

Self-Cured High Strength Concrete-An Experimental Study

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Abstract: The effect of elevated temperature and durability studies is studied on fifty-four numbers of self-cured high strength concrete cubes of 100mm size with ultrafine mineral admixture, Alccofine 1203. Optimum dosage of internal curing compound and Alccofine used is 0.25% and 10% respectively. Non-destructive, elevated temperature, and durability studies are conducted on the specimens. Between the temperatures 100°C to 900°C, the percentage of loss in weight is found to be decreased. But, compressive strength is increased at 300°C and decreased at higher temperatures. The weight and compressive strength are increased for the cube specimens due to the specimens immersion in Sulphate, Chloride and Alkali solutions and Sea water respectively.

Index Terms: Elevated temperature, non-destructive tests, Durability tests, Weight, Compressive strength.

I. INTRODUCTION

A. Self- Curing

In conventional curing, curing happens ‘from external to internal’. In self-curing, curing happens ‘from internal to external’ through the internal reservoirs. Internal curing reduces the water evaporation from concrete and increases the water retaining capacity of the concrete. The difference between conventional and internal curing is presented in Fig.1.

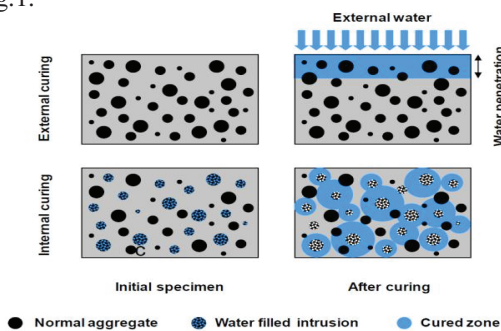


Figure 1. Conventional (external) curing and internal curing

As per ACI-308-2013, “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”.

B. Necessity of self curing

- In high strength concrete, the depth that the external water can penetrates is limited due to the low water-cement ratio of concrete. In such a case, Self-curing (SC) of concrete solves the problem of degree of

cement hydration because self-curing enables the water to distribute more equally throughout the cross-section.

- SC is a good solution where there is an acute shortage of water.
- SC is a good solution for curing vertical members, inclined members, extreme corner locations, top-most members/areas where normal curing is difficult.
- SC is a right choice for curing of high-rise structures.
- SC is an appropriate alternative when the dependency on unskilled labour for conventional curing is high.
- SC is preferable in hot weather regions where large quantity of water is required for curing owing to the evaporation losses.
- SC is advisable when the cost of obtaining water with the desired quality is expensive.
- SC is desirable when it is required to reduce the cost of operations, quicker turn-around time in precast plants.

C. Significance of present study

Now-a-days, the foremost challenge in construction field is the lack of availability of water. Construction industry must switch over to alternate curing methods like self-curing method for the sustainable development of the environment. Self-cured concrete does not require water for curing hence, there will be no excess usage of water. Therefore, an attempt is made in the present paper to achieve the required strength and durability of high strength concrete by internal curing with suitable admixtures and the effect of elevated temperatures on self-cured high strength concrete and conventionally cured high strength concrete.

II. LITERATURE REVIEW

The water movement from internal curing agents into hydrating cement paste with a low water-cement ratio was studied and observed that the amount of water first received by the paste in the proximity of the Super-absorbent Polymer can be redistributed later to a large volume of hardening paste when the permeability becomes very low[1]. Characterization of a super-absorbent polymer was studied by determining compressive strength, split tensile strength and flexural strength of the concrete containing SAP and compared with conventionally cured concrete[2]. Three different curing techniques were used and the variation of compressive strength of medium strength and self-compacted concrete was studied. Immersion curing method gave maximum compressive strength. Internal curing with Polyethylene Glycol (PEG) gave only 5% lesser compressive strength than immersion curing[3]. Workability and strength characteristics of Normal Strength and High

Strength Concrete with Polyethylene Glycol and S orbital were studied and compared with the conventionally cured concrete of M20, M30 and M40, M60, M70 and M80 grades [4]. The variation of weight, compressive strength, flexural strength and split tensile strengths of concrete cubes was investigated with the use of PEG4000 and PEG200 at 0.1%, 0.5%, 1% in M70 grade concrete. Durability tests were also conducted [5]. Strength characteristics of M20 concrete with PEG400 were compared with the conventionally cured concrete at 3days, 7days, 14 days and 28 days [6]. Strength and workability tests were conducted on M20 and M25 grade concrete using PEG600 at 0.5%, 1%, 1.5%, and 2% [7]. Strength properties of M20 grade concrete were studied using PEG400 at different percentages [8]. Effect of solid Paraffin wax on the strength properties of concrete was studied and compared with the properties concrete made with Master Rheo-build [9].

