Effect of Alccofine and Fly Ash Addition on the Durability of High Performance Concrete

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Abstract— The aim of this Study is to evaluate the performance of concrete (HPC) containing supplementary cementitious materials such as Fly ash & Alccofine. The necessity of high performance concrete is increasing because of demands in the construction industry. Efforts for improving the performance of concrete over the past few years suggest that cement replacement materials along with Mineral & chemical admixtures can improve the strength and durability characteristics of concrete. Alccofine (GGBS) and Fly ash are pozzolanic materials that can be utilized to produce highly durable concrete composites.

This study investigates the performance of concrete mixture containing Local Alccofine. in terms of Compressive strength, Sulphate Attack tests, Alkali test and RCPT (Rapid chloride penetration test) at age of 28 and 56 days. In addition find out the optimum dosage of alccofine and fly ash from that get M70 Strength, in final mix proportion perform a given test. Result show that concrete incorporating Alccofine and fly ash had higher compressive strength and alccofine enhanced the durability of concretes and reduced the chloride diffusion. An exponential relationship between chloride permeability and compressive strength of concrete is exhibited.

Keywords: Alccofine, durability, Compressive strength, Sulphate Attack tests, Alkali test, and RCPT (Rapid chloride penetration test).

I. INTRODUCTION

The durability of cement concrete is defined as its ability to resist weathering action, chemical attack, or any other process of deterioration. Durable concrete will retain its original form quality, and serviceability when exposed to environment.

One of the main reasons for deterioration of concrete in the past is that too much emphasis is placed on concrete compressive strength rather than on the performance criteria. The deterioration of reinforced concrete structures usually involves the transport of aggressive substances from the surrounding environment followed by physical and chemical actions in its internal structure. The transport of aggressive gases and/or liquids into concrete depends on its permeation characteristics. As the permeation of concrete decreases its durability performance, in terms of physio-chemical degradation, increases. Therefore, permeation of concrete is one of the most critical parameters in the determination of concrete durability in aggressive environments.

Since high resistance to chloride penetration can be directly related to low permeability that dominates the deterioration process in concrete structures, the resistance to chloride penetration is one of the simplest measures to determine the durability of concrete. Therefore, in this study, the rapid chloride permeability test method designated in ASTM C 1202(1997) is adopted. The advantage of adopting this rapid chloride permeability test (RPCT) test is direct cost savings could be quantified when compared to other tests and the brief procedural steps involved significