Strength and durability properties (effect of salts) of internal curing concrete

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Abstract. Concrete is the second most largely consumed material on Earth. The strength and durability parameters of concrete largely depends on the curing process. The quality of concrete to a great extent relies upon the process of curing. It is estimated that 1m$^3$ of concrete requires about 3m$^3$ of water, approximately and a period of 28 days continuous water curing is required to develop the desired properties. In order to restrict the usage of excess amount of water, Internal Curing of Concrete is perhaps the best other option. In this study, internal curing agent – Poly Ethylene Glycol is used at various dosages, 0%, 0.5%, 1.0%, 1.5%, 2%, 2.5%, and 3.0% by cement weight and the mechanical properties are evaluated. The effect of salts on Internal Cured Concrete are evaluated by using two salt solutions viz., NaCl and CaCl$_2$. It was perceived that 2% PEG solution was effective for compressive strength and 1.5% for split tensile and flexural strengths. NaCl and CaCl$_2$ solutions had shown an adverse effect on Internal Cured Concrete.

1. INTRODUCTION

Due to rapid increase in construction of structures, concrete manufacturing and consumption has become more, hence the usage of water at various stages during the construction process has also been upsurge. Curing can be defined as the way toward influencing the rate and degree of dampness from a concrete member while in the process of hydration. So as to acquire great quality concrete, a fitting blend must be trailed by legitimate relieving in an appropriate situation during the beginning times of hardening. Also for durability as well as performance of structure proper and homogeneous curing is necessary.

External curing and internal curing are the two available methods of curing. At the point when concrete member is wide open to nature, dissipation of water happens and loss of dampness will decrease the underlying w/c proportion which will bring about the inadequate hydration and consequently bringing down the strength properties of concrete. The temperature at the time of curing is the main considerations which influence the strength. The ACI characterizes internal curing as “providing water all through a naturally set cementitious blend utilizing pore liquids, by means of LWA, that promptly discharge water varying for hydration or to supplant dampness lost through evaporation.”

2. LITERATURE REVIEW

Patel et.al. [1] studied on strength quality of internally cured concrete and observed that compressive strength of internal cured specimens was raised about 36% at 1% replacement with PEG 600 and at the same percentage, PEG 1500 exhibited 33.9%. For M25 mix, the ideal dosage of 1% is observed for both the types of PEG solutions.
Mohanraj et.al. [2] processed the influence of PEG on internal curing concrete and observed, self-cured concrete exhibited better results when compressive strength was determined by using NDT methods compared to conventional cured concrete. And when compressive and split tensile strengths was determined by using CTM, self-cured concrete shown better results. Internally-cured concrete shown less water assimilation and water sorptivity esteems contrasted when concrete cured by different techniques.

H.Famili, et.al. [3] This experimental work was carried out to investigate the high strength self-consolidated internal cured concrete using the LWA. Performance of self-consolidating concrete was carried out by using 0.28 and 0.33 w/b. In this research various parameters of concrete like durability and mechanical properties were investigated. During this experimental work, 25% of typical weight coarse aggregate volume was supplanted with soaked LWA of same size and its impact on properties were explored.

In a paper studied by Niravkholia et.al [4], it was concluded that the durability of the hardened concrete is incredibly impacted by curing method since it remarkably affects the hydration process. The progressions in the development and chemical industry have cleared route for the advancement of the new curing systems and development of synthetic substances, for example, Membrane relieving mixes, Self-restoring operators, Wrapped restoring, Accelerators, Water sealing mixes.

Manojkumar [5] conducted investigations on mechanical properties of Internal-curing concrete made using wax put together film relieving compound and SAP with respect to the grade M40 concrete. Internal cured concrete circulates the additional restoring water (consistently) all through the whole microstructure with the goal that it is all the more promptly accessible to keep up immersion of the concrete glue during hydration, maintaining a strategic distance from self-drying up and lessening shrinkage.

In an investigation, Chella. [6]studied high performance internal curing concrete made with SAP and LWA. Blend is accomplished by including SAP at 0.3% replacement of cement and another blend is acquired by supplanting 25% of LWA to fine aggregate. Quality and toughness are contemplated tentatively and the outcomes yielded more noteworthy quality of LWA blend. Burden conveying limit in shear and flexure additionally more prominent and the sturdiness results uncover that blend with SAP is better contrasted with the remaining blends.

Sathanandham. T [7] studied properties at various dosages of PEG 4000 solution. The impact of PEG 4000on mechanical properties of internal cured concrete was found efficient compared with normally cured concrete.

3. OBJECTIVES
After a detailed study on available literature, the objectives are:
(a) Mix preparation of M30 grade concrete with varying percentages of PEG-400 solution viz., 0%, 0.5%, 1.0%, 1.5%, 2.0%, 2.5%, 3.0% by weight of cement.
(b) To evaluate the hardened Internal Cured Concrete properties and compare with conventional cured concrete.
(c) To understand the effect of salts (NaCl & CaCl) on Internal Cured Concrete.

