Service Life Prediction of High-Performance Concrete with Respect to Chloride Ion Penetration by Incorporated with Fly Ash and Silica Fume

B. Daya Rani, B. Kameswara Rao

Abstract: Fly ash is a very small particle which makes the concrete high dense and reduces the permeability of the concrete. The concrete mixture generates a very low heat of hydration which prevents thermal cracking. Its plays a vital role when concrete is exposed to marine environment. Silica fume benefits are evident in the fresh concrete state before it begins to harden. Because of high surface area silica fume particles affecting a mobility of water with in concrete, segregation and bleeding of concrete are virtually eliminated. Service life is the period of time during which a building, a structure or material meets or exceeds the requirements established for it. Chloride diffusivity is a very important property of concrete that affects the durability and service life of reinforced concrete structure. Deterioration of reinforced concrete structures due to chloride ingress followed by reinforcement corrosion is a growing problem all over the world. This paper is focused on increasing of service life of a reinforced concrete structure by incorporation of fly ash and silica fume in concrete. The studies have been conducted on twelve mixes of different workability with three water binder ratios of 0.3,0.4,0.5 and three replacements of OPC by fly ash and silica fume of 0,70,60,50,40 and 30%. Chloride penetration studies have been carried out for exposure ages of 28 and 90 days. The specimens were exposed to 3.5% of sodium chloride solution with respect to water, Where as chemical analysis is carried out to the exposed specimens.

Index Terms: fly ash, silica fume, corrosion, service life prediction, water binder ratio, chloride ion penetration.

I. INTRODUCTION

Reinforced concrete structures are presented to brutal conditions yet are regularly presented to last with next zero fixes or support for significant lots of time. To do this a tough structure should be created. For fortified solid structures, one of the real types of natural assault is chloride entrance, which prompts consumption of strengthening steel and a resulting decrease in the quality, functionally, and style of the structures. This may prompt early fix or untimely substitution of the structure.

A typical technique for averting such decay is to keep chlorides from entering the structure to the dimension of the strengthening steel bar by utilizing moderately invulnerable cement. The capacity of chloride particles to infiltrate the solid should then be referred to for configuration just as quality control purposes. The penetration of chloride ions in to the concrete is controlled or decreased by replacing the supplementary cementitious material like fly ash and silica fume.

II. II. METHODOLOGY

A. CHLORIDE ION PENETRATION

Chloride that appears at the surface of concrete migrate inside and concentrates within the concrete. This chloride penetration in concrete is a very complicated process, involving many material properties such as diffusivity, binding capacity etc, as well as different physical modes of penetration of salt solution, capillary absorption of salt solution. Temperature also place a vital role in chloride penetration. In moisture saturated concrete diffusion is the dominate phenomena where as in dry capillary absorption is more influential. Thus, under conditions of cyclic exposure to chlorides, the process is likely to be combination of both. It promoting diffusion whereas, surface layer often becomes partially dry, subsequently allowing capillary absorption. But, since the capillary absorption mechanism is active only in thin outer layer of concrete, it is the diffusivity of concrete.

B. CHLORIDE DIFFUSION

Diffusion can be defined as the process matter is transported by one part of a system to another as a result of random molecular motion. In this phenomenon though there is no preferred direction of motionof any particular molecule, yet on an average the transfer takes place from a region of higher concentration to that of lower concentration.

C. FLY ASH

Fly ash has been utilized in solid creation for a long time as a straight forward method to enhance the functionality, solidness and manageability of concrete. fly ash remains has additionally been proposed as a technique for moderating the impacts of early-age warm volume change in cements. This is practiced by supplanting a part of concrete with fly ash. While a segment of the fly ash can respond using pressurized water like Portland bond, a part of the fly ash experiences a pozzolanic response, in which the silica present in fly ash responds with the calcium hydroxide framed in concrete hydration, making fly cinder respond at later ages.

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Verifiably, fly ash has been utilized in cement at levels going from 15%to 25% by mass of the cementitious material part. The genuine sum utilized shifts broadly relying upon the application, the properties of the fly ash remains, particular breaking points, and the geographic area and atmosphere. More elevated amounts (30% to 50%) have been utilized in huge structures (for instance, establishments and dams) to control temperature rise. In ongoing decades, inquire about has shown that high dose levels (40% to 60%) can be utilized in basic applications, delivering concrete with great mechanical properties and durability.

D. SILICA FUME

Silica fume, a byproduct of the ferrosilicon business, is a profoundly pozzolanic material that is utilized to upgrade mechanical and solidness properties of cement. It might be added straightforwardly to concrete as an individual fixing or in a mix of Portland bond and silica fume. The utilization of silica fume in cement ought not be aimless but rather ought to be constrained to particular applications that can take full favorable position of its novel properties.

