Compressive Strength and Durability of Self Curing Concrete

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Abstract—*Water play a significant role in making concrete both in the stage of mixing and curing. It is also an important item for the life on the earth. Curing of concrete plays a major role in strength development and development of microstructure in concrete. It is absolutely necessary to conserve this precious natural resource. In view of this, self-curing concrete (SCC) has been developed In the present study, an attempt has been made to develop self-curing concrete by using super absorbing polymers. SCC is a very promising technique that can provide additional moisture in concrete for a continuous and effective hydration. By the introduction of curing agents into concrete, additional moisture can be maintained. Super Absorbent Polymers (SAP) are polymeric materials which have the ability to absorb a large amount of moisture from the surroundings. Thus it can be retained in the composite. A concrete mix of M25 was proportioned. Workability, strength characteristics and acid resistance of the concrete with 0, 0.12, 0.24 and 0.48% of super absorbent polymer by the weight of cement were carried out. It was found that concrete with this self-curing agent SAP, exhibits higher strength and acid resistance compared to the conventionally cured concrete.*

Keywords: Self curing of concrete, Super Absorbent Polymers, strength and durability of concrete.

1.INTRODUCTION

Curing is the process of preventing the loss of moisture from the concrete by maintaining a satisfactory temperature regime. Excessive evaporation of water from fresh concrete should be avoided; otherwise, the degree of cement hydration would get lowered and thereby concrete may develop unsatisfactory properties. Curing operations should ensure that adequate amount of water is available for cement hydration to occur. The ACI-308 states that "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." Conventionally, curing concrete means creating conditions such that water is not lost from the surface i.e., curing is taken to happen 'from the outside to inside'. In contrast, 'internal curing' is allowing for curing 'from the inside to outside' through the internal reservoirs (in the form of saturated lightweight fine aggregates, superabsorbent polymers, or saturated wood fibres) created. 'Internal curing' is often also referred as 'Self–curing. The use of self-curing admixtures is very important from the point of view that water resources are getting valuable everyday (i.e., each 1 m^3 of concrete requires about 3 m^3 of water for construction most of which is for curing).The lavish application of water for water curing is not possible reasons of economy. It is observed in most of the construction sites that the vertical structure especially columns are unable to cure properly. Thus the benefit of using self-curing admixture is more significant, in areas where water is not adequately available and leaving the responsibility of curing to the workers. The mechanism of self-curing can be explained as; Continuous evaporation of moisture takes place from an exposed surface due to the difference in chemical potentials (free energy) between the vapor and liquid phases. The polymer added in the mix mainly form hydrogen bonds with water molecules and reduce the chemical potential of the molecules which in turn reduces the vapor pressure. Physical moisture retention also occurs. This reduces the rate of evaporation from the surface. [7]It is very important to monitor the behavior of self-curing compound in concrete at fresh stage as well as at hardened stage. Patel manishkumar et.al., [1] have explained the methods of self-curing includes a brief study about the usage of super absorbent polymers in self-curing concrete.- It was studied that the use of Polyethylene Glycol (PEG400) in conventional concrete as an admixture helps better hydration and hence the strength of concrete. The effect of admixture (PEG400) on compressive strength, split tensile strength and modulus of rupture by varying the percentage of PEG by weight of cement from 0 to 2% were studied. The study shows that PEG400 could help with self-curing by giving strength on par with conventional curing. Manojkumar [2] carried out the study on the use of self-curing materials such as Super Absorbent Polymer (SAP) and the application of wax based membrane curing compound on the demoded M40 concrete specimens. The effect of variation in strength parameters i.e., Compressive Strength, Splitting Tensile Strength and Flexural Strength were studied for different dosage of self-curing agent. Self-curing distributes the extra curing water (uniformly) throughout the entire 3-D concrete microstructure so that it is more readily available to maintain saturation of the cement paste during hydration, avoiding self-desiccation (in the paste) and reducing autogenous shrinkage. In his study, Chella.[3] has examined on internal curing of high performance concrete using super absorbent polymers and light weight aggregates by carrying out the various tests regarding the strength and durability factors of self-curing high performance concrete (HPC) which is popular for its low water-to-cementations materials ratio (w/cm). Mix is achieved by adding SAP at 0.3% weight of cement and another mix is obtained by replacing 25% weight of LWA to fine aggregates. Strength and durability of these HPC are studied experimentally and the results show greater strength with LWA mix. Load carrying capacity of the beams in flexure and shear also greater in LWA mix and the durability study results reveal that mix with SAP is better compared to the other two mixes. Sathanandham.T [4] carried out the study of compressive strength tests for various admixture replacement ratios for the cement. This study involves the use of shrinkage reducing admixture polyethylene glycol (PEG 4000) in concrete which helps in self-curing and better hydration and