III. EXPERIMENTAL PROGRAMME

A. Materials Used

The specific gravity of ordinary Portland Cement (53 grade) used is 3.10. The specific gravity of sand (fine aggregate) used is 2.65. The specific gravity of coarse aggregate used is 2.70. Potable water is used for making the concrete. The Superplasticizer used is Master Glenium ACE30JP (at 1.2% by weight of binder). The supplementary cementitious material used is Alccofine 1203. The internal curing compound used is Polyethylene Glycol 8000. The mix proportions used for the preparation of high strength concrete are 1:0.556:1.629:0.25.

B. Elevated Temperature Studies

Influence of temperature on Compressive strength, Weight loss and Durability properties of cubes is studied in this paper. Duration of temperature is 02 hours and varied from 100°C to 900°C at an interval of 100°C as presented in Fig.4.

Air-cooled cubes Ultrasonic pulse velocity is measured using Portable Ultrasonic Non-destructive Digital Indicating Tester [10] and the quality of concrete is studied.

C. Ultrasonic Pulse Velocity (UPV)

For cubes with high density, homogeneity and uniformity, higher velocities values are observed. In case of poor quality cubes, lower velocities are observed. The test results of Ultrasonic pulse velocity are presented in Fig. 2.

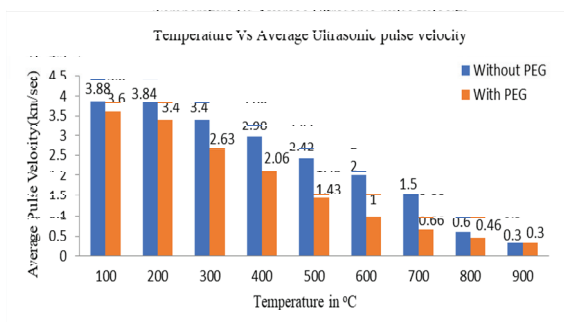


Figure 2. Ultrasonic pulse velocity of cubes

D. Percentage loss in weight

The percentage loss in weight of cubes without PEG8000 is calculated at different temperatures and presented in the Fig.3. The percentage loss in weight of cubes is found to be increased up to 900°C.

Similarly, the percentage loss in weight of cubes with PEG8000 is calculated at different temperatures and presented in the Fig.3. The percentage loss in weight of cubes is found to be increased up to 900°C.

The comparison of percentage weight loss of cubes without and with PEG8000 at different temperatures is presented in Fig.3.

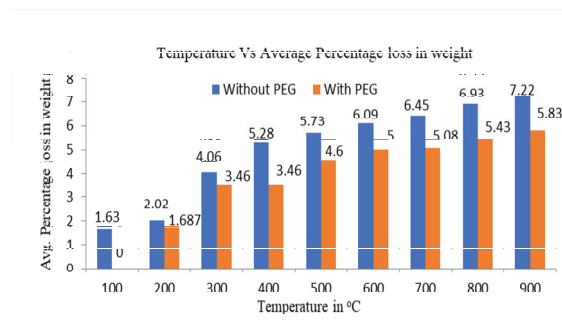


Figure 3. Weight loss of cubes without and with PEG8000

E. Compressive Strength

Compressive strength of 100mm cubes with different dosages of PEG8000 is presented in Fig.4. Total cubes cast (with different dosages of PEG8000 from 0.1% to 2.25%) are thirty-four. From Fig.3, the optimum dosage of PEG8000 is found to be 0.25%.

