CHLORIDE PENETRATION IN FLY ASH CONCRETE

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Abstract

Concrete is a very widely used material for construction all over the world. Production of concrete needs usage of large quantities of cement. Production of cement involves release of Carbon dioxide into the environment. Hence, to reduce these emissions the most effective way is to replace cement with other materials. Fly ash is a promising replacement material for cement because of improvement in durability over long term.

The penetrability of concrete is not desired and affects the durability of concrete so in this paper a detailed presentation of experimental investigations carried out is made. These investigations are carried out to evaluate the penetrability properties by Rapid Chloride Permeability Test of concrete specimens in which cement was partially replaced with Class F fly ash are presented. 30%, 40%, 50% and 60% percentages of Class F fly ash by weight and volume fractions are used to replace cement. Tests were performed for which chloride penetration was determined after 28 days and 90 days of curing. Test results indicate that the chloride penetration in concrete containing fly ash is reduced. With age the chloride penetration decreased upto 82.2% with addition of 60 % fly ash content after 90 days.

Keywords: *Rapid Chloride Permeability Test, fly ash, chloride,*

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1. INTRODUCTION

Environmental pollution is the biggest concern for people today. In our construction industry, cement is the main material for the concrete production. During manufacture of Cement, large amount of environmental impacts happen at all stages of the process. Airborne pollution is caused due to emission of Carbondioxide gas. Also when operating machinery and blasting in quarries, other pollutions such as dust, noise and vibration also occur. During manufacture of Cement CO_2 is released in the atmosphere. The cement industry produces about 5% of global man made CO_2 emissions. The amount of CO_2 emitted by the cement industry is nearly 900 kg of CO_2 for every 1000 kg of cement produced.

Historically, fly ash has been used in concrete in volume content varying from 15% to 25% by mass of the cementitious material component. The actual amount of fly ash consumed varies depending on the properties of the fly ash and its application, the geographic location and climate. Malhotra and Mehta (2002) reported that the water cement ratio of 0.40 has a permeability of 10-12 m/s. At high levels problems may be encountered with extended set times and slow strength development, leading to low early-age strengths. When properly cured the fly ash concrete provides excellent water tightness and durability (Mehta P.K, 2004).
Fly ash which is a finely divided amorphous alumino silicate powder, reacts with the calcium hydroxide. Calcium hydroxide is released during hydration process and produces various calcium silicate hydrates and calcium aluminum hydrates. In High Volume Fly Ash Concrete, increase in the quantity of cementitious C-S-H phase and calcium aluminum hydrates enhances the long term strengths and reduces the permeability. Thus improves the durability properties [1].

2. MATERIALS USED

2.1 Cement

The cement used in the experimental investigations is ordinary Portland cement of 53 grades supplied from Ultra Tech cement factory. It is tested for physical properties as per IS 12269: 2013 standard. The preliminary test results of the cement are tabulated in table 1 below.

Table 1 Properties of cement

Property	Values
Specific gravity	3.15
Fineness	95%
Normal consistency	35%
Initial setting time	30mins

2.2 Fine Aggregate

River sand conforming to Grading zone II of IS 383 –1970 was used in the study. Used as a filler. It accounts 60-80%

of volume and 70-80 % of weight of concrete and defines concrete dimensional stability. Sand passing through less than 4.75 mm was used. The physical properties of soil are tabulated in table 2.

Table 2 Properties of Fine aggregate

Property	**Value**
Specific gravity of FA	2.55
Zone	III

2.3 Coarse Aggregate

Locally available crushed granite stones conforming to graded aggregate of nominal size 20mm as per IS 383 – 1970 is used. Properties of aggregates have large impact on the strength, durability, workability and economy of concrete.

2.4 Fly Ash

Class F Fly ash obtained from Ennore Power Plant which confines as per IS 3812 – 2000 is used. Properties of fly ash are mentioned in table 3.

Table 3 Properties of Fly ash

PROPERTIES	**VALUES**
Specific gravity	2.2
Fineness	320 kg/m^2

2.5 Super Plasticizer

High range water reducing and retarding Sulphonated naphthalene formaldehyde based super plasticizer type G - CONPLAST SP 430 was used as chemical admixture to enhance the workability of the concrete.