hence strength. The effect of admixture (PEG 4000) on compressive strength, split tensile strength and modulus of rupture by varying the percentage of PEG by weight of cement were studied for M20. Vinayak V (2013) [5] carried out the experimental study by replacing the natural aggregates by pumice aggregates in different percentage, such as 0%, 10%, 20%, 30%, 40%, 50%. The specimens are casted by soaking the pumice stone in water and without water curing of specimen for 28 days. Another set of specimens were casted without soaking the pumice stone in water and curing the specimen in water for 28 days. After 28 days immerse the specimens in H2SO4 media of PH 3 for 90 days, later different strength characteristics such as compressive strength, tensile strength, flexural strength, impact strength and shear strength are studied. Viktor Mechtcherine (2013) [6] has presented the results of a round robin test performed by 13 international research groups (representing fifteen institutions) in the framework of the activities of the RILEM Technical Committee 225-SAP ‘‘Applications of Superabsorbent Polymers in Concrete Construction’’. Two commercially available SAP materials were used for internal curing of a high-performance, fine-grained concrete in combination with the addition of extra water. The result showed considerable decrease in autogenous shrinkage attributable to internal curing. Also, with regard to the shrinkage-mitigating effect of both particular SAP materials, the results were consistent. This demonstrates that internal curing using SAP is a robust approach, working independently of some variations in the concretes’ raw materials, production process, or measuring technique. Furthermore, the effects of internal curing on other properties of concrete in its fresh and hardened states were investigated. Aswath [7] studied that the monitoring of self-curing concrete has been done by assessing the various properties of self-curing concrete in fresh state and hardened state , includes workability, cohesiveness, bleeding, segregation, bulk density, strength, durability and degree of hydration of concrete. Ambily P.S. [8] briefly studied about the use of super absorbent polymer for self-curing concrete which is added at rate of 0–0.6 % weight of cement. The authors also studied about advantages of Internal Curing, autogenous shrinkage in self-curing concrete, self-desiccation in self curing concrete and the monitoring methods of self-curing concrete has been done. El Dieb.A.S [9] explained about the water retention capacity of concrete containing self-curing agents by determining the concrete weight loss and internal relative humidity measurements with time. The author also studied about non-evaporable water at different ages was measured to evaluate the hydration. Water transport through concrete is evaluated by measuring percentage of absorption, permeable voids, water sorptivity and water permeability. The effect of the concrete mix proportions on the performance of self-curing concrete were investigated, such as, cement content and w/c ratio. Pietro Lura [10] reviewed about the special techniques needed to study internal water curing and direct evidence of internal water curing with internal relative humidity and degree of saturation. The primary consequences of internal water curing that is degree of hydration, internal water movement and autogenous strain. The study also stated the secondary consequences of internal water curing includes mechanical properties, porosity, pore size distribution, interfacial transition zone, self-induced stress, cracking, durability and use of light weight aggregate in internal curing concrete. Ole Mejihede Jensen [11] discussed about self-curing using saturated lightweight aggregate particles and superabsorbent polymers in high-performance concrete. The research focuses on the various substances which can be used for self-curing concrete i.e. calcium-aluminate compound, Bentonite clay, superabsorbent polymers, Pumice, Perlite, liapor, Leca, Stalite and diamaceous earth. Tarun R Naik [12] reviewed the efficiency of internal curing of high-strength concrete to eliminate autogenous shrinkage. The strength of concrete was assessed by the durability test of self-curing concrete in 7 days and 28 days strength. It also revealed that prevention of autogenous shrinkage in high-strength concrete by internal curing using wet lightweight aggregates and the influence of microstructure on the physical properties of self-curing concrete was studied. Jensen [13] used superabsorbent polymers in concrete. His study focused on the strength and shrinkage of concrete. He concluded that the shrinkage of concrete due to loss of water to the surroundings is the cause of cracking both in the plastic and in the hardened stage. This type of cracking can effectively mitigated by slowing down the water loss. The superabsorbent polymers use in concrete has the potential to reduce concrete cracking.

2. OBJECTIVES OF THE STUDY

i) To study various properties of SCC (self-curing concrete) M25 grade by mixing different dosages of super absorbent polymer into concrete.

ii) To determine the weight loss and physical properties of self-curing concrete.

iii) To determine the compressive, split tensile and flexural strength of SCC.

iv) To determine the short term resistance to acid.

3. EXPERIMENTAL PROGRAMME

3.1 Materials required:

3.1.1 Cement

Ordinary Portland of 53 grade cement conforms to the specifications of IS: 12269-1987 was used. The properties of OPC used is shown in Table 1.

Table.1 Properties of Cement

Sl.No.	Property	Value
1	Normal Consistency	26 %
2	Initial setting time, minutes	36
3	Final setting time, minutes	269
4	Fineness	9 %
5	Specific gravity	3.15

3.1.2 Fine aggregates

Locally available natural river sand passing through 4.75mm sieve was used for all of the mixes of self-curing concrete. The fine aggregate was free from organic impurities. The properties of fine aggregate used are shown in Table 2.

