion of internal curing concrete after site correction

CEMENT (kg)	FINE AGGREGATE (kg)	COARSE AGGREGATE (kg)	WATER (kg)
425.731	607.941	1095.212	209.652
Or MIX Proportion			
1	**1.42**	**2.57**	**0.45**

4.5 Casting Schedule:

Casting of the specimens were done as per IS:10086-1982,

Table No: 4 Mix proportion

Mix Proportion	Cement (kg)	Fine Aggregate (kg)	Coarse Aggregate (kg)	Water(kg)
M-30 Grade Conventional concrete	425.73	607.94	1095.21	209.65
M-30 grade Self-curing concrete	421.75	606.82	1093.21	209.65

4.6 Test on Concrete:

Slump cone test: There is a concrete workability test because concrete can be mixed, transported, and used in a specific application. The most popular method for assessing workability is the slump test. It doesn't measure every element that affects workability.

TABLE-5 Slump Values of conventional Concrete and Self curing concrete

Mix Proportion	PEG-400	W/C Ratio	Slump Value(mm)	Average Value(mm)
Conventional concrete	0.0%	0.45	79	77.66
			78	
			76	
SCC Mix-01	0.50%	0.45	77	79
			79	
			81	
SCC Mix-02	1.00%	0.45	80	81.33
			83	
			81	
SCC Mix-03	1.50%	0.45	82	82
			84	
			80	

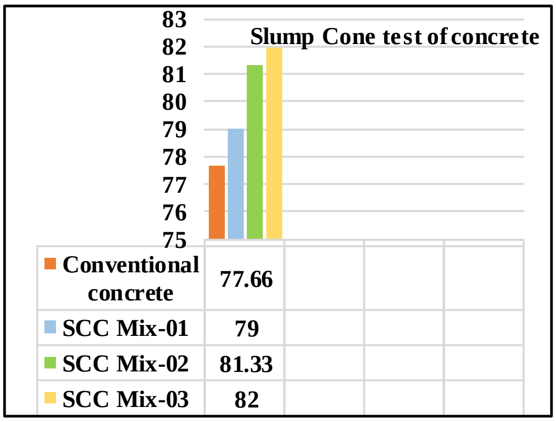

Chart-1 Slump cone test of conventional concrete vs self-curing concrete

4.7 Casting of Cube, Beam and Cylinder:

The strength parameters of self-cured concrete were compared with conventional cured concrete at 7days, 14days and 28days.

Fig-01 Casting process of concrete for beam cube and cylinder

4.8 Compressive Strength Test:

Casted concrete cube 150×150×150mm size and it was tested for 7, 14and 28days.

Fig -02 Compressive strength test of concrete cube in UTM

TABLE-6 compressive strength values of conventional Concrete and Internal cured concrete

Mix Proportion	PEG-400 %	Age (Days)	Stress (N/mm^2)
Conventional concrete	0.0	7	20.85
		14	28.87
		28	39.20
SCC Mix-01	0.50	7	23.35
		14	31.24
		28	40.28
SCC Mix-02	01.00	7	25.35
		14	34.24
		28	42.86
SCC Mix-03	01.50	7	23.35
		14	33.24
		28	41.27

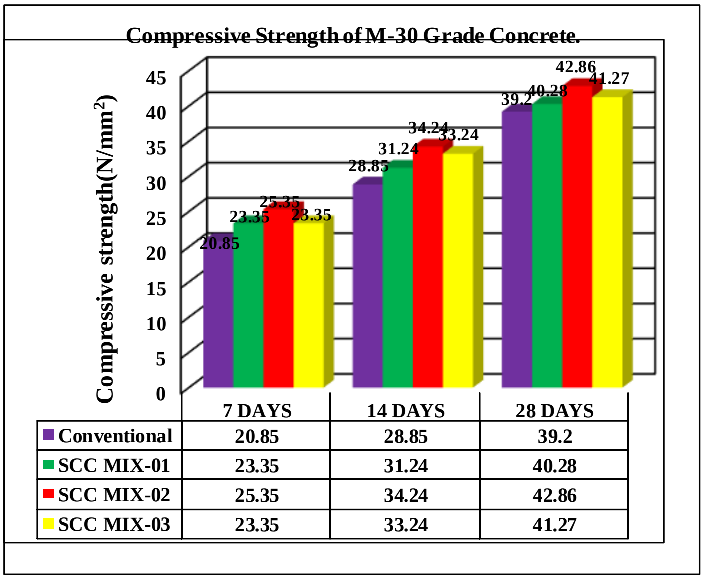

Chart -02 compressive strength behaviour of conventional concrete after 7, 14 and 28-days vs Self curing concrete.

Split tensile strength test of concrete:

The study examined split tensile strength utilizing 150mm diameter and 300mm height cylinders cast and tested over 7, 14, and 28 days using a universal testing equipment with a 2000KN capability.

Fig- 03 Split tensile strength test for cylinder.

