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

E.V. Prudhvi sai, B. Kameswara Rao

Abstract: ***service life of reinforced concrete structure as time period during which structure will full fill the required performance under defined repair and maintenance. Performance and service life of reinforced concrete structure are governed by several parameters such as strength, quality of concrete, concrete cover and most significantly exposure conditions. Fly ash is used as a supplementary cementitious material in the production of Portland cement concrete. By using fly ash is beneficial in reinforced concrete for low heat of hydration and better resistance against entry of chlorides. Reinforced concrete structures exposed to severe marine environments usually is attributed to the aggressive nature of chloride ions. This work is focused on predicting the remaining service life of reinforced concrete structure against chloride ion penetration due to incorporation of fly ash in concrete. The studies have been conducted on twelve mixes with three water binder ratios of 0.3,0.4,0.5 with respective fly ash percentages are 0,70,60,50,40,30%. The exposure ages of chloride penetration specimens are 28 and 90 days. For this study 84 number of cubes (150*150*150) were casted. The specimens were exposed to 3.5% sodium chloride solution. Chemical analysis is carried out to the exposed sodium chloride specimens.***

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

I. INTRODUCTION

Concrete can be exposed to chloride attack in marine environment, Where sea water contains large amount of dissolved salts, predominantly sodium chloride. Other sources of chloride include use of sea-sand and water in concrete construction, deicing salts used in cold regions to melt away snow on highways etc., and sometimes ground water containing chloride salts. A critical chloride concentration one, which break down the protective environment around reinforcing steel. The determination of chloride diffusivity by immersion or ponding in salt solution, though time-consuming, is most near the actual exposure conditions and to some reflects the gradual changes with time that may take place in the diffusivity under natural exposure. To decrease the critical chloride concentration, fly ash is used with different percentages with respect to different water cement ratios.The present study is focused on increasing service life of the RC structure against corrosion by decreasing the chlorine content in concrete. The partial replacement of Ordinary Portland Cement with fly ash decreases the chlorine content in concrete. The chlorine content in concrete at a depths of 5mm,10mm,15mm,20mm,25mm need to be calculated. Compressive strength of concrete also calculated for w/c ratios (0.3,0.4,0.5) with respect to different percentage of fly ash (70,60,50,40,30%) for 28,90 days.

II. +METHODOLOGY

A. Chloride Ion Penetration

Capillary absorption, hydrostatic weight, and scattering are the techniques by which chloride particles can enter concrete. The most regular system is spread, the improvement of chloride particles under a center slant. For this to occur the strong must have a predictable liquid stage and there must be a chloride molecule center tendency. A second instrument for chloride entrance is saturation, driven by weight angles. In the event that there is a connected water powered head on one face of the solid and chlorides are available, they may pervade into the solid. The ability of concrete to resist the penetration of chloride ions is a critical parameter in determining the service life of steel reinforced concrete structures exposed to deicing salts or marine environment (contains above 3.5% salt, predominantly chlorides). Therefore, it is impermeability of concrete, which is the most desirable property of concrete for protection of reinforcement against corrosion. The low permeability is usually obtained by the use of low water/binder ratio, proper grading of aggregates and, now a days, by using mineral admixtures in concrete such as fly ash.

B. Chloride Diffusion

It is the process matter is transported by one part of a system to another as a result of random molecular motion. Recognizing the analogy of diffusion mechanism with that of heat conduction, first Fick put diffusion on a quantitative basis by adopting the mathematical equation of heat conduction derived by Fourier. Thus, Fick's first law states that in an isotropic medium the rate of transfer of diffusing substance through unit area of a section is proportional to the concentration gradient measured normal to the section.It is important to understand that whereas the Fickian diffusion model holds essentially for a non-reactive medium, the assumptions are only partly valid in the case of chloride diffusion in concrete.