E. HIGH PERFORMANCE CONCRETE

High performance concrete is a concrete mixture, which passes high durability and high strength when compared to conventional concrete. This concrete contains one or more cementitious materials like fly ash, ground granulated blast furnace slag.

III. MECHANISM OF CORROSION

The transformation of iron to rust is accompanied by an increase in volume, which, depending on the state of oxidation may be as large as six times to that of the original metal.

$$\text{Anode: } Fe\pi \rightarrow Fe^{++} + 2e^{+}$$

$$\text{Cathode: } \frac{1}{2}O_2 + 2e^{+} \rightarrow 2[OH]$$

$$\text{Finally: } Fe^{++} \rightarrow Fe\,[OH]_2$$

$$Fe[OH]_2 + O_2 \rightarrow [Oxides\ of\ Hydroxide\ of\ iron$$

IV. EXPERIMENTAL PROCEDURE

Concrete cube specimens having a size of 150*150*150 were prepared. And the specimens were casted using fly ash and silica fume to replace the cement at different percentagesi.e.(0,30%,40%,50%,60%,70%)with respect to different water cement ratios i.e.(0.3,0.4,0.5).Silica fume can be utilized as 5% in the concrete mixture. Silica fume is a property enhancing material. It is not a replacement material for Portland cement. To the above mix proportions the compressive strength values for 28, 90 days lists all in table noI,II.

After casting for 24 hours all the concrete specimens were demoulded and cured in water for 28 days. Then after the cubes were exposed to 3.5%Nacl solution with respect to the water for 28,90 days.

COMPRESSIVE STRENGTH TEST

Compressive strength of concrete cube test gives a thought regarding every one of the attributes of cement. By this single test one judge that in the case of concreting has been done properly or not. Compressive quality of cement relies upon numerous variables, for example, water-bond proportion, concrete quality, nature of solid material, quality control amid generation of cement and so on.The compressive strength is calculated from the failure load divided by the cross-sectional area resisting the load and reported in units of pound-force per square inch (psi) or mega Pascal's (MPa) in SI units.

Fig1: compression testing machine

Fig 2: Analog display.

V. CHEMICAL ANALYSIS

After exposure to Nacl solution, the concrete specimens were dried. The dried specimens were drilled and collect the concrete powder to the respective depths (5,10,15,20 and 25 mm) from each side of the cube. Distilled water is added to the collected concrete powder. Stir the mix thoroughly using magnetic stirrer. This process ensures the digestion of chloride from concrete powder sample. The sample was rest for one hour to obtain the solution stay. After one hour filtered the water and titrate against 0.01N Agno3, which gives the total chloride content of the concrete.

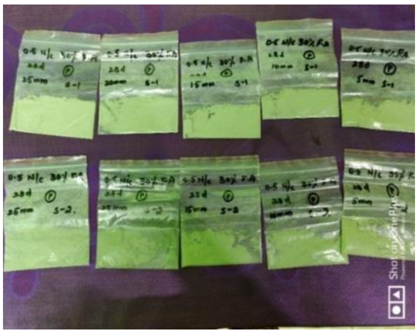

Fig3: concrete powder

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Percentage of chloride in concrete powder=[(K*N*W)]%

Where,

K= A constant, depending upon total volume of solution made and the volume of solution take for titration

N=Normality of $AgNO_3$ solution, Here equal to 0.01

V=Volume of $AgNO_3$dispendedto reach the end point

W=Weight of the concrete powder.

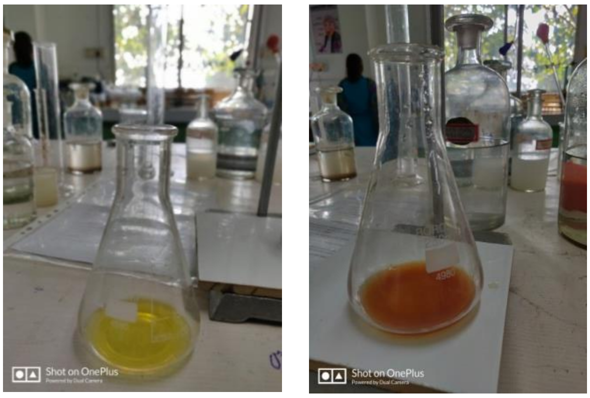

Fig.4: Titration process

VI. TEST RESULTS

a) Compressive Strength Results

Table I gives Compressive strength of concrete at 28 days for plain concrete is converted to average stress for different water to cement ratios 0.3, 0.4 and 0.5 respectively.