TABLE-7 tensile strength result of conventional Concrete and internal cured concrete

Mix Proportion	PEG-400	Age (Days)	Stress (N/mm^2)
Conventional concrete	0.0%	7	06.63
		14	07.15
		28	10.67
SCC Mix-01	0.50%	7	8.51
		14	10.07
		28	11.37
SCC Mix-02	1.00%	7	8.75
		14	11.27
		28	12.02
SCC Mix-03	1.50%	7	08.23
		14	9.06
		28	11.69

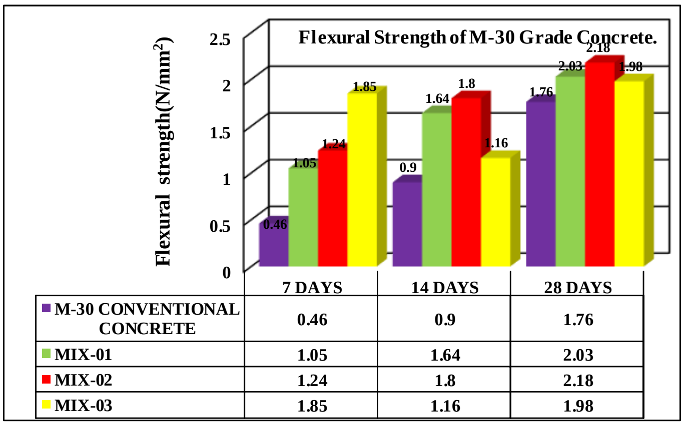

Chart 3 Tensile strength behaviour of conventional concrete after 7, 14and 28-days vs Self curing concrete.

Flexural strength:

The beam specimen of size 150×150×700 mm is tested on universal testing machine with a 2000 KN load for point loading to create a pure bending. Observed that the strength of the concrete mix at 7, 14, and 28 days. f strength =WL/bd²

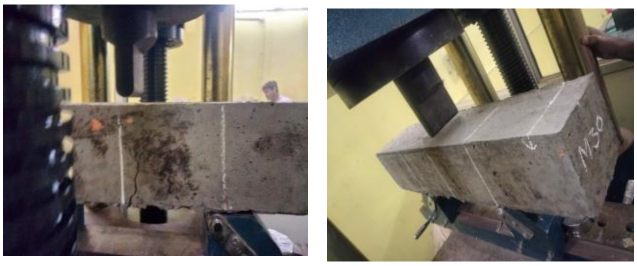

Fig -04 Flexural strength test of concrete beam.

TABLE-8 t strength result of conventional Concrete and internal cured concrete

Mix Proportion	PEG-400	Age (Days)	Stress (N/mm^2)
Conventional concrete	0.0%	7	0.46
		14	0.90
		28	1.76
SCC Mix-01	0.50%	7	1.05
		14	1.64
		28	2.03
SCC Mix-02	1.00%	7	1.24
		14	1.80
		28	2.18
SCC Mix-03	1.50%	7	1.85
		14	1.16
		28	1.98

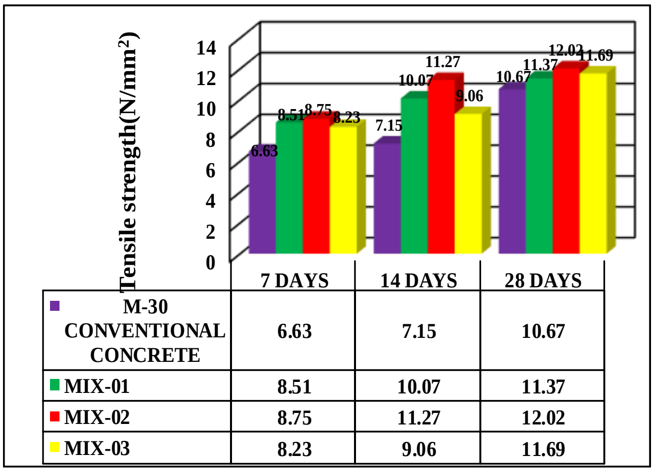

Chart 4 Flexural strength behaviour of conventional concrete after 7, 14and 28-days vs Self curing concrete.

3. CONCLUSIONS

1. The aforementioned result indicates that PEG-400 achieves 1% of the mix-30's compressive, tensile, and flexural strengths.
2. Chemical admixtures are advised in order to produce high-quality concrete.

3. Using self-curing PEG-400 concrete instead of traditional concrete curing at the ages of 7 and 28 resulted in an average increase in compressive strength of 11.99% and 12.77%, respectively.
4. There is a significant expansion in the construction sector, which leads to more construction activities. The construction industry also uses a lot of water, and the curing process wastes more water every day. The use of alternative methods, such as self-curing mechanisms, is required to attain sustainability in water management.
5. The self-healing mechanism lowers the need for labor and is advantageous when used in areas where there is a shortage of water.
6. Utilizing PEG-400 was determined to be the superior choice in order to produce internally cured concrete without sacrificing its strength. All of the water required for curing can be saved because internal cured concrete doesn't need a curing process.

SCOPE OF RESEARCHS

- The chemical addition needs to make the concrete more workable.
- to contrast the strength characteristics of concrete produced using a curing compound—polyethylene glycol—with concrete produced using traditional curing.
- Calculate the concrete's relative humidity.

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