Self-Curing Concrete Using Water-Soluble Polymer for Developing Countries

Udayabanu T1, Rajamane N P2, Makendran C3, R. Gobinath4 and S Chandra Chary5
1Research Scholar, Department of Civil Engineering, SRM University, Chennai, Tamil Nadu, India.
2Professor, Department of Civil Engineering, SRM University, Chennai, Tamil Nadu, India.
3Assistant Professor, Department of Civil Engineering, Wollega University, Ethiopia, East Africa.
4Department of Civil Engineering, S R Engineering College, Warangal, Telangana.
5Sumathi Reddy Institute of Technology for Women, Warangal, India.

E Mail: dr.makendranc@gmail.com

Abstract. In a developing country construction of residential and commercial buildings including roads construction plays a vital role of economic development and usage of various construction materials, such as cement, sands, and water are quite common. Water is an important resource for preparing and curing of concrete. In present situation, water resource is very constraint around the world and need the alternate solution to manage this water crisis. Using of alternative materials reduces the construction costs directly. In this regard, proposed to introduce the chemical of Polyethylene Glycol PEG400 for self-curing of concrete. This study deals with the investigation on self-curing concrete with added % of PEG400 by weight of cement from 0% to 1.5% as the quantity for self-curing component. Test results were investigated and compared with conventional and self-cured concrete on compressive, flexural and split tensile strength for M20 grade mix. The result found that PEG 400 provides good results of self-curing concrete.

1. Introduction
In developing countries building construction plays vital role using various materials, such as cement, sands, and water [1]. Water is an important resource for preparing and curing of concrete. In present situation water is very constraint in the world and need the alternate solution due to water constraint. Using of alternative materials reduces the construction costs directly. Water is very essential because it takes part in hydration of concrete. Portable water is most suitable for preparation and curing of concrete. Bore water should be checked as it may contain impurities which can affect setting and other properties. Usage of exact quantity of water leads to economy as well as improved quality. The main motto is to use exact quantity and make the structure more durable and economical. ACI (2008) reported that curing plays a crucial role in strengthening the concrete for all concrete structures. Curing process is repeatedly used to express the process through which hydraulic cement concrete established and enhanced hardened properties over time as an outcome of the continuous hydration of the cement in the occurrence.
of enough water [2]. The aim is to reduce permeability of concrete and thereby improve durability. Curing is not blindly pouring water on concrete. Francis, and J John, (2013), conducted an experimental study for strengthen properties onself-curing concrete. The normal curing was attained by conventionally spray water after hardening of cement concrete for duration of about 28 days. Self-curing is a progression of saved moisture content in concrete for more potential hydration of cement and reduction of self-desiccation in concrete [3]. Dhir et al., (1994) water-soluble polymers added in self-curing concrete gives a signifying improvement for construction industry [4]. Hans et.al (1998) made efforts and conducted self-curing for high performance of concrete. Curing has predominant role for strengthening of concrete. It is directly influenced on the hardened concrete. Properly cured concrete increases the durability and strength. Poor curing leads to failure of any concrete structure due to reduced strength and impermeability [5]. Dhir et al., (1998). Study conducted for water preservation in concrete includes a self-curing compound. Study concluded that the advantage of using self-curing compoundsdirectly reduces water evaporation from concrete, accordingly increases its water preservation capability compared to the normal concrete [6]. S. Wrber, H.W. Reinhardi (1996) made efforts and attempted different curing method for high-performance concrete. In addition of polyethylene glycol by weight of cement and it reduces the water desertion from self-curing concrete, and consequently increases the water preservationability of the concrete [7].

Shikha Tyagi (2015) a study conducted on self-curing concrete by using Polyethylene glycol PEG 400 for M25 and M40 grade. Dosages from 1 to 2% were added in concrete. Study concluded that the optimum dosage of PEG400 for maximum compressive strength obtained, 1% for M25 and 0.5% for M40 grade of concrete [8]. Junaid et. al. (2015) a study conducted the self-curing concrete is achieved by self-curing agent. The strength was increased 10% by polyethylene glycol from 0.1 % - 0.2 % of cement compared to that of the conventional concrete [9]. Wen-Chen Jau (2007) acknowledged that internal curing concrete was significantly improved hydration of cement in concrete [10,11]. A.S. EL-Dieb et al (2013) a study conducted on water preservation for the cement concrete mixes. Study founded that water permeability and water absorption rate was decreased in self-curing concrete. The concrete age represents lesser absorbent proportion as an effect of the prolongation of hydration of cement [12,13].