Table 2. Physical properties of fine aggregate (IS: 2386-1963)

Sl.No.	Properties	Value
1	Silt content	0.7 %
2	Specific gravity	2.66
3	Bulking of sand	16 %
4	Moisture content	0.65 %
5	Fineness modulus	3.29

3.1.3 Coarse aggregates

Crushed granite aggregate passing through 20 mm and retaining on 4.75mm was used for all of the mixes of self-curing concrete. The properties of coare aggregates are shown in Table 3.

Table.No.3 Properties of coarse aggregate

Sl.No.	Properties	Value
1	Impact value	15.50 %
2	Crushing value	25 %
3	Specific gravity	2.69
4	Moisture content	0.16 %

3.1.4 Super Absorbent Polymer (SAP)

Superabsorbent polymers (SAP) (slush powder) are polymers that can absorb and retain extremely large amounts of a liquid relative to their own mass.Water absorbing polymers, which are classified as hydrogels when cross-linked absorb aqueous solutions through hydrogen bonding with water molecules They are Acrylamide/acrylic acid copolymers. The properties of SAP used in the investigation are shown in Table 4.

Table.4. Physical properties of super absorbent polymer (ESORB 2GH)

FORM – dry	Crystalline white powder / granules
FORM – wet	Transparent gel
Particle size, mm	0-2
Water absorption for 1 g, g	800
pH of absorbed water	Neutral
Density, g/cc	1.08
Bulk density, g/cc	0.85
Hydration / Dehydration	Reversible
Decomposition in sun light, months	6
Available water (Approx), %	95

One type of SAPs are suspension polymerized, spherical particles with an average particle size of approximately 200 mm; another type of SAP is solution polymerized and then crushed and sieved to particle sizes in the range of 125–250 mm. The size of the swollen SAP particles in the cement pastes and mortars is about three times larger due to pore fluid absorption. The swelling time depends especially on the particle size distribution of the SAP. It is seen that more than 50% swelling occurs within the first 5 min after water addition. The water content in SAP at reduced RH is indicated by the isotherm.

4. MIX DESIGN

The mix design is carried out according to IS 10262:2009 for the mix of grade M25.

Table.5 Mix proportion (kg/m^3)

Cement	Water	Fine aggregate	Coarse aggregate	w/c ratio
383	191	729	1107 kg	0.50

The SAP was added at 0.0, 0.12, 0.24 and 0.48% by the weight of cement and tested for fresh properties of concrete and hardened properties including durability tests of M25 concrete specimens.

After 28 days of self-curing the specimens were immersed in 5% hydrochloric acid solution. After removing the specimens from the solution, the surfaces were cleaned with a soft nylon wire brush under the running tap water to remove weak products and loose material from the surface. Then the specimens were allowed to surface dry and masses were measured and compressive strength test has been carried out.

5. RESULTS AND DISCUSSION

5.1 FRESH PROPERTIES OF SCC

The mix design was carried out for the M25 grade concrete as per IS 10262:2009. The total cement content and water / cement ratio is taken according to the range specified by IS 456. For all the mixes, fresh SCC properties were ascertained by conducting the slump cone test for the workability.

5.1.1 Slump test

The slump values for various percentages of SAP are given in Table 6. It was found that as the percentage of super absorbent polymer increases, the slump reduces.

Table 6. Slump Values at different mix proportions

Sl.No.	% of SAP	Slump (mm)
1	0	73
2	0.12	69
3	0.24	66
4	0.48	62

5.2 HARDENED PROPERTIES OF CONCRETE

5.2.1 Compressive strength of SCC:

The compressive strength of conventional (0 % SAP) and self-cured concrete was determined at the age of 7 and 28 days and shown in Fig.1. It can be noticed that the strength increases with the age. The strength was almost same for different dosages of SAP and also for the conventional concrete without SAP. It is possible to obtain the same strength without conventional curing.

5.2.2 Split tensile strength of SCC

The variation of the split tensile strength of conventional and self-cured concrete is shown in Fig.2. It can be observed that as percentage of SAP increases the split tensile strength increase and maximum at 0.48% of SAP. It is same for both the ages. The split tensile strength also remained constant for different percentages of SAP.

5.2.3 Flexural strength of SCC

The variation of the flexural strength for various mixes with different of SAP is shown in Fig.3. It can be observed that the maximum strength of concrete mix at 7 days and 28 days were found to be 3 and 8 N/mm^2 respectively. The trend of flexural strength is same as compressive strength.

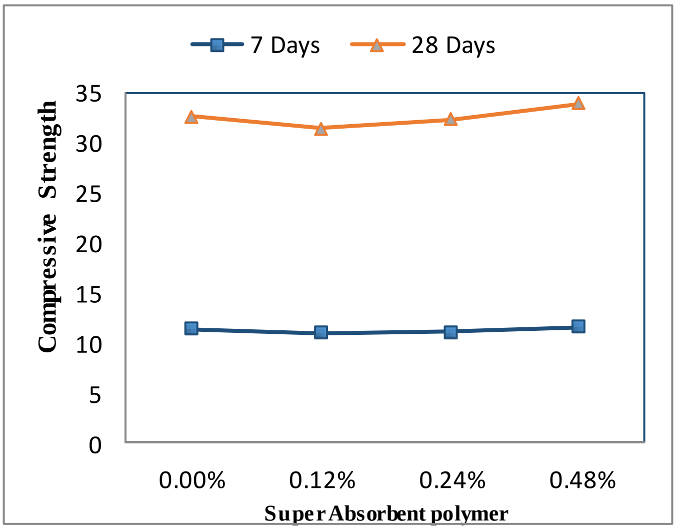

Fig.1 Average Compressive strength for 7 days and 28 days

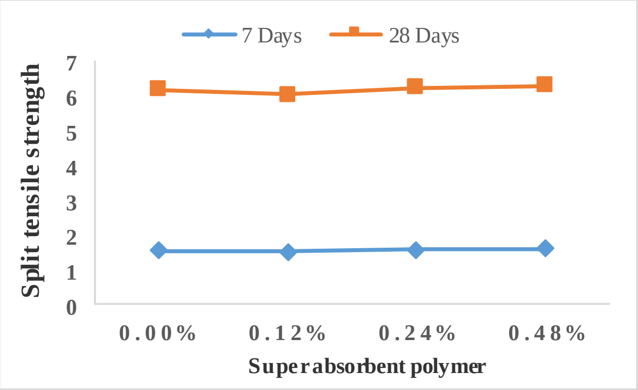

Fig.2 Average Split tensile Strength for 7 and 28 days

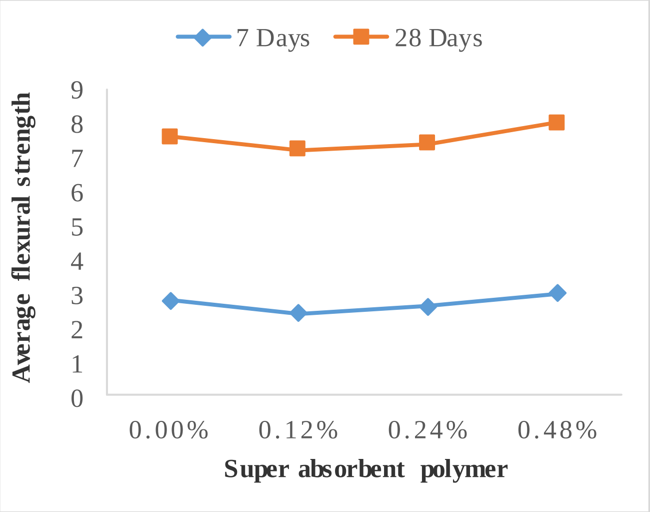

Fig.3 Average Flexural strength for 7 days and 28 days

5.3 *ACID RESISTANT TEST*

The results of acid resistance test are tabulated in Tables 7 and 8. It can be seen that the weight of concrete without SAP was much higher compared to the concrete with SAP. The compressive strength loss of concrete without SAP is much higher compared to the concrete with SAP. It can be noted that the concrete with SAP is more resistance to acid compared to the conventional concrete without SAP.

Table 7. Comparison of weight of cubes

Sl.No.	% SAP by the weight of cement	Weight of cube before immersing in HCL solution (Kg)	Weight of cube after immersing in HCL solution for 7 days (Kg)
1	0.00	8.12	7.24
3	0.12	8.15	7.29
4	0.24	8.19	7.38
5	0.48	8.23	7.51

Table 8. Comparison of Compressive strength of cubes

Sl.No.	% SAP	Strength before acid test (N/mm^2)	Strength after acid test (N/mm^2)
1	0.00	32.60	28.8
3	0.12	31.35	26.9
4	0.24	32.26	28.3
5	0.48	33.86	30.2

6. CONCLUSIONS

Based on the limited study following broad conclusions can be drawn.

- Water retention for the concrete mixes incorporating self-curing agent is higher compared to conventional concrete mixes, as found by the weight loss with time.
- Performance of the SCC is affected by the amount of super absorbent polymer added in the mix by % weight of cement.
- Use of super absorbent polymer (0.48% by the weight of cement) as self-curing agent Provides higher compressive, tensile as well as flexural strength than the strength of conventional mix.
- Acid resistance of SCC is much higher compared to conventional concrete.

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