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C. Fly ash

Fly ash a powder resembling cement, has been used in concrete since 1930'sFly ash is a result of consuming pounded coal in an electrical creating station. In particular, it is the unburned buildup that is diverted from the consuming zone in the evaporator by the vent gases and after that gathered by either mechanical or electrostatic separators. The execution of fly ash in cement is firmly affected by its physical, mineralogical and chemical properties.The spherical shaped particles of fly ash act as miniature ball bearings within the concrete mix, thus providing a lubricant effect. This same effect also improves concrete pump ability by reducing frictional losses during the pumping process and flat work finish ability. The properties of the fly ash can be altogether different among sources and accumulation strategies. The consuming conditions inside a power plant can likewise influence the properties of the fly ash.

Class F: Fly ash remains regularly delivered from consuming bituminous coalthat meets the applicable requirements. This class of fly ash remains has pozzolanic properties.

Class C: Fly ash remains regularly delivered from lignite or sub-bituminous coal that meets the requirements. This class of fly slag, in expansion to having pozzolanic properties, likewise has some cementitious properties.

D. Advantages Of Fly Ash

Now a day's industries waste are heavily used in construction.fly ash is the one of the waste by product of electric power plants.The use of fly ash gives concrete good work ability, durability and finish.

- Low heat of hydration in mass construction
- Reduced bleeding, segregation and leaching
- Higher strength at later ages.
- Better resistance against sulphates

E. High Performance Concrete

High performance concrete as a specially engineered concrete, one or more specific characteristics of which have been enhanced through the selection of component materials and mix proportions. This does not cover single product but a family of high tech concrete products whose properties have been tailored to meet specific engineering needs , such as high workability, very-high early strength, high toughness and high durability to exposure conditions.

F. Mechanismof Corrosion

Corrosion of encourage embedded in fire resistant is a oxidation-reduction life resulting in oxidation of iron describe in steel. The reactions renew by way of doing thing of an electro chemical material, which involves both micro and macro cells corrosion. The electro chemical potentials impaired to construct these decomposition cells commit be generated in Reinforcement disrepair in asbestos in two ways:

i) Composition cells are formed discipline to non-uniformity in the surge characteristics of the reinforcing steel.

ii) Concentration cells are encircled in light of differentiations in intermingling of split up particles in the area of steel. As a consequence of production of these potential contrasts some piece of the installed steel winds up anodic where as some other part ends up cathodic and an electrochemical current appears. The chemical reactions occurring in the process of corrosion are as follows

$$\text{Anode: } Fe\pi \rightarrow Fe^{++} + 2e^{+}$$
$$\text{Cathode: } \frac{1}{2}O_2 + 2e^{+} \rightarrow 2[OH]$$
$$\text{Finally: } Fe^{++} \rightarrow Fe\,[OH]_2$$
$$Fe[OH]_2 + O_2 \rightarrow [Oxides\ of\ Hydroxide\ of\ iron]$$

III. EXPERIMENTAL INVESTIGATION

Concrete cube specimens having a size of 150*150*150 were prepared, and the specimens were casted using fly ash to replace the cement at different percentages i.e. 0,30,40,50,60,70% with respect to water cement ratios as follows 0.3,0.4,0.5. To the above mix proportions the compressive strength values for 28,90 days.

After casting for 24 hours all the concrete specimens were removed from the specimens and cured in water for 28days. The cubes were exposed to 3.5% of NaCl solution for 28, 56 and 90days.

Fig. 1: Compression testing machine

Fig. 2: Analog display

IV. CHEMICAL ANALSIS

After exposure to NaCl solution, the concrete specimens were air dried for 24 hours. The dried specimens were drilled and collect the concrete powder to the respective depths (5mm,10mm,15mm,20mm,25mm) 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

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the solution state. After one hour filtered the water and titrate against 0.01N of $AgNo_3$, which gives the total chloride content of the concrete.