Table I:Plain concrete values

w/c ratio	Avg stress (N/mm^2)
0.3	63.407
0.4	47.990
0.5	25.923

Table II: variation in fly ash percentages with cement in different water to cement ratio compressive strength were converted to average stress and mentioned for 28 days.

Table II: Fly ash concrete compressive strength for 28 days

w/c ratio	% of fly ash	Avg stress (N/mm^2)
	70	43.403
0.3	60	45.620
	50	53.037
	60	35.258
0.4	50	45.230
	40	49.026
	50	35.567
0.5	40	36.737
	30	31.850

Table III gives Compressive strength of concrete at 90 days for plain concrete is converted to average stress for different water to cement ratios 0.3, 0.4 and 0.5 respectively.

Table III :Plain concrete values

w/c ratio	Avg stress (N/mm^2)
0.3	57.925
0.4	60.444
0.5	33.036

Table IV: variation in fly ash percentages with cement in different water to cement ratio compressive strength were converted to average stress and mentioned for 90 days.

Table IV: Fly ash concrete compressive strength for 90 days

w/c ratio	% of fly ash	Avg stress (N/mm^2)
	70	50.962
0.3	60	56.592
	50	67.555
	60	50.073
0.4	50	60.740
	40	54.663
	50	47.407
0.5	40	49.481
	30	47.258

b) Chemical Analysis Results

The following results are obtained for the plain concrete which is exposed to NaCl solution for different time spans.Fig. 5 shows that the chloride percentage by weight of concrete to the average depth of drilling for variation in water to cement ratio 0.3, 0.4 and 0.5 percentages for 28 days.

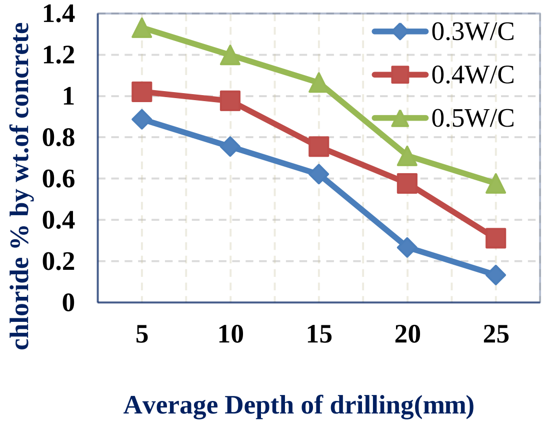

Fig. 5: chloride ion penetration for 28 days plain concrete cubes

Fig. 6 shows the graph for chloride percentage by weight of concrete to the average depth of drilling for variation in water to cement ratio 0.3, 0.4 and 0.5 percentages for 56 days.

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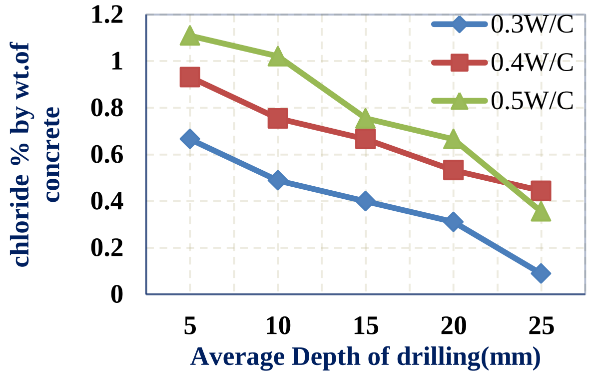

Fig. 6: chloride ion penetration for 56 days plain concrete cubes

Fig.7 shows the chloride percentage by weight of concrete to the average depth of drilling for variation in water to cement ratio 0.3, 0.4 and 0.5 percentages for 28 days.

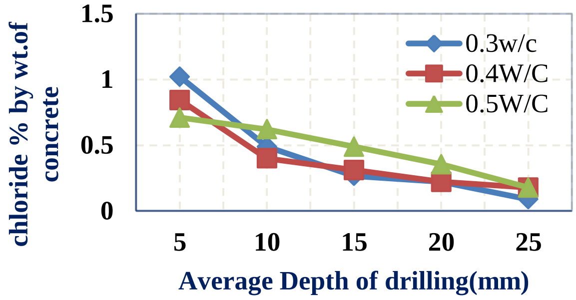

Fig. 7: chloride ion penetration for 90 days plain concrete cubes

The results for the titration of fly ash and silica fume mixed concrete for different water to cement ratios, different penetration depths for variation in time span gives the following results. The collected powder samples from the variation of fly ash and silica fume percentages with cement in concrete cubes for different time spans gives the following results. Fig. 8,9 and 10 shows that the variation in fly ash replaced with cement concrete in percentage as chloride percentage by weight of concrete to the penetration depth of drilling for 28 days curing in NaCl solution.

