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Study of Strength and Durability of High Volume Fly Ash Concrete with Different Self Curing Agents

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Abstract: ***High volume fly ash concrete system addresses all the major sustainability issues. It is recommended over the ordinary concrete as it considerably saves cement and also prevents environmental pollution. It is also act as high performance concrete. But if high performance concrete performs smartly without any human care from first day without compromising the good workability, strength and durability then it is said to be smart high performance concrete. This can be achieved by self curing agents which reduces the water evaporations form concrete .In this investigation polyethylene glycol and Spinacia oleracea is use as self curing agent in high volume fly ash concrete to study its effect on workability ,strength and durability when internally cured by them. The present paper is focusing on M30 concrete mix with 50 percent fly ash replacement to form high volume fly ash concrete. The optimum dosage of poly ethylene glycol and Spinacia oleracea was taken as 0.5% and 0.8% by the weight of the binder. The slump test show it fulfill the medium range workability. Compressive strength of conventionally cured high volume fly ash concrete was less then self cured once and performance for durability of self cured concrete was good for the given conditions.***

Keywords: Polyethylene glycol, Spinacia oleracea, Self curing agent, high volume fly ash concrete etc

1. Introduction

The process of early-age cracking is unguarded and depends on thermal effects, autogenous strains, and stresses, drying stress relaxation. This early age cracking occurs due to autogenous shrinkage and it depends upon the internal relative humidity of cement system. This shrinkage is major problem in high performance concrete .The effect of the water-cement ratio (w/c) on autogenous shrinkage is related to the chemical potential of the cement systems, which is due to the influence of the contraction of calcium silicate hydrate gel. While this cracking may or may not compromise the compressive strength of these concretes, it likely does compromise their long-term durability. Normally used method of curing like ponding, spraying, damp sand, polythene sheeting are not effective in the case of autogenous shrinkage.

These external curing can eliminate the autogenous shrinkage only to the small cross section or part because of the penetration of water from the external surface is limited. In high volume fly ash concrete the internal microstructure which form due the reaction between fly ash and cement is very dense plus the HVFA concrete is also more sensitive to the quality of the curing provided to it during construction [1], as mix water that is not consumed in early-age chemical reactions or absorbed by early-age hydration products may evaporate if the concrete is exposed to a drying environment. When we use high volume fly ash concrete in order to get early strength and more compressive strength we make the mix at low water cement ratio that is below 0.4 so while the hydration and pozzolanic reactions occur, the capillary pores within the microstructure disconnect (depercolate) so that the imbibitions rate of external water will be significantly inhibited, resulting in self-desiccation this will become significant at depths just a few centimeters below the external water surface. The self-desiccation is accompanied by the generation of internal stresses that may contribute to early-age cracking of the concrete. Moreover curing process in dry area where potable water is very less is a challenge for the engineer and supplying an external water source for vertical surfaces is much more difficult than doing so for horizontal ones. Thus, the access of external water turns out to be unviable to assure continuous saturation of the total bulk volume [2]. In view of these limitations, different methods have been developed in recent years, based on the use of internal water reservoirs; one strategy is the addition of a self-cure chemical to concrete during mixing it.

Internal curing or self curing is defined by the American concrete institute as "supplying water throughout a freshly placed cementitious mixture using reservoirs ,via pre-wetted lightweight aggregate ,that readily release water as needed for hydration process of cement and to replace moisture lost through evaporation mainly in dry areas or self desiccation" . Presently in most of the construction projects internal water is typically supplied by using relatively small amounts of saturated, lightweight, fine aggregates or superabsorbent polymer particles in the concrete. Implementing the technique of self curing resulted in increased hydration process of concrete mix and strength development with respect to time, reduced autogenous shrinkage and cracking, reduced permeability and increased durability. From the internal studies of concrete which was treated with self curing agents shows that the impact of internal curing begins immediately with the initial hydration of the cement which was observed at ages as early as 2 days. This method is especially beneficial in the low water-cement ratio (w/c) concretes because of low water cement ratio chemical shrinkage occurs along with low permeability during hydration of concrete. The water that is chemically bound and absorbed by the cement hydration products has a specific volume less than that of bulk water, a hydrating cement paste will imbibe water 9 about 0.07g water/ g cement) from an