2.6 Water

Ordinary Potable water is used for casting and curing.

2.7 Mix Proportion

Mix design was carried out as per IS:10262:2000 and the after trial mixes, a mix ratio of 1:1.1:2.0 is used. The water binder ratio is 0.36.

3. EXPERIMENTAL WORK

The methodology adopted in this work is Rapid Chloride Permeability Test as per ASTM C1202. In this method electrical current is passed through 51 mm thick slices of 100 mm nominal diameter cores or cylinders for a 6 hr period. A potential difference of 60V direct current is maintained across the ends of the specimen. Each of the specimens is immersed in a sodium chloride solution and sodium hydroxide solution separately. The total charge passed, in coulombs, is measured and it gives the resistance of the specimen to chloride ion penetration. As per ASTM specifications,

Table 4 Chloride Ion Penetrability Based on Charge

Charge Passed (coulombs)	**Chloride Ion Penetrability**
> 4,000	High
2,000 - 4,000	Moderate
1,000 - 2,000	Low
100 - 1,000	Very Low
< 100	Negligible

For carrying out the test, initally a core or cylinder of 100 mm diameter is obtained. A 50 mm thick cylindrical specimen is cut from the sample. The surface of the cylindrical specimen is coated with glue and is allowed to dry. After drying, the specimen is put in vacuum chamber and then it is placed in the testing device. The left side (-) of the test cell is filled with 3% Sodium Chloride Solution and solution and the right side (+) is filled with 0.3 N Sodium Hydroxide solution. Now, a potential of 60 Volt is applied for 6 hours. Every 30 mins readings are noted. After 6 hours the specimen is removed and the total amount of charge passed through the specimen is calculated.

Fig 1. Cylindrical core extracted

Fig 2. Standard size specimens

Fig 3 Vacuum Saturation Apparatus

Fig 4 Test Set Up

4. RESULTS AND DISCUSSIONS

4.1 28 Days Test Results

The test results obtained after 28 days of casting are presented in table 5 below. As the fly ash content increased the chloride penetration decreased in concrete after 28 days of curing. One of the major advantages of using fly ash in concrete is the increase in durability of concrete.

Table 5 28 days RCPT test results

Specimen	RCPT Value In Coulombs after 28 Days	% reduction in chloride penetration
0 % FA	2422	-
30 % FA	2381	1.69
40 % FA	2242	7.43
50 % FA	1660	31.46
60 % FA	1614	33.36