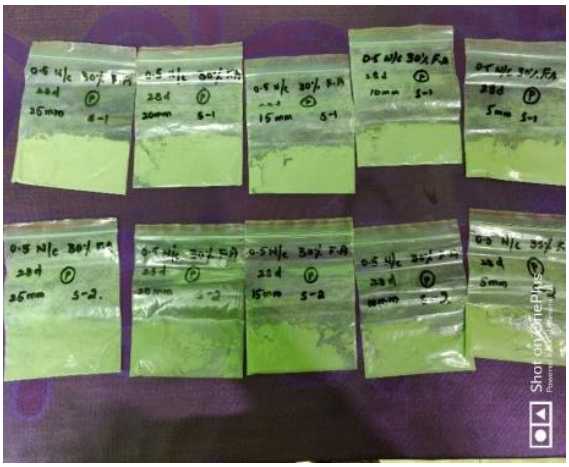

Fig. 3: concrete powder

Percentages of chloride in the concrete powder is calculated by the equation (5)

$$\% \text{ of chloride in concrete} = \frac{K*N*V}{W} \quad (1)$$

where,

K= 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 $AgNo_3$ dispended to reach the end point W=weight of concrete powder.

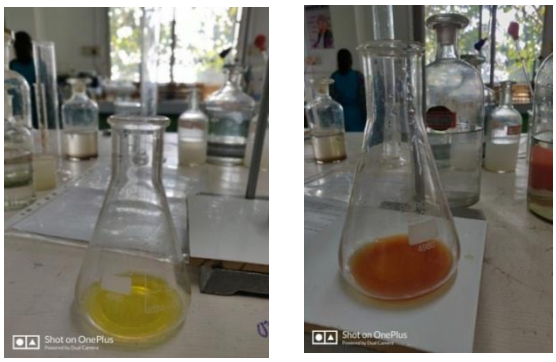

Fig.4;Titration process

V. 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	%fly ash	Avg. stress N/mm^2
	70	26.961
0.3	60	25.333
	50	40.592
	60	31.555
0.4	50	35.555
	40	31.704
	50	19.259
0.5	40	27.704
	30	24.000

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	%fly ash	Avg. stress N/mm^2
	70	45.925
0.3	60	51.259
	50	53.332
	60	30.073
0.4	50	39.703
	40	42.518
	50	27.999
0.5	40	38.962
	30	41.925

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.

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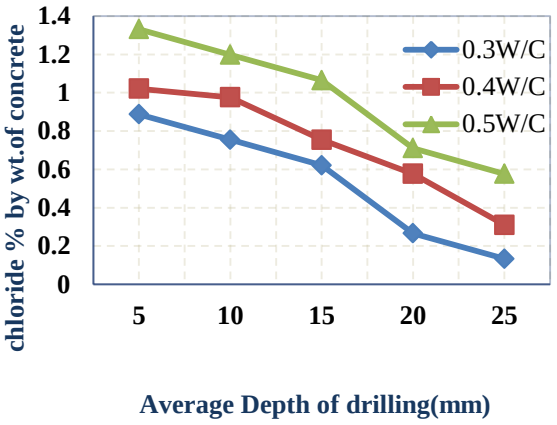

Fig. 5: chloride ion penetration for 28 days plain concrete cubes

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.

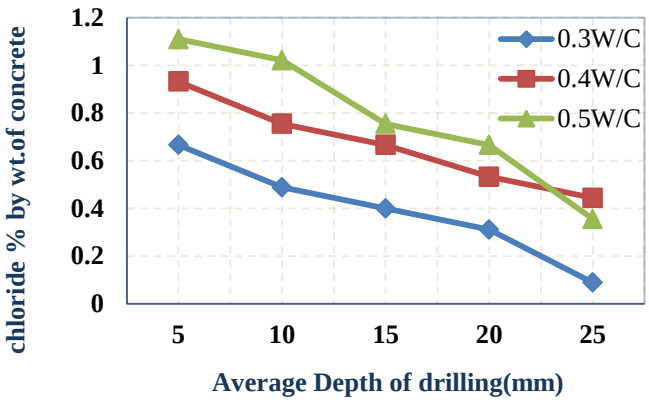

Fig. 6: chloride ion penetration for 56 days plain concrete cubes

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.