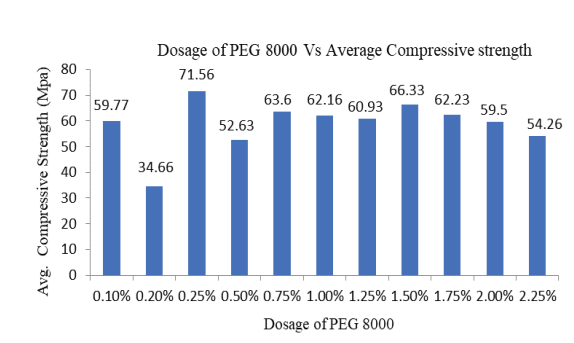


Figure 4. Compressive strength of cubes

Twenty-seven 100mm cubes are cast for studying the weight loss and compressive strength at room temperature. Twenty-seven more cubes of 100mm size are tested to study the variation in the weight loss and compressive strength cubes before and after subjecting to the elevated temperatures. After 28 days of conventional curing, cubes without PEG8000 are air dried and tested to 100°C, 200°C, 300°C, 400°C, 500°C, 600°C, 700°C, 800°C and 900°C temperature for 02 hours in a high Temperature Furnace of 1000°C capacity. No visible cracks are observed up to 300°C. Cracks are observed in the specimens when tested to 400°C and 500°C. Pronounced cracks are seen on the surface of the cubes at 600°C, 700°C, 800°C and 900°C respectively. Upto 600°C, no change in the colour of cubes is observed. At 700°C, the color of cubes changed to pink/red. Beyond

700°C, the color of cubes changed to grey. Cubes are tested for residual compressive strength under Automatic Compression Testing Machine.

Residual compressive strength of cubes without PEG8000 is shown in Fig.5. The Compressive strength of concrete is decreased, when the cube specimens are exposed to a temperature from 100°C to 200°C. The Compressive strength is found to be increased at 300°C. From 400°C to 500°C, there is a nominal decrease in the compressive strength. From 600°C to 900°C, an increase in the percentage decrease is observed in the compressive strength. At 600°C, the average percentage decrease in compressive strength is 26.81%. At 700°C, the average percentage decrease in compressive strength is 32.15%. At 800°C, the average percentage decrease in compressive strength is 52.08%. At 900°C, the average percentage decrease in compressive strength is 69.83%. The decrease in compressive strength between 600°C and 800 may be due to the decomposition of C-S-H gel and dehydration of calcium hydroxide (CH) into free lime. Decomposition of calcium carbonate and the loss of free water may be the reason for the decrease in compressive strength of concrete at 900°C.

Comparison of residual compressive strength of cubes without and with PEG8000 is presented in Fig.5. Compressive strength of concrete is decreased, when the cubes are exposed to a temperature from 100°C to 200°C. The Compressive strength is found to be increased at 300°C. The increase in strength at 300°C may be due to the increase in the surface forces among the gel particles. From 400°C to 500°C, an increase in the decrease of compressive strength is observed. From 600°C to 900°C, the compressive strength is decreased.

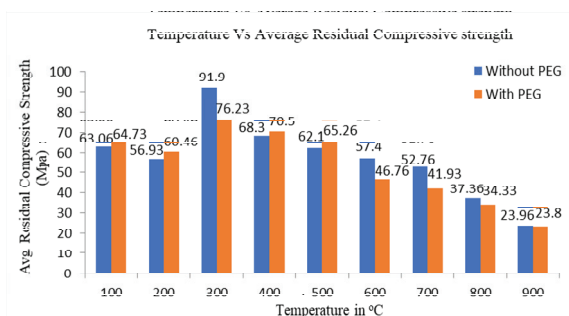


Figure 5. Average residual compressive strength of Cubes without and with Polyethylene Glycol 8000

F. Sulphate Test

Three cubes of 100mm size are cured in water for 28 days. Then the cubes are dried at 50°C for 24 hours and weights are taken before placing in the Sulphate solution (2.5% Na₂SO₄ and 2.5% MgSO₄ by weight of water). After the prescribed period, the average percentage loss in weight of cubes is calculated at 7, 14, 28 and 56 days and shown in Fig.6.