available source. But when we use higher w/c concretes, the curing water can be supplied by any external curing method, in low w/c concretes; the permeability of the concrete quickly becomes too low to allow the effects of water from the external surface to the concrete interior. Therefore in my research we have used self curing agents like polyethylene glycol and Spinacia oleracea to cure the high volume fly ash concrete in particular amount, so that effect of self curing on concrete can be checked .The effect of polyethylene glycol on Portland concrete have been studied but how it effect the high volume fly ash concrete is studied in this project along with biomaterial Spinacia oleracea which have similar way of reaction with water like polyethylene glycol .

2. Research Significance

As we know curing of concrete is an important process for maintaining satisfactory moisture content in concrete during its early stages in order to develop the desired properties like strength, durability, etc. From past researches we can say that 5 % loss in moisture leads to nearly 75 % loss in strength.Secondly, now a day the level of the water table is going down day by day. So, if water is to be purchased for construction works, the cost of construction goes much higher. Also, in world of skyscraper the concreting works done at a very heights and in sloped roofs, (slope of the roof is too steep) curing is very difficult. Part of structure where the thickness of concreting is larger, the percolation of water in the concrete, especially in case of high strength concrete is difficult. So, internal curing is used as a substitute to overcome such problems. Mostly used self-curing agents like lightweight aggregate, superabsorbent polymer, and wood powder have shown positive results in the reduction of self-desiccation and autogenous shrinkage but also have the negative impact on strength and durability. So in this project, I have used polyethylene glycol and biomaterial Spinacia oleracea as curing agent without compromising the strength and durability and compared it to strength and durability of externally cured high volume fly ash concrete.

3. Material

3.1 Cement

Ambuja Portland pozzolanic cement was used which had 34% fly ash by weight. The cement conform the standard of IS 1489-1991.

Table 1: Properties of cement

S.no	Description	Properties	Requirement IS 1489-1991
1	Fineness (retained on 90 micron sieve)	7.6	10 Le chatelier
2	Normal consistency (%)	28%	-
4	Specific gravity	3.1	3.15 max

3.2 Fly ash

Class F fly ash was used in this study which was purchased from Dadri National Thermal Power Plant. It was light grey in colour. Properties of fly ash is shown table 2.

Table 2: Properties of fly ash

S.No.	Parameters	Fly ash
1.	Specific gravity	1.90-2.55
2.	Plastic index	Non plastic
3.	Compaction factor MMD (gm/cc) OMC(%)	 0.90-1.60 38.00-18.00
4.	Angle of internal friction	30^{0}-40^{0}
5.	Cohesion(KN/$m^{2)}$	Negligible
6.	Compression index	0.05-0.4
7.	Permeability(cm/sec)	10^{-3}-10^{-5}
8.	Particle size distribution Clay size fraction (%) Silt size fraction (%) Sand size fraction (%) Gravel size fraction (%)	 1-10 8-85 7-90 0-10
9.	Coefficient if uniformity	3.1-10.7

3.3 Fine and Coarse Aggregate

The coarse aggregates are naturally occurring material from divided rock material and crushed granite stone. In this project we have used angular coarse aggregates of maximum size 20mm is tested as per IS: 383-1970. The mine waste was used as fine aggregate after conforming to Zone II of IS: 383-1970.

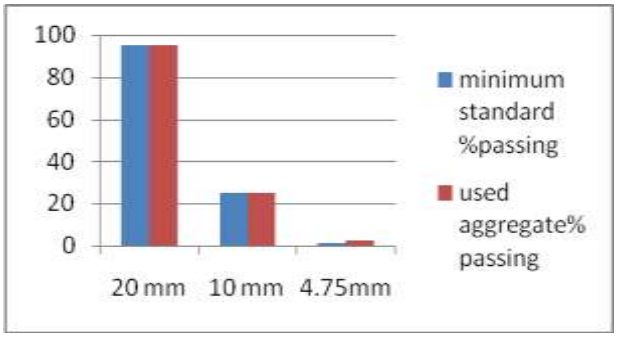

Chart 1: Sieve analysis of coarse aggregate

Table 3: Properties of fine and coarse aggregate

S no	*description*	*Fine aggregate*	*Coarse aggregate*
1	Specific gravity	2.57	2.73
2	Fineness modulus	2.93	6.97