Based on the above literatures and studies, it is evident that newly introducing water-soluble polymers as a self curing agent for self curing concrete[14]. It is essential to investigate the mechanical strength properties, behavior, and cost reducing of this self curing concrete for Indian. Building construction in developing countries is undertaken as a combination of alternative materials and reducing costs in especially curing of concrete[15,16]. In this regard, introduce water-soluble polymers of polyethylene glycol PEG400 for self curing compound. In this study to investigate the strength properties of compressive, tensile, split and workability of concrete using water soluble polyethylene glycol PEG400 as self-curing compound. To comparison of conventional and self curing concrete, and cost analysis of self curing and conventional concrete[17,18].

2. Methodology
This study deals with the investigation on self curing concrete using water-soluble polymer of Polyethylene Glycol PEG 400 consists of six stages are as follows:

First stage is selection of materials for the experimental purpose. Quality of materials such as cement OPC 53 Grade, aggregates, portable water and polyethylene glycol PEG 400 and to be conducted engineering property tests of these materials. The engineering properties test such as specific gravity, grade of cement. Specific gravity, water absorption test for aggregates both course and fine aggregates. Solubility, density, odour, mean molecular weight, appearance for polyethylene glycol PEG400. Second stage is percentage of PEG by weight of cement from 0% to 1.5% as the dosage to be added for self curing concrete. The mix ratio arrives for M20 mixes. Third stage is laboratory evaluation of mechanical strength parameters of concrete, performance test on concrete. Fourth stage is to be
arrived optimum polyethylene glycol PEG400 and its dosage percentage. Fifth stage to calculate the analysis of cost economics. Finally, sixth stage is conclusion and recommendations were drawn.

**Figure 1. Study methodology**

2.1 Cement

Cement is the binding materials of concrete and mortar. In this study, ordinary grade of M20 concrete prepared Cement OPC 53 Grade was used to prepare the concrete mix. The cement tests were carried out as per code provision IS 12269: 2013. The cement properties and test values are presented below in Table 1.
Table 1. The Engineering properties of cement test

| Test on cement OPC 53 Grade | Result |
|-----------------------------|--------|
| Specific gravity (Sp.gr)    | 3.15   |
| Initial setting time        | 27 minutes |
| Final setting time          | 8 hours |
| Fineness range              | 1.5 -10 microns |

The table 1 obtained test results were within limit. Hence, satisfied that the cement properties.

2.2. Aggregates
For this study purpose the aggregates obtained from Thiruneermalai is a town panchayat in Chennai in Chengalpattu district, Tamil Nadu, Indian. Superior quality of crushed blue granite aggregates was used. Nominal size of 20 mm well graded aggregate utilized with conformation IS: 383 – 1970. Fine aggregates have free from clays with clean and dry river sand was used. Fine aggregatesare passing is 4.75 mm sieve confirming is 383-1970. The both fine and coarse aggregates properties and test results are presented in table 2.

Table 2. The aggregates properties

| Engineering properties test for aggregate | Fine aggregate | Coarse aggregate |
|------------------------------------------|----------------|-----------------|
| Bulk density                             | 1618 kg/m³     | 1625 kg/m³      |
| Water absorption test                    | 1.35%          | 2.0%            |
| Specific gravity                         | 2.625          | 2.710           |

The table 2 obtained test results are within limit. Hence, satisfied that the properties of both fine and coarse aggregates.

2.3 Water
Concrete was prepared used in portable water. Portable water has free from oil and organic matter. The pH value was 7. Fresh potable water used for all the concrete mixes and conformation with IS: 456-2000.

2.4 Polyethylene GlycolPEG 400
In this study developed self-curing concrete using low-molecular-weight grade of Polyethylene Glycol 400. PEG400 has eco-friendly Material of water-soluble polymer. PEG 400 has thenon-poisonous, fragrance-free, and non-irritant and is used in a mixture of medication [19]. PEG 400is a concentration with portable water and Polymer of Ethylene Oxide (PEO). The Polyethylene Glycol from 0.5 to 1.5% was used. PEG 400 in physical parameter test results is presented in Table 3.
Table 3. Parameter of polyethylene glycol (PEG – 400)

| Property           | Value          |
|--------------------|----------------|
| Density            | 1.13 kg/cm³    |
| Solubility         | Soluble in water |
| Specific Gravity   | 1.12           |
| Odour              | Mild odour     |
| Flash point        | 4 to 8 °C      |
| Viscosity          | 238 °C         |
| pH                 | 7              |
| Molecular weight   | 390kg/m³       |
| Colour             | Clear Fluid    |