4. EXPERIMENTAL WORK
4.1. Materials
The different materials used in the present research are listed below:
Ordinary Portland Cement of grade 53 confirming to IS 12269-1987 with 3.11 specific gravity.
Coarse aggregate are obtained from local quarry with size ranging from 10-20 mm, confirming to IS 383-1970, of specific gravity 2.84.
Fine aggregate of size below 4.75 mm with 2.65 specific gravity are used confirming to IS 383-1970.
Poly Ethylene Glycol – 400, obtained from Jeevan Enterprises, Hyderabad.
Water used in the study is potable water.
4.2. Mix Design

Weigh batching is adopted for all the materials. Standard cubes, cylinders and beams were cast for all mixes in concrete. The concrete of grade M30 was prepared using IS 10262:2009 and mixture quantities are listed in Table 1.

| Mix Quantity for M30 grade concrete for 1m³. |
|---------------------------------------------|
| Cement(kg) | Fine Aggregate(kg) | Coarse Aggregate(kg) | Water(kg) | W/C ratio |
| 488.25     | 792.22             | 1011.92             | 195.3     | 0.4       |

Table 2 shows the properties of PEG-400 used in the study.

| Table 2. Properties of PEG-400. |
|----------------------------------|
| Parameters                        | Specifications          |
| Appearance @ 25°C                 | Clear, colourless liquid|
| pH (5% aqueous solution) @ 25°C   | 4.5-7.5                 |
| Water content, %                  | 0.2 max                 |
| Solubility in water               | Complete                |
| Average molecular weight          | 380-420                 |

Table 3 shows the different concrete mixes with varying percentages of PEG-400.

| Table 3: Concrete Mixes. |
|--------------------------|
| Mix Number | Specifications         |
| M0         | 0% PEG - 400           |
| M1         | 0.5% PEG - 400         |
| M2         | 1% PEG - 400           |
| M3         | 1.5% PEG - 400         |
| M4         | 2% PEG - 400           |
| M5         | 2.5% PEG - 400         |
| M6         | 3% PEG - 400           |

4.3 Specimen preparation and tests

4.3.1 Mechanical properties

The standard specimens of size 150 x 150 x 150 mm (for cubes) were cast for conducting compressive strength, cylinders of 150 mm diameter and 300 mm height were cast to perform split tensile strength test and beams to perform flexural test of size 100 x 100 x 500 mm were prepared. The specimens after cast were demoulded after 28 hours and kept at normal temperature conditions for 28 days curing. The conventional concrete specimens were water cured for 28 days before testing. Compaction factor test and Slump cone test were conducted to measure workability of fresh concrete.

4.3.2 Durability Property (Salt Attack)

Carbonation process is accelerated by salts, a process that decreases the pH levels in concrete through contact with CO₂. Most salts are impartial to somewhat acidic (pH of 4.5 – 7), and ingestion of the salts (saline solution) by the solid will quicken the pH decrease of the solid. Salts are the essential wellspring of chlorides brought into concrete.

To understand the effects of the salt attack on internal curing concrete, the mix which gave the highest strength was adopted. The specimens made using 2% PEG-400 are used to evaluate the effect of salt attack. Two salt solutions, NaCl and CaCl₂, are used for salt attack tests.
The cube and cylindrical specimens are prepared and kept at room temperature for 28 days. The specimens are then kept in both the solutions for 7 days. The concentration of the solution is taken as for every one litre of water, 5 g of NaCl and CaCl₂ are mixed. At the end of the 7 days, tests for mechanical properties are performed.

5. RESULTS

5.1 Fresh state properties
Table 4 shows the compaction factor and slump cone test results for various mixes.

| Mix Number | Specifications  | Slump (mm) | Compaction Factor |
|------------|----------------|------------|-------------------|
| M0         | 0% PEG 400     | 92         | 0.89              |
| M1         | 0.5% PEG 400   | 94         | 0.88              |
| M2         | 1% PEG 400     | 94         | 0.91              |
| M3         | 1.5% PEG 400   | 96         | 0.95              |
| M4         | 2% PEG 400     | 99         | 0.96              |
| M5         | 2.5% PEG 400   | 100        | 0.95              |
| M6         | 3% PEG 400     | 101        | 0.93              |

5.2 Hardened concrete properties

5.2.1 Compressive strength
Figure 1 shows the compressive strength test results conducted for various mixes cast performed on Compression Testing Machine.

For conventionally cured specimens i.e., at 0% PEG – 400, the compressive strength observed was 32 MPa and as the percentage PEG solution increases the compressive strength shown an increasing trend upto 2.0% of PEG and with further increase in PEG percentages the compressive strength shown a decreasing trend. It is observed that at 2% of PEG-400 solution, the maximum compressive strength was obtained, 36.2 MPa.

5.2.2 Tensile strength
Figure 2 shows the results of tensile strength conducted for various mixes cast.
Figure 2. Tensile strength for varying percentages of PEG-400.

For conventionally cured concrete the tensile strength was 1.8 MPa and as the proportion of PEG solution raises the tensile strength shown an increasing trend up to 1.5% of PEG and with further increase in PEG percentages the tensile strength shown a decreasing trend.

5.2.3 Flexural strength

The flexural strength test results conducted for various mixes are tabulated in Figure 3.

Figure 3. Flexural strength for varying percentages of PEG-400.

5.3 Salt Attack

Figure 4 shows the results evaluated for mechanical properties of Internal Cured Concrete.

Figure 4. Salt attack test results.
NaCl and CaCl$_2$ has shown adverse effect on strength parameters of SCC. The compressive strength had decreased to 29MPa and 26MPa from 35MPa when the specimens are immersed in NaCl and CaCl$_2$ solutions. Similarly, the flexural strength and split tensile strength results had shown a decreasing trend.

6. CONCLUSIONS

From the study the following conclusions are withdrawn:

- PEG-400 solution is one of the best available solutions to be used as self-curing agent.
- Compressive strength is 25% higher for Self-Cured Concrete than the concrete cured conventionally.
- Similarly, the flexural strength and split tensile strengths also increased by 30% and 70% for self-cured concrete.
- Concrete cured using PEG-400 has shown an increase in strength parameters than concrete cured conventionally.
- When self-cured concrete is exposed to salts like NaCl and CaCl$_2$, decrease in strengths were observed. This is majorly due to the presence of salt chemicals in the solution which made the concrete weak.
- Overall, self-cured concrete will be one of the best possible alternatives in the near future.

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