3.4 Polyethylene Glycol

Polyethylene glycol is a polymer of ethylene oxide and water. The general formula of PEG is H(OCH 2CH 2)nOH, where n is the average number of repeating oxyethylene groups typically from 4 to about 180. It has many applications from industrial manufacturing to medicine. It is synthesized by suspension polymerization. One common feature of PEG appears to be the water-soluble nature. Polyethylene glycol is a non-toxic and odorless liquid .It has neutral Ph value. From last few years it is used as self curing agents because it reduces the evaporation rate of water to large extant and help in maintaining the water content required for hydration process.

Table 4: Property of polyethylene glycol

S. no.	Description	Properties
1	Molecular weight	400
2	Appearance	Clear Fluid
3	Moisture	0.2%
4	pH	6
5	Specific gravity	1.12

Figure 1: Polyethylene glycol 400

3.5 Spinacia oleracea

Spinacia oleracea is scientific name of spinach (Palak) greens in all over India and it is a type of green vegetable popularly consumed as the food product. The curing agent was prepared by grinding it in grinding machine and the filtrating it. 6.59 was its pH value. This liquid extract was added at the time of preparing concrete that is while adding water to the dry ingredients. Placing and compacting the fresh concrete was done similarly as we do with the conventional concrete, but no external curing is provided to self cured concrete mixture. From the previous studies of Spinacia oleracea by using Fourier Transform Infra-Red it shows that the chemical structure contains (-O-) and (-OH) functional groups that is hydroxyl and ether functional group because of which the Spinacia oleracea used as internal curing agent.

Figure 2: Spinacia oleracea extracts

3.6 Mixing Proportion

The M30 concrete mix is considered in which 50% fly ash is added by replacing cement by weight. The ratio of each material that is cement, fly ash, sand and coarse aggregate will be calculated according to IS 10262:2009. As Portland pozzolanic cement is used which already contain 34% fly ash, we have added 16% more fly ash to make it 50%.Mix design used was 1:1.45:2.7 with water cement ratio 0.36.the dosage of self-curing agents was optimized and found to be Spinacia oleracea at 0.8% by weight of cement and fly ash and Polyethylene glycol at 0.6% by weight of cement and fly ash for experimental studies.

4. Experimental Programme

Slump test was conducted on the freshly prepared mix to know its workability as per IS 1199 – 1959 and then the sample slump value which will be conventionally cured is compared with samples in which Polyethylene glycol and Spinacia oleracea is added as a self-curing agent. The compressive strength of all 3sample was tested at 7, 28 and 56 days by casting cube of 150*150*150 mm size according to IS 516 – 1959.

Figure 3: Mixing of concrete material for slump test

The durability properties were checked under acidic environment and alkaline environment. The acid resistance tests were carried out on cube specimens immersed in water diluted with 1% by weight of sulphuric acid for 28 days continuously. Then, the weight and the compressive strength of the specimens were determined, and the average percentage of loss of weight and the percentage loss of compressive strengths were calculated. The alkaline resistance tests were carried out on cube specimens which were weighed and immersed in water diluted with 3% sodium hydroxide by weight of water for 28 days continuously. Then, the compressive strength of the specimens was measured, and the average percentages of loss of compressive strengths were calculated.

5. Results and Analysis

5.1 Workability

Firstly slump test was performed for checking workability and it was observed that slump value of self-cured concrete with Spinacia oleracea and polyethylene Glycol was almost similar it was only 5% to 6% less than conventionally cured concrete slump value. Even though it is satisfied the minimum value of 50 mm slump for medium workability.

The chart below shows the variation in slump value due to adding of self-curing agents.