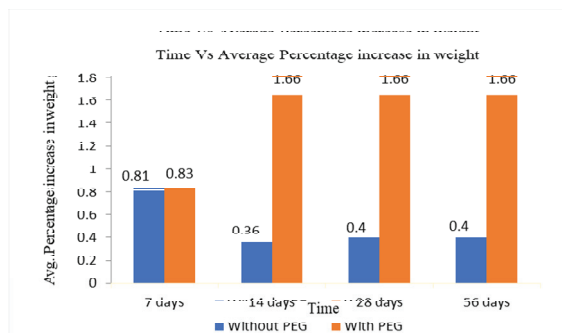


Figure 6. Average percentage increase in weight of cubes tested for Sulphate attack

G. Chloride Test

Three cubes of 100mm size are cured in water for 28 days. Then the cubes are dried at 50°C for 24 hours and weights are taken before placing in the Sodium chloride solution (5% of NaCl by weight of water). After the prescribed period, the average percentage loss in weight of cubes is calculated at 7, 14, 28 and 56 days and shown in Fig.7.

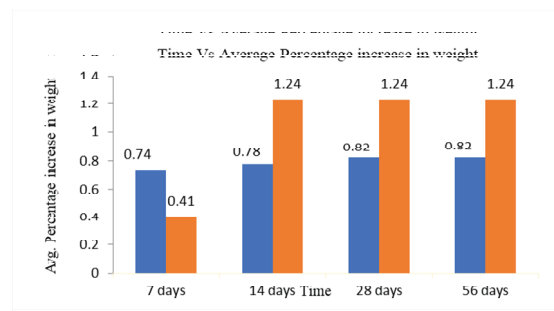


Figure 7. Average percentage increase in weight of cubes tested for Chloride attack

H. Alkali Test

Three cubes of 100mm size are cured in water for 28 days. Then the cubes are dried at 50°C for 24 hours and weights are taken before placing in the Sodium hydroxide solution (5% of sodium hydroxide solution by weight of water). After the prescribed period, the average percentage loss in weight of cubes is calculated at 7, 14, 28 and 56 days and shown in Fig.8.

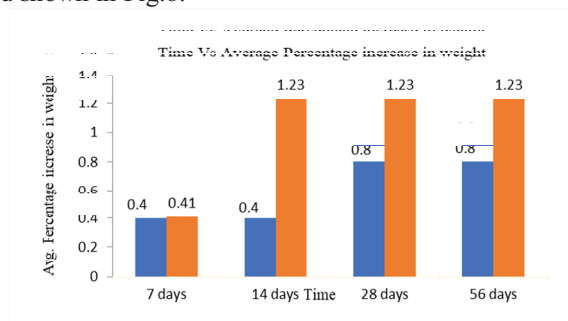


Figure 8. Average percentage increase in weight of cubes tested for NaoH attack

I. Sea Water Test

Three cubes of 100mm size are cured in water for 28 days. Then the cubes are dried at 50°C for 24 hours and

weights are taken before placing in the sea water (5% of Sea water solution).After the prescribed period, the average percentage loss in weight of cubes is calculated at 7, 14, 28 and 56 days and shown in Fig.9.

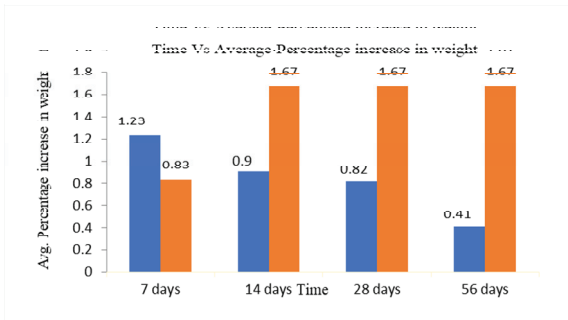


Figure 9. Average percentage increase in weight of cubes tested for Sea Water attack

J. Pulse Velocity

The average pulse velocity of cubes without and with PEG8000 is presented in Fig.10.