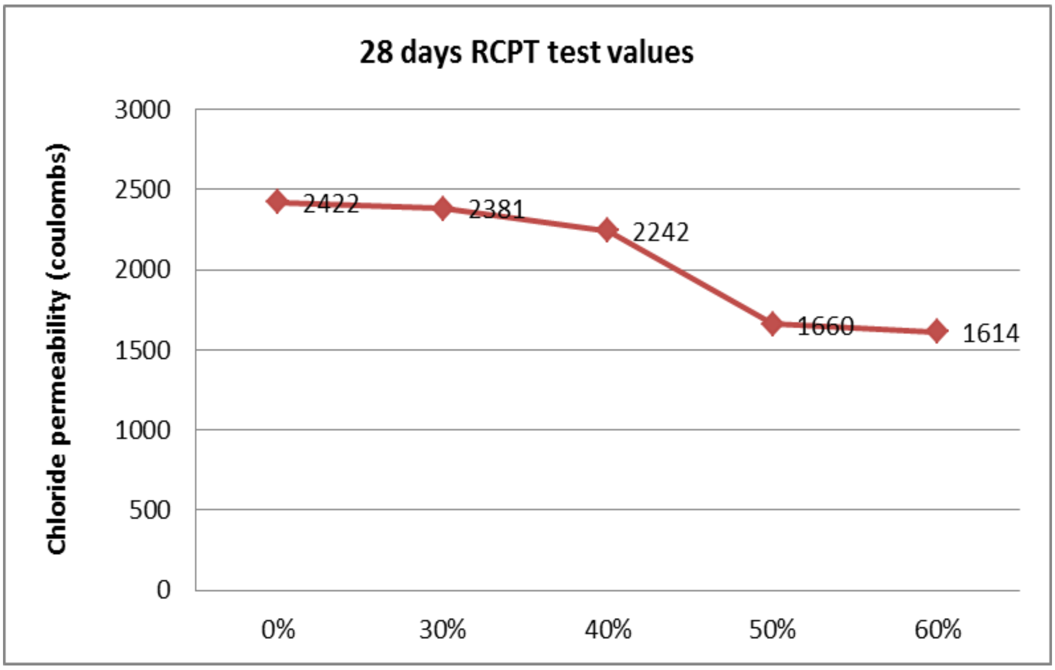

Fig 5. RCPT values after 28 days testing

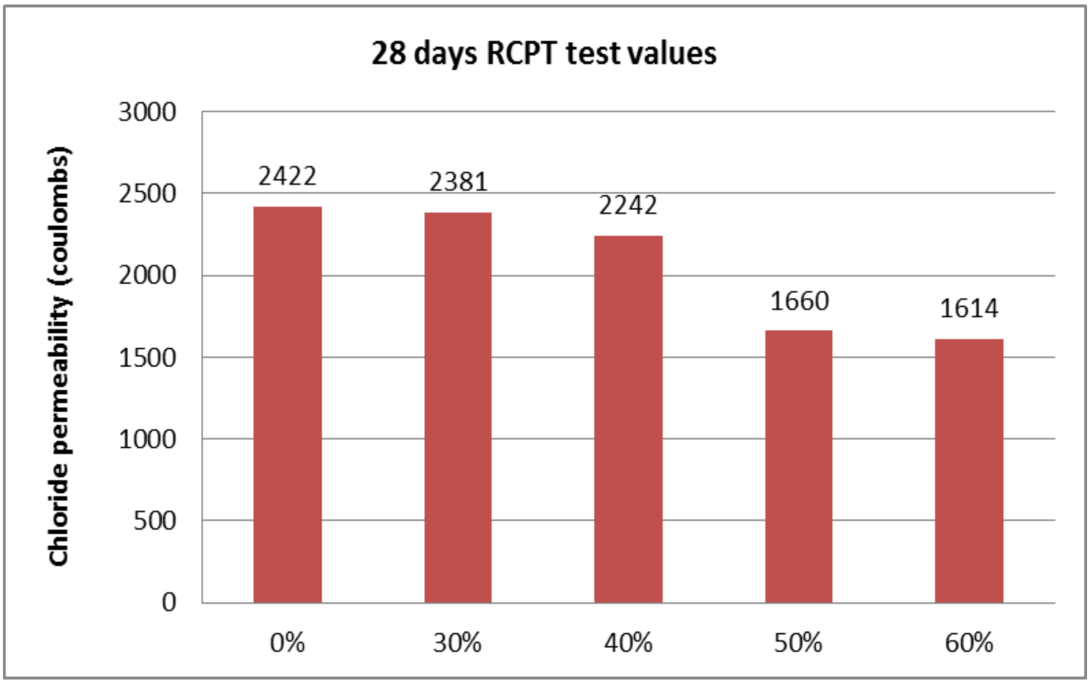

Fig 6. RCPT values after 28 days testing

4.2 90 Days Test Results

The test results obtained after 90 days of casting are presented in table 6 below. As the fly ash content increased the chloride penetration decreased in concrete after 90 days of curing. The chloride penetration fly ash concrete reduced significantly with increase in volume of fly ash. The reduction in chloride penetration in concrete with 30%, 40%, 50 % and 60 % fly ash content is 69.7%, 71.2%, 81%, 82.2% respectively. It is observed that the chloride decreased upto a maximum of 82.2% when 60 % fly ash content is used.