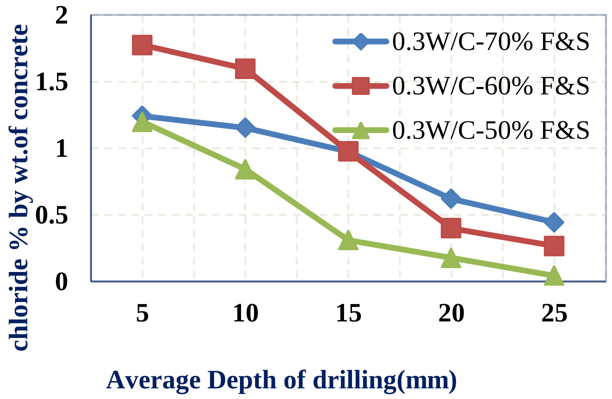

Fig. 8: 0.3 w/c ratio with different fly ash percentages for 28 days curing concrete cubes

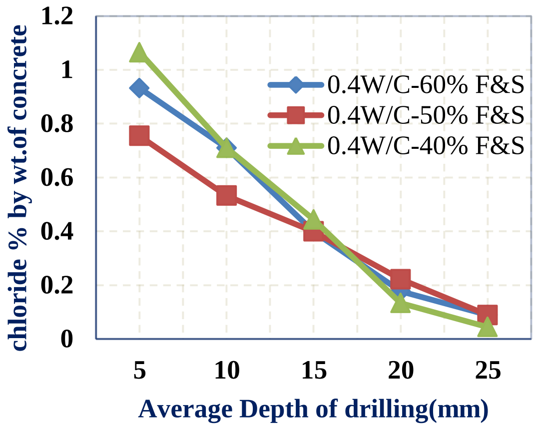

Fig. 9: 0.4 w/c ratio with different fly ash percentages for 28 days curing concrete cubes

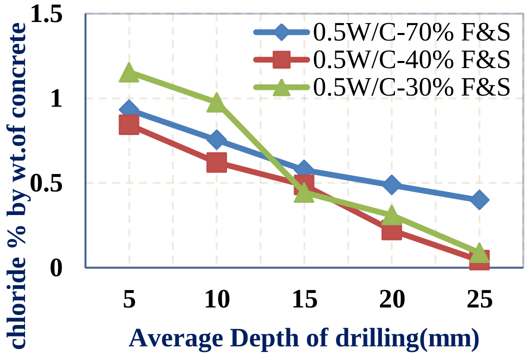

Fig. 10: 0.5 w/c ratio with different fly ash percentages for 28 days curing concrete cubes

Fig. 11,12 and 13 shows that the penetration depth of fly ash and silica fume replaced with cement concrete in percentage as chloride percentage by weight of concrete to the penetration depth of drilling for 56 days curing in NaCl solution.

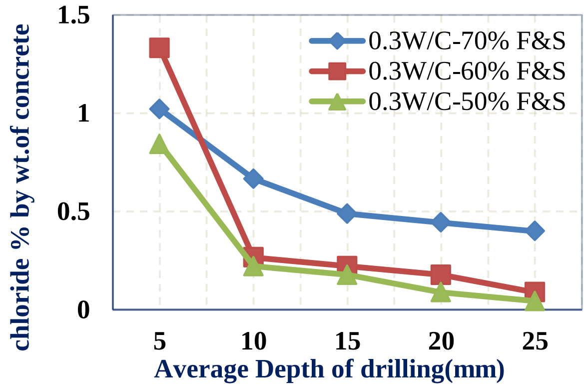

Fig. 11: 0.3 w/c ratio with different fly ash percentages for 56 days curing concrete cubes

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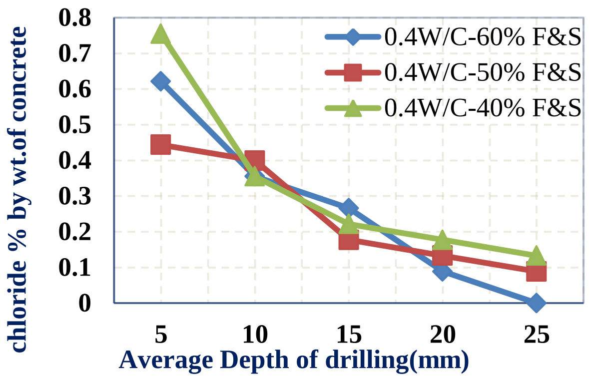

Fig. 12: 0.5 w/c ratio with different fly aspercentages for 56 days curing concrete cubes

Fig.14, 15 and 16 shows that the penetration depth of fly ash and silica fume replaced with cement concrete in percentage as chloride percentage by weight of concrete to the penetration depth of drilling for 90 days curing in NaCl solution.