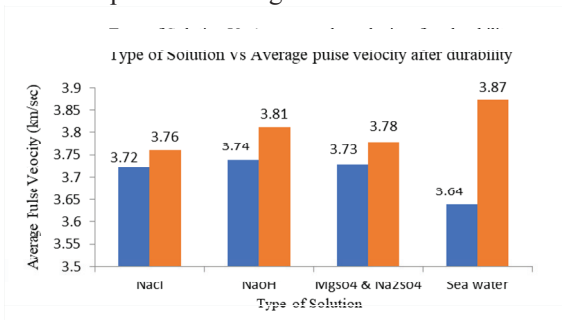


Figure 10. Average pulse velocity cubes

The interfacial transition zone thickness variation and the decrease in the voids ratio of hardened concrete may be attributed to the increase in weight and compressive strength of the cubes.

K. Sorptivity Test

100mm concrete cubes are placed in the oven at a temperature of 50°C for 03 days, before placing cubes in contact with water[11]. Sorptivity coefficient is calculated as $1.5873 \times 10^{-4} \text{ mm/min}^{0.5}$. Sorptivity values are presented in Fig.11.

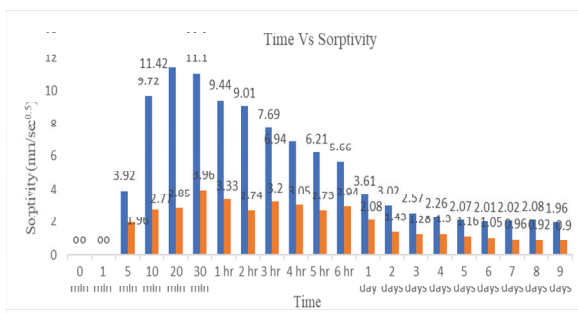


Figure11.Sorptivity of concrete cubes without and with PEG8000

IV. DISCUSSIONS AND CONCLUSIONS

Self-curing of concrete using PEG8000 is found to be a good alternative for conventional curing of concrete. Discussions and conclusions are presented below.

1. 10% replacement of cement replacement by Alccofine1203 is found be an optimum percentage forobtaining an average compressive strength of 79.93MPa without PEG8000.
2. Optimum dosage of PEG8000 is found to be 0.25% by weight of binder forobtaining an average compressive strength of 71.56MPa. The percentage of difference between the compressive strengths achieved without and with PEG8000 was 10.47%.
3. Without PEG8000, the average Compressive Strength of concrete cubes at 56 days of curing in Nacl, NaoH, MgSO₄ plus Na₂SO₄ solutions and Sea water is found to be 91.83 MPa, 94.6 MPa, 86.93 MPa and 89.10 MPa respectively. Without PEG8000, the average Compressive Strength of concrete cubes before 56 days of curing was 69.71MPa, 79.93 MPa, 63.55MPa and 78.40MPa.The percentage increase in compressive strength is found to be 31.73, 18.35,36.78 and 13.64.The increase in compressive strength may be due to the increase in density of concrete cubes.
4. Compressive Strength of concrete cubes with PEG8000 after 56 days of curing in Nacl, NaoH, MgSO₄ plus Na₂SO₄ solutions and Sea water is found to be 75 MPa, 77 MPa, 72.56 MPa and 73.33 MPa respectively. The average Compressive Strength of high strength concrete cubes without PEG8000 before 56 days was 71.3MPa, 71.2 MPa, 69.2MPa and 70.73MPa.The percentage increase in compressive strength was found to be 5.18, 3.77, 4.85 and 3.67.
5. Initial rate of water absorption of high strength concrete cubes without and with PEG8000 is not linear due to the increase in water absorption whereas the secondary rate of absorption is linear due to less water absorption. More water absorption may be attributed to the precondition of the concrete cube specimens at a temperature of 100°C for 24 hours. Less water absorption during 1day-7days may be attributed to the less pore space available after the initial absorption period of 1min-6hour.
6. Compressive strength of 100mm cubes after two hours at 300°C is found to be increased by 18.55%. The increase in compressive strength at 300°C may be due to the increase in surface forces between gel particles because of the removal of moisture content. After critical temperature of 300°C, the compressive strength of cubes is decreased considerably upto 900°C. Similar trend is observed for concrete cubes with PEG8000.

As per the discussions, the use of PEG8000is recommended for the preparation of high strength concrete in the water scarce areas or where potable water is not available for the preparation of concrete.

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