Table 6 90 days RCPT test results

Specimen	**RCPT Value In Coulombs after 90 Days**	**% reduction in chloride penetration**
0 % FA	2298	-
30 % FA	697	69.7
40 % FA	662	71.2
50 % FA	437	81
60 % FA	409	82.2

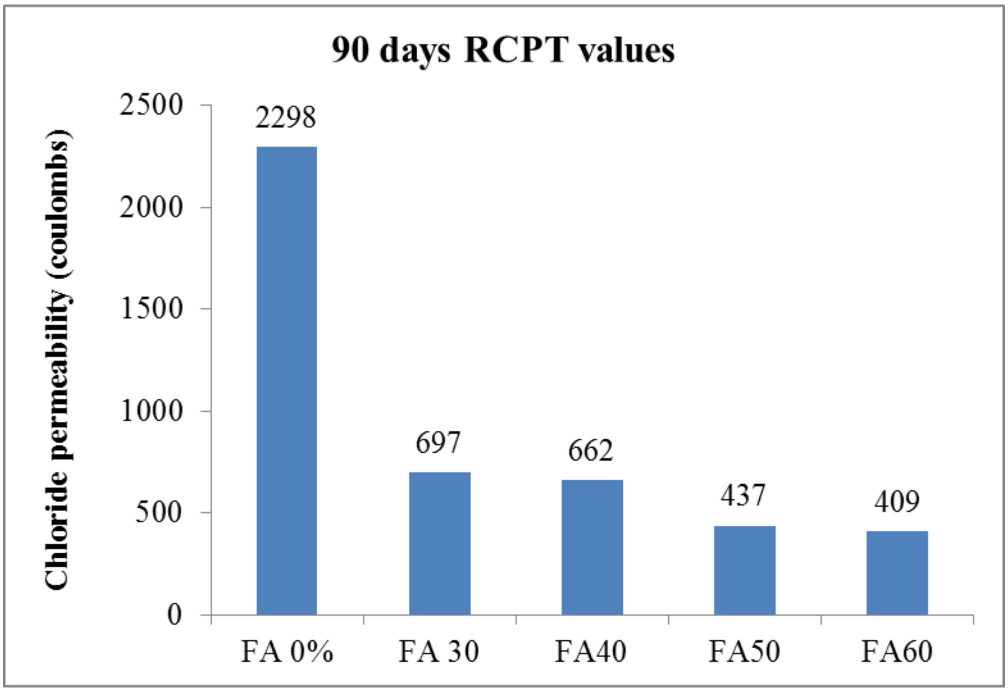

Fig 7. RCPT values after 90 days testing

4.3 Effect of Age on Fly Ash Concrete

From the experimental results it is observed that presence of fly ash reduces significantly the chloride penetration in concrete. The presence of large pores and crystalline products in ordinary concrete are greatly reduced in fly ash concrete. Addition of fly ash decreases the water content required and also leads to low porosity due to production of additional cementitious compounds. Permeability is reduced because of this discontinuous pore structure. Because of slow reactions that occur in fly ash concrete, with age, the formation of crystalline products and discontinuous pore structure take place and thus reduce the chloride permeability at later ages compared to early age.