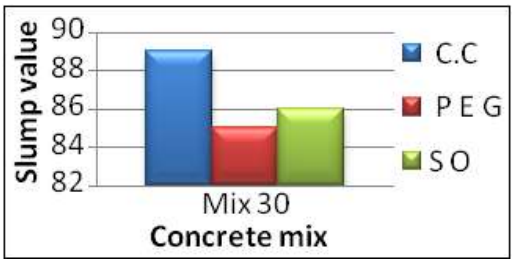

Chart 1: Slump value of samples

5.3 Compressive Strength

The compressive strength of all samples was tested after 7 days, 28 days and 58 days. The chart shows the variation in strength with is slow as we have used high volume fly ash concrete by adding 50 % fly ash which lowers the initial strength gain in concrete but after few days due to fly ash pozzolanic reaction take place, there is a greater increase in strength after 56 days. Spinacia oleracea shows the maximum strength as compare to Polyethylene glycol and polyethylene glycol show greater strength than the conventionally cured sample.

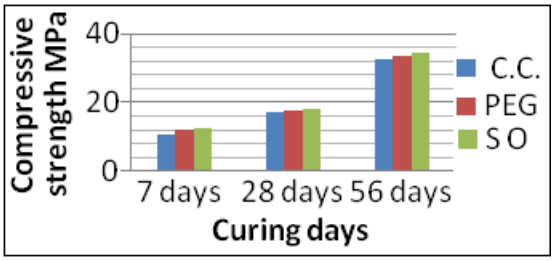

Chart 2: variation in strength with time and curing process

This was because of the presence of ether and hydroxyl functional groups in the concrete enhance the formation of a continuous system of gel which provides better strength development at early ages. Continuous hydration of the mixture at later ages, promoted by the available water due to curing agent, also contributes to the strength increase. Microcracks due to aggregate restraint were minimized since cement paste expanded at an early age rather than shrinks and hence improves the strength of concrete

5.3 Durability

Durability of samples were investigated ,it was observed that the percentage chance for the attack of concrete by acid is less as the pore structure of concrete becomes water tight and does not allow further entry of acid water into the concrete when self cured with self curing agents because of which the acid attack was less on concrete which was self-cured by Spinacia oleracea as less weight loss and about 14% less compressive strength loss as compared to conventionally cured concrete similarly Polyethylene glycol has 6% less compressive strength loss Chart 4 shows the affect of alkaline on strength of concrete .Spinacia oleracea shows the least loss of strength than the polyethylene glycol when both compared with conventionally cured high volume fly ash concrete.

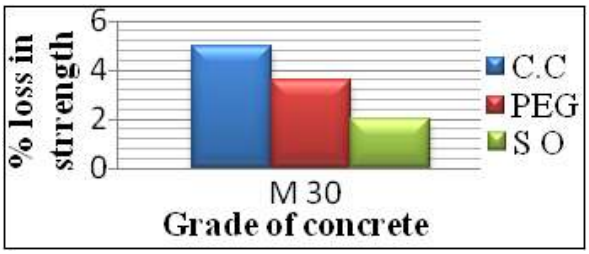

Chart 3: Strength loss of concrete due to acid attack.

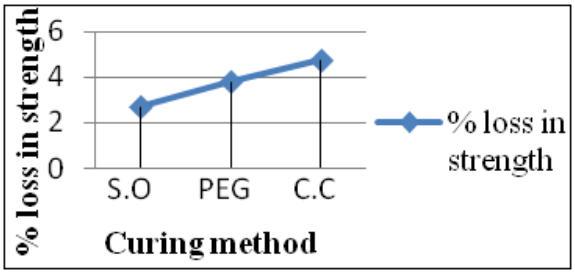

Chart 4: Alkaline resistance of differently cured concrete

6. Conclusions

- From the above results, we can see the workability, strength, and durability studies done by using Polyethylene glycol and one biomaterial Spinacia oleracea as the self-curing agent show positive results because of the presence of OH ions in self-curing concrete.
- Moreover, Spinacia oleracea is vegetative eco-friendly and very cheap self-curing agent compare to polyethylene glycol which results in an overall decrease in cost of the project by reducing potable water use during curing.
- Self-curing concrete is an alternative to conventional concrete in desert regions where scarcity of water is a major problem.

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Author Profile

Sarita Sharma graduated in 2014 and now pursuing her master degree in civil engineering from Dr. Abdul Kalam Technical University Lucknow. She has worked as the project assistant in CSIR-Central Road Research Institute, New Delhi, India from 2014 to 2015."

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