2.5 Preparation Of Specimens
In this study, a basic experimental approach to arrive at the optimum Polyethylene Glycol 400 by concrete of mix design (IS 10292: 2009) was followed [20,21,22,23]. Concrete mix samples were prepared for M20 grade concrete and PEG 400. Weighing of required specimen materials and Casting of the specimens IS: 10086-1982. Mix proportioning is prepared for M20 grade concrete. The Cubes of 150x150x150 mm³, Cylinders of 150mm diameter x 300mm height and Prisms mouldof 100x100x500 mm³ are prepared and casted for the testing of specimens. Self-curing agent Polyethylene Glycol 400 was adapted at the range of 0%, 0.5%, 1% and 1.5% weight of cement. The specimens for compressive strength, split tensile strength and flexural strength are tested in 7th, 14th and 28th days respectively. The properties such as compressive strength, tensile and split were evaluated at laboratory of arrived optimum Polyethylene Glycol 400 content values.

3. Result And Discussion
In this laboratory study, self-curing concrete utilized in polyethylene glycol were successfully performed on compressive, flexure and tensile strengths results were presented are below subsequently sections [24]. The outcome of curing of concrete on workability test such as slump and compaction factor test were carried out in Table 4. It is found that Polyethylene Glycol 400 self-curing agent was improved workability.

Table 4. Workability of Concrete used Polyethylene Glycol 400

| Workability | Conventional concrete | 0.5% of PEG-400 | 1% of PEG-400 | 1.5% of PEG-400 |
|-------------|-----------------------|-----------------|---------------|-----------------|
| Slump in mm | 60                    | 74              | 98            | 119             |
| Compaction factor | 0.80          | 0.82            | 0.88          | 0.90            |

3.1 Compressive strength
In the present study, M20 grade of conventional and self-curing concrete specimens using optimized dosage of polyethylene glycol as internal curing are developed. The concrete with Polyethylene Glycol 400 by weight of cement from 0%, to 1.5% as the dosage of internal curing compound was used. The compressive strength test results values presented in Table 5.
Table 5. Compressive strength test for normal and various dosage of PEG 400 concrete

| Days on which tests were conducted | Compressive strength in N/mm² |
|-----------------------------------|-------------------------------|
|                                   | Conventional concrete | 0.5% of PEG-400 | 1% of PEG-400 | 1.5% of PEG-400 |
| 7th DAY                           | 15.56                       | 15.56           | 24.4          | 17.78          |
| 14th DAY                          | 17.78                       | 24              | 25.3          | 23.71          |
| 28th DAY                          | 20.4                        | 25.78           | 31.56         | 21.3           |

Figure 2. Comparison of compressive strength of concrete between normal mix and PEG

The above graph 2 shows the comparison of compressive strength of concrete between normal mix and PEG 400 using various dosages from 0.50%, 1.0% and 1.50%. The compressive strength values were showing in 7th, 14th and 28th days respectively.
From the above graph 3 shows compressive strength of concrete between normal and Polyethylene Glycol 400 mix. The addition of Polyethylene Glycol 400 significantly increased the compressive strength of concrete mix. Maximum compressive strength was for 0.1% Polyethylene Glycol 400 addition, which achieved strength of 31.56 N/mm².

3.2 Flexural strength
The Flexural strength test results values are presented in Table 6. Flexural strength of concrete beam with normal and Polyethylene Glycol 400 used dosages from 0.50, 1.0 and 1.5 %. Flexural strength values were showing in 7th, 14th and 28th days respectively.

| Days on which tests were conducted | Flexural strength in N/mm² | Conventional concrete | 0.5 % of PEG | 1.0 % of PEG | 1.5 % of PEG |
|-----------------------------------|---------------------------|-----------------------|--------------|--------------|--------------|
| 7th DAY                           |                           |                       |              |              |              |
|                                   | 9.9                       | 6.24                  | 13.5         | 7.35         |
| 14th DAY                          | 16.91                     | 9.56                  | 16.2         | 10.53        |
| 28th DAY                          | 15.63                     | 9.68                  | 25.25        | 5.52         |
Figure 4. Flexural strength of concrete between normal mix and PEG

From the above graph, the flexural strength of concrete between conventional concrete and PEG 400 mix. The addition of Polyethylene Glycol 400 significantly improved the flexural strength. Maximum flexural strength was for 0.1% Polyethylene Glycol 400 addition, which achieved strength of 25.25 N/mm².