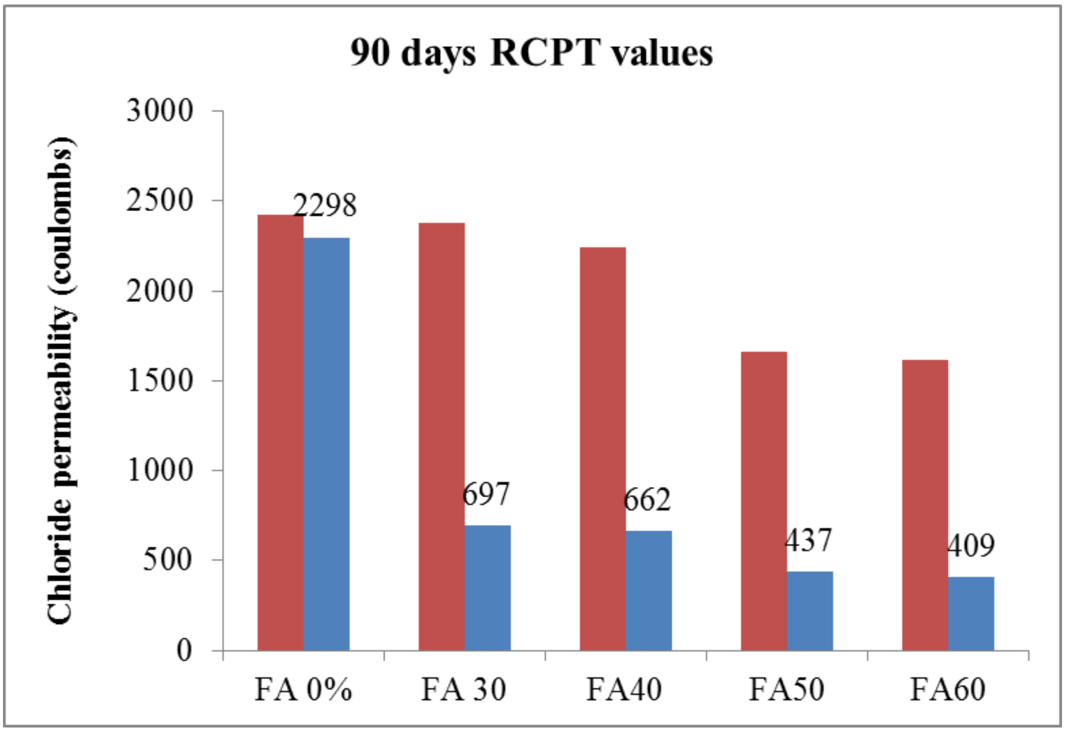

Fig 8. Comparing RCPT values after 28 and 90 days age

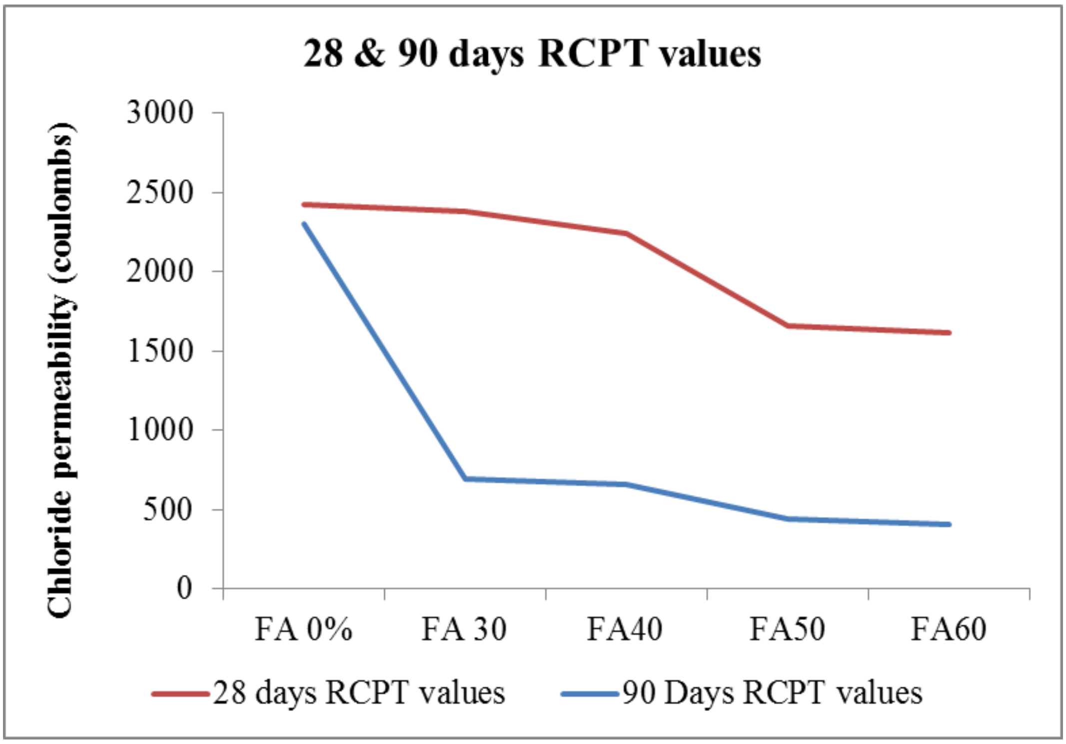

Fig 9. Comparing RCPT values after 28 and 90 days age

Specimen	RCPT Value In Coulombs after 28 Days	RCPT Value In Coulombs after 90 Days	% reduction in chloride penetration with age
0 % FA	2422	2298	5.1
30 % FA	2381	697	70.7
40 % FA	2242	662	70.5
50 % FA	1660	437	73.7
60 % FA	1614	409	74.7

