A novel approach on properties of internal curing concrete and impact of salts

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Abstract. The curing process for massive and inaccessible structures is troublesome. To overcome this difficulty and to reduce the evaporation by increasing the performance of mechanical properties, the process of internal curing is the superlative method. This research is aimed to investigate the mechanical and salt properties of Internal Cured Concrete prepared using Polyethylene Glycol (PEG) solution. M25 grade concrete is prepared at various proportions of PEG viz., 0%, 0.5%, 1%, 1.5% and 2% by cement weight. The average maximum compression and flexural strengths were observed at 2% of PEG solution, while the maximum split tension strength was recorded at 1.5% of PEG. NaCl, KCl solutions are used to investigate the influence of salts. The specimens were prepared by utilising the mix that resulted the maximum compressive strength. The specimens are then immersed in both salts for 14 days and the results are evaluated. It was observed that, both the chemicals have shown hostile effect on concrete prepared using PEG-600 solution resulting in deterioration.

1. Introduction

Concrete structures have become one of the most prominent in the field of construction. Curing of concrete is very much essential in attaining the strength and shows a foremost role in enhancing the durability properties. In general, curing promotes the hydration process of cement. The various methods available for curing are water curing, steam curing, self-curing, curing by infrared radiation, electrical curing, etc., but by these methods huge amount of water is being used which eventually may lead to the scarcity of water.

Exterior and interior curing are the two core concrete curing approaches available. For conventional concrete, external curing process is adopted after mixing, placing and finishing processes. In the places where the scarcity of water is present the prolonged curing process is impossible. Water in concrete gets evaporated as when concrete surfaces are open to environment. This reduces the amount of water content used during concreting works which will affect the cement hydration process by diminishing the quality of the concrete. At higher temperatures, strength loss is observed in conventional concrete due to the formation of cracks amongst paste produced from cement and aggregates (coarse and fine). The technique in internal curing involves provision of additional moisture in concrete for effective cement hydration. This study uses Poly Ethylene Glycol (PEG)-600 solution as an internal curing agent.
2. Literature study
A Ananthi et. al. [1] used Gelnium, a super plasticizer which is helpful to progress the workability of Self Curing Concrete. PEG 600 is used at varying percentages, 1%, 2%, and 3% by weight of cement and the properties are evaluated for M40 grade of mix. It was witnessed that the ideal amount for compressive strength was originate to be at 2% and the tensile strength results shown the maximum strength at 1%. From the workability test, it was seen that an increase in Glenium dosages increases the workability at the rate of 3.3% and compressive strength was increased by 2.25%. Sundararaman et.al. [2] studied mechanical properties of M25 concrete using PEG and the results are 18.76, 32.6 and 44.5 N/mm$^2$ for 0.5%-2% of PEG (3,7,28 days), and for 1% and 1.5% the maximum values are 47.8 and 43.1 N/mm$^2$. As the percentage of PEG increased the results shown a decreasing trend. Split tensile strength at the end of 3,7 and 28 days for 0.5% PEG showed the increasing values of 1.76, 2.84 and 5.09 N/mm$^2$, and 5.16 and 4.72 N/mm$^2$ are observed for 1% and 1.5% of PEG and additional escalation of PEG resulted in decreasing trend.

Nirav Kholia et.al [3] determined the properties of hardened concrete. In a work carried by Kastro Kiran et al [4] maximum compressive strength was obtained at 2% of PEG solution (600) and tensile and flexural strengths were maximum when at 1.5% of PEG solution.

3. Objectives and methodology
The following are the main objectives of the present study:
(a) Preparation of M25 grade of concrete at various dosages using PEG-600 viz., 0%, 0.5%, 1%, 1.5%, 2.0% by replacement of cement.
(b) Determination of mechanical properties of hardened SCC and comparing the results with traditionally cured concrete.
(c) Investigation of influence of salts on hardened SCC using NaCl and KCl solutions.

From the available literature, it is noted that self curing concrete is prepared by using poly ethylene glycol, poly vinyl alcohol and light weight aggregates and the mechanical properties are determined at various dosages. In this research, besides mechanical properties determination, the tests are further extended to influence of salts on self curing concrete.

The research is grouped under two categories. In the primary phase of research, preliminary tests on cement, coarse aggregate and fine aggregate are performed and M25 grade of concrete mix is prepared and the results are evaluated in comparison with conventionally cured concrete. In the secondary phase, the mix which resulted the maximum compressive strength in Phase 1 is adopted and tested for Salt attack.

4. Experimental investigation
4.1. Materials used
a) Cement: OPC 53grade confirming to IS 12269:1987 is used which has a specific gravity of 3.14.
b) Coarse aggregate: Crushed granite of size ranging between 10 mm - 20 mm confirming to IS 383:1970 is used with a specific gravity of 2.71.
c) Fine aggregate: The sand was acquired from proximate river shore of size less than 4.75 mm confirming to IS 383:1970 is used with a specific gravity of 2.81.
d) Poly Ethylene Glycol (PEG) 600: PEG is a condensed polymer, liquid solution, used as a self-curing agent. Table 1 demonstrates the specifications of PEG-600 used in the present work.
e) Water: Potable water is used for preparing concrete.

| Table 1. Specifications of PEG-600 |
|-----------------------------------|
| Parameters                      | Specifications   |
| Appearance @25°C                 | Colorless       |
| pH @25°C                        | 4 – 7           |
| Water content, %                | 0.20 maximum    |
| pH value                        | 6 – 7           |
| Solubility in water             | Completely soluble |
Typical molecular weight: 570 – 630
Density: 1.12/ml at 20°C

4.2. Mix details and preparation of specimens

The mix design is prepared as per IS 10262:2009. Table 2 shows the mix details of M25 grade of concrete for varying percentages of PEG-600.