3.3 Split tensile test

The Split tensile test results values are presented in Table 7. Split tensile test of concrete beam with normal and Polyethylene Glycol 400 used dosages from 0.50, 1.0 and 1.5 %. Split tensile test values were showing in 7th, 14th and 28th days respectively.

Table 7. Split tensile test for normal and various dosage of PEG 400 concrete

| Days on which tests were conducted | Split Tensile strength in N/mm² | Conventional concrete | 0.5% of PEG 400 | 1% of PEG 400 | 1.5% of PEG 400 |
|-----------------------------------|--------------------------------|-----------------------|-----------------|---------------|-----------------|
| 7th DAY                           |                                | 1.7                   | 1.41            | 1.56          | 1.13            |
| 14th DAY                          |                                | 3.11                  | 1.7             | 1.98          | 1.41            |
| 28th DAY                          |                                | 3.54                  | 2.21            | 2.41          | 1.84            |
Figure 5. Flexural strength of concrete between normal mix and PEG

From the figure 5 showed Split tensile values between conventional and Polyethylene Glycol 400 mix. The addition of Polyethylene Glycol 400 significantly increased the Split tensile strength. The maximum flexural strength was for 0.1% Polyethylene Glycol 400 addition, which achieved strength of 2.41 N/mm² at the age of 28 days.

In this study, M20 grade of mix was used. After laboratory experimental investigated that mechanical strength properties were significantly improved in self-curing concrete of compressive, split-tensile and flexural strengths. The concrete with PEG 400 by weight of cement from 0% to 1.5% as the dosage of internal curing compound was used and significant improvement occurred to the continuation of the hydration process. The PEG 400 of self-curing concrete produces results of continuous availability of water resulting in, very low voids and pores. It created good bond between the cement fine and coarse aggregate.

3.4 Cost analysis

The cost required for curing in conventional, Self-curing in Indian Rupees (INR) per one cubic meter and details presented in Table 8.

| The conventional concrete required water for curing for one cubic meter (Liter of water) | Cost of curing water per liter in (INR) | Labor charge for apply water on concrete for curing (No. of labor * Daily wages) | Total cost required for curing in conventional concrete in one cubic meter in (INR) |
|---|---|---|---|
| (a) | (b) | (c) | (a*b) + (c) |
| 3000 | 0.75 | 6 * 400 | 4650 |
Table 9. The cost analysis details of Self-curing concrete

| Self-curing concrete required water for one cubic meter (Liter of water) | Cost of curing water per liter in (INR) | Polyethylene Glycol 400 (No. of liter * Cost) | Total cost required for self-curing concrete in one cubic meter in (INR) |
|---|---|---|---|
| (a) | (b) | (c) | (a*b) + (c) |
| 175 | 0.75 | 3.20 * 600 | 2051.25 |

Table 10. Comparison external and internal curing concrete

| Total cost required for curing in conventional concrete in one cubic meter In (INR) | Total cost required for internal curing concrete using PEG 400 in one cubic meter in (INR) | Cost saved for curing one cubic meter in (INR) |
|---|---|---|
| 4650 | 2051.25 | 2598.75 |

4. Conclusions

In this laboratory experimental study, self-curing concrete used in polyethylene glycol were successfully performed on compressive, flexure and tensile strengths, cost analysis and conclusions are given.

The laboratory study express that a significant progress occurs in the self-curing concrete by polyethylene glycol PEG400. The optimum measured quantity of PEG400 for maximum compressive strength was found in 1% for M20 grade of concrete and also compressive strength was increased in 1% when comparison of conventional curing of concrete. Study recommended suitable PEG400 as an internal self-curing agent as it was completely soluble in water. Polyethylene glycol PEG400 was high molecular weight compare than portable water. PEG400 was directly reduced the surface tension of portable water and decrease evaporation from concrete. Self-curing concrete can reduce curing cost around Rs. 2598.75 for one cubic meter of concrete. Study recommended that polyethylene glycol PEG400 used internal curing concrete is a preferable preference in water crises country and scarcity of water especially developing countries.

5. References

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