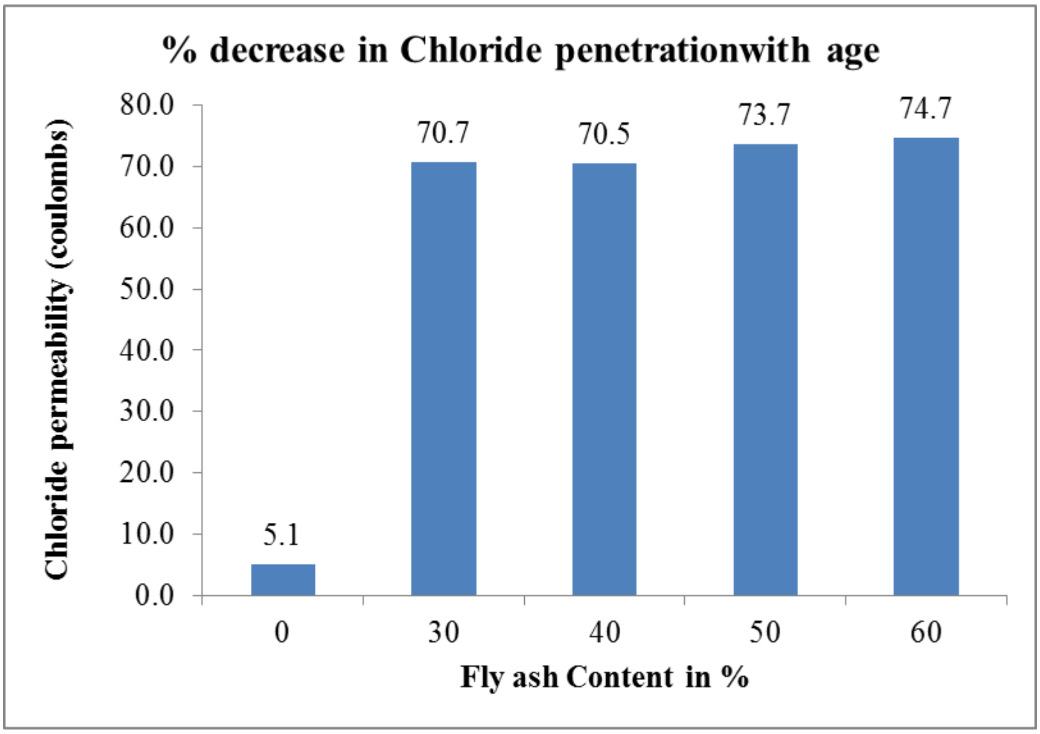

Fig 10. % Decrease in Chloride penetration comparing 90 days with 28 days.

5. CONCLUSION

1. With the increase in fly ash content, the permeability of concrete decreases.
2. Fly ash in 30%, 40%, 50% and 60% content decreases the permeability by 1.69% , 7.43%, 31.46% and 33.36% respectively after 28 days.
3. As the volume of fly ash increases, after 28 days the chloride penetration reduced, to the extent of 33.36% with 60% replacement of cement with fly ash.
4. With addition of fly ash in 30%, 40%, 50% and 60% the decrease in permeability was 69.7% , 71.2%, 81% and 82.2% respectively after 90 days.
5. As the volume of fly ash increases, at 90 days the chloride penetration reduced, to the maximum of 82.2% with 60% replacement of cement with fly ash.
6. The reduction in the pores and interconnectivity of pores with the addition of fly ash, helps in reducing the permeability.
7. With age, the chloride permeability in concrete decreased significantly and at 90 days it is found to be reduced by 70.7%, 70.5%, 73.7%, 74.7% compared to 28 days in concrete with fly ash content of 30%,40%, 50% and 60 % respectively, while it is just 5.1% in conventional concrete.

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