Table 2. Mix values for M25 grade concrete

| S.No. | PEG-600 (%) | Slump values (mm) | Compaction factor |
|-------|-------------|-------------------|-------------------|
| 1     | 0 %         | 78                | 0.85              |
| 2     | 0.5 %       | 86                | 0.87              |
| 3     | 1.0 %       | 89                | 0.92              |
| 4     | 1.5 %       | 92                | 0.93              |
| 5     | 2.0 %       | 98                | 0.95              |
| 6     | 0 %         | 78                | 0.85              |

Cubes and cylinders of size 150x150x150 mm and 150 mm diameter with a height of 300 mm are prepared to conduct compressive and split tension strength tests. Beams of 700x150x150 mm size are cast, tested for flexural strength. PEG-600 is mixed while adding water and hand compaction is adopted in preparation of all the specimens. After cast of specimens, the cubes, beams, and cylinders are air cured for 28 days. Traditional concrete specimens (cubes, cylinders & beams) were water cured for 28 days and hardened properties are evaluated.

5. Results and discussions

5.1. Fresh state – slump and compaction factor

Table 3 shows the slump cone and compaction factor test results. It was noted that with the rise in the percentage of PEG, slump and compaction factor values have increased.

Table 3. Slump cone and Compaction factor results

5.2. Hardened concrete properties

5.2.1. Compression strength

The cubes are tested on CTM of capacity 2000 kN after air curing for 28 days. Figure 1 demonstrates the average compression values for conventionally cured concrete and internally cured concrete obtained at 28 days.
The compression strength results have consistently shown an increasing trend with an increase in the percentage of PEG - 600 solution. For traditionally cured concrete (water curing), compression strength of 28 MPa observed and for every 0.5% increase in PEG - 600 the values had increased and the maximum strength, 36.7 MPa, was recorded at 2%. It was noted that when SCC prepared with 2% of PEG solution there is an increase in strength by 8.7 MPa when compared with conventional concrete.

5.2.2. Split tension & Flexure

Cylinders of above said size were cast and tested to determine the split tension strength. Figure 2 depicts the average split tension and flexure strength outcomes.

It was observed as when the concrete cured with PEG-600 solution had shown an upsurge in split tension strength in comparison to the conventionally cured concrete and maximum split tensile strength was observed when 1.5% PEG solution is used by weight of cement, 3.33 MPa. The lowest strength was observed at 0.5% PEG solution. When the percentage of PEG solution has increased
beyond 1.5%, the values had shown a diminishing trend. On the other side, for water cured concrete the flexural strength was observed as 2.86 MPa and the maximum flexural strength, 4.1 MPa, was observed at 2% replacement of cement with PEG 600 solution.

Both compressive strength and flexural strength had shown maximum values at 2% and 1.5% of PEG solution. It is perceived that, in regard to the mechanical properties, self-cured concrete had shown improved outcomes in comparison with conventionally cured concrete.

6. Salt attack
6.1. Introduction
Salt is hygroscopic in nature. When concrete is exposed to salts, it is capable to attract almost 10% additional water into the pore spaces of concrete. This phenomenon results in less expansion in the pore structure of concrete which consecutively creates high pressure to the concrete, instigating the surface to chip, scale, and pop.

6.2. Methodology
To comprehend the effect of the salts on self-curing concrete, in the primary phase, the mix which resulted the maximum strength i.e 2% PEG – 600 solution was adopted to evaluate the influence of salts. As the water which is used for curing process contains Chlorides and Potassium, NaCl and KCl salts are used to evaluate the influence of various salts on internally cured concrete.

The specimens are cast, reserved at typical room hotness (28 days). The specimens were immersed in solutions, separately, for 14 days. For each litre of water, 15g of NaCl and KCl salt crystals are mixed and allowed them to dilute completely. After 14 days of immersion of specimens, tests were performed.

6.3. Discussion on results – Salt attack
Figure 3 shows salt test results evaluated for mechanical properties.

NaCl and KCl had shown hostile effect on various properties. The compression strength was diminished to 31.5 MPa and 30.67 MPa from 36.7 MPa as when the specimens are exposed to NaCl and KCl solutions. Correspondingly, the split tension and flexure strengths too also revealed a declining tendency. Deterioration was also observed on the top of concrete specimens.

7. Inferences
The following inferences are noted from the present research:

![Figure 3. Salt attack outcomes](image-url)
i. Compressive and flexural strengths were maximum at 2% PEG solution relatively being higher than the targeted strength.

ii. Conversely, the supreme split tension strength was observed at 1.5% and with additional upsurge in PEG solution, the results shown a declining pattern.

iii. With respect to conventional concrete, self-curing concrete shown better results for mechanical properties.

iv. The strengths of internal cured concrete when exposed to NaCl and KCl were decreased and deterioration was observed

8. References

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