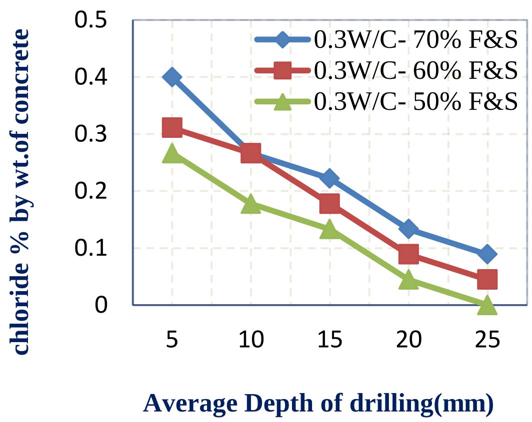

Fig. 14: 0.3 w/c ratio with different fly ash percentages for 90 days curing concrete cubes

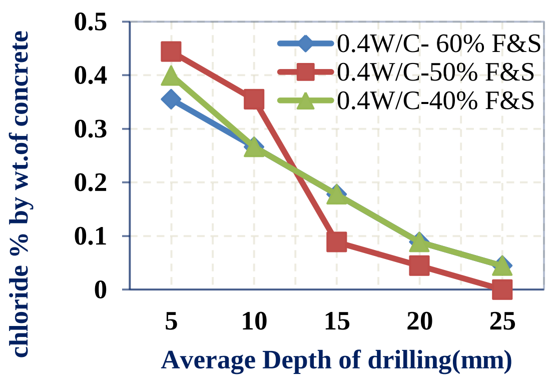

Fig. 15: 0.4 w/c ratio with different fly ash percentages for 90 days curing concrete cubes

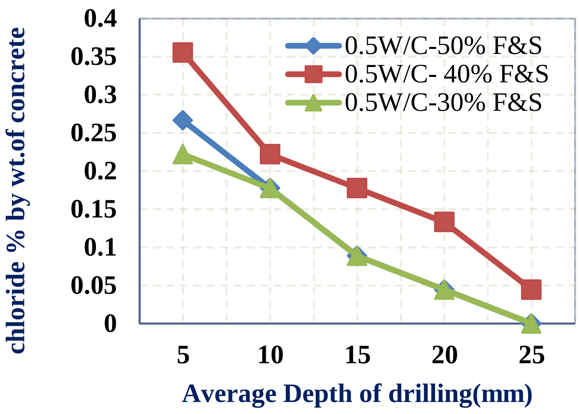

Fig. 16: 0.5 w/c ratio with different fly ash percentages for 90 days curing concrete cubes

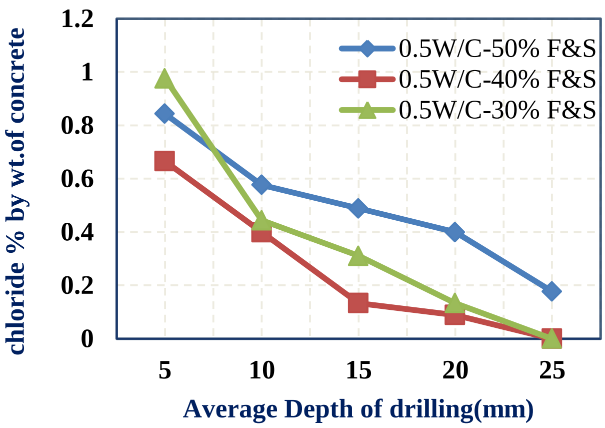

Fig. 13: 0.5 w/c ratio with different fly ash percentages for 56 days curing concrete cubes

VII. CONCLUSION

The study focused on effects of utilization of fly ash and silica fume on the properties of concrete, in terms of its strength development and resistance to chloride penetration. Due to this the service of reinforced concrete structure is increases.The following conclusions are adopted from the results obtained for plain concrete and the water cement ratio with different variations in fly ash percentage.

1. Plain concrete gives the high strength for 28 days.
2. Fly ash mixed concrete for 0.3 w/c ratio gives the low chloride ion concentration for 90 days
3. Fly ash mixed concrete for 0.4 w/c ratio gives the low chloride ion concentration for 90days
4. Fly ash mixed concrete for 0.5 w/c ratio gives the low chloride ion concentration for 90 days

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