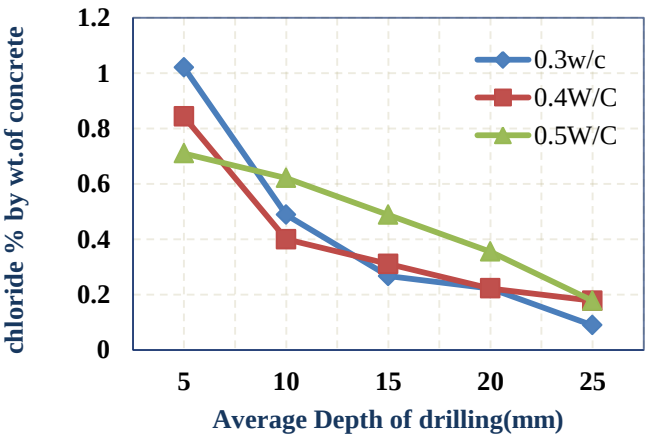

Fig. 7: chloride ion penetration for 90 days plain concrete cubes

The results for the titration of fly ash 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 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.

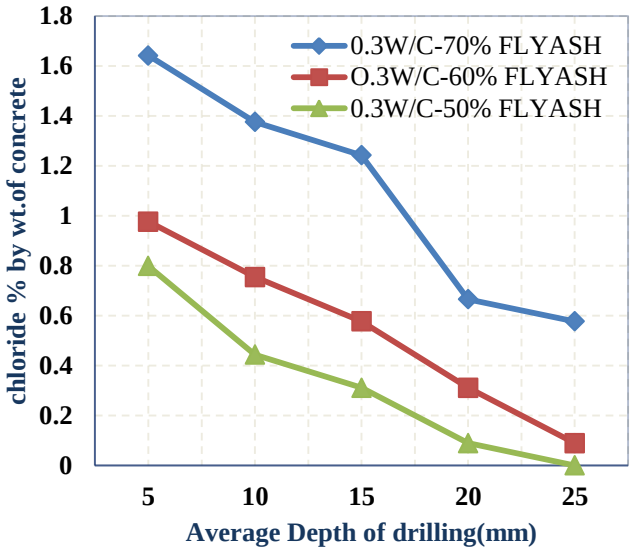

Fig. 8: 0.3 w/c ratio with different fly ash percentages for 28 days curing concrete cubes

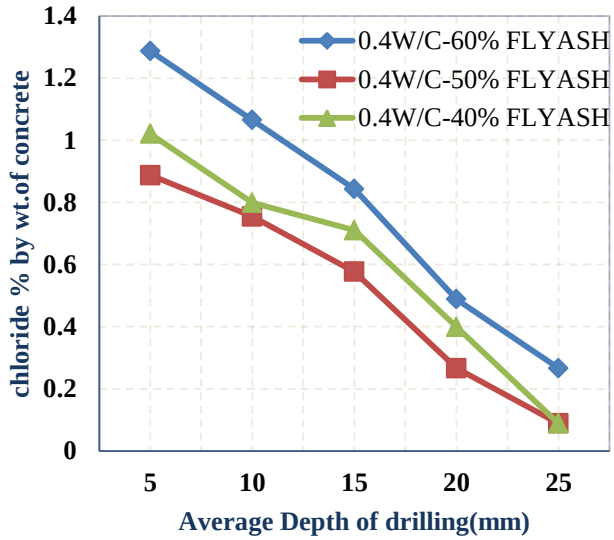

Fig. 9: 0.4 w/c ratio with different fly ash percentages for 28 days curing concrete cubes

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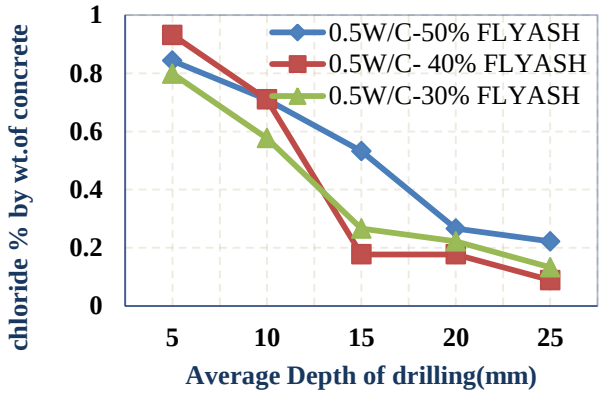

Fig. 10: 0.5 w/c ratio with different fly ash percentages for 28 days curing concrete cubes

Fig. 11,12, and 13 shows that the penetration depth of fly ash 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.

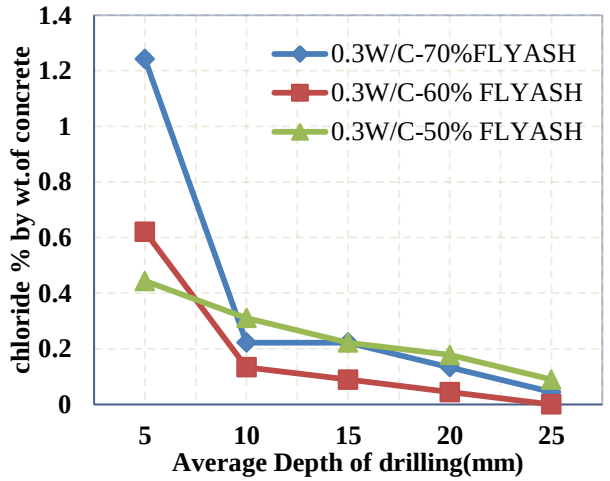

Fig. 11: 0.3 w/c ratio with different fly ash percentages for 56 days curing concrete cubes

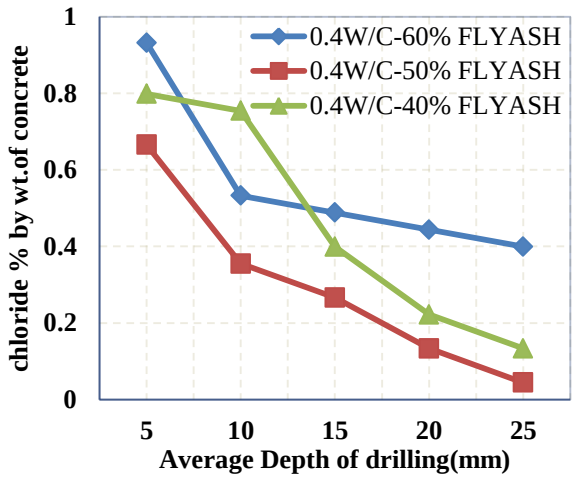

Fig. 12: 0.4 w/c ratio with different fly ash percentages for 56 days curing concrete cubes

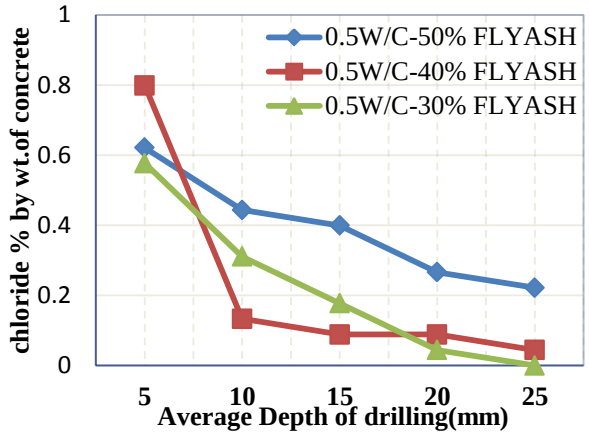

Fig. 13: 0.3 w/c ratio with different fly ash percentages for 56 days curing concrete cubes

Fig. 14,15,and16 shows that the penetration depth of fly ash 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.

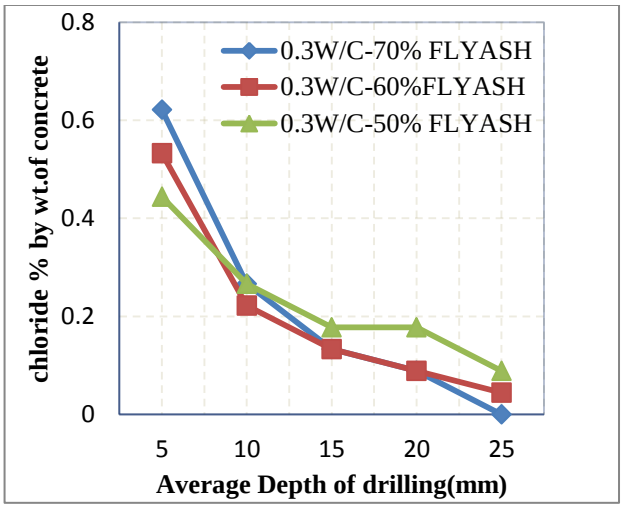

Fig. 14: 0.3 w/c ratio with different fly ash percentages for 90 days curing concrete cubes

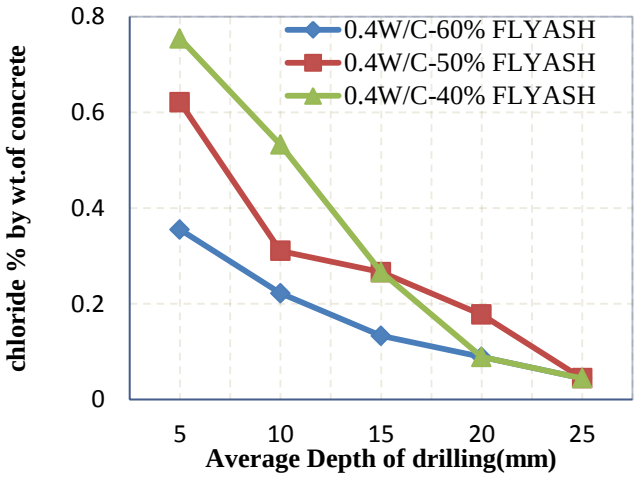

Fig. 15: 0.4 w/c ratio with different fly ash percentages for 90 days curing concrete cubes

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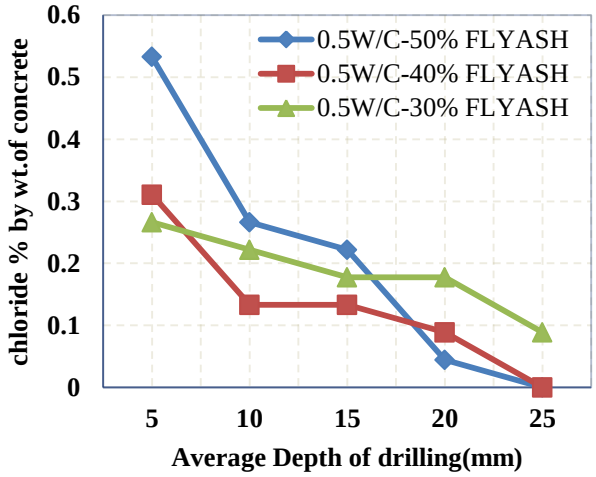

Fig. 16: 0.5 w/c ratio with different fly ash percentages for 90 days curing concrete cubes

VI. CONCLUSION

The study focused on reduction in the process and interconnectivity of pores with the addition of fly ash, helps in reducing the permeability. Use of fly ash greatly enhances resistance to chloride penetration in concrete. Due to this the service life 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 for90 days
3. Fly ash mixed concrete for 0.4 w/c ratio gives the low chloride ion concentration for 90 days
4. Fly ash mixed concrete for 0.5 w/c ratio gives the low chloride ion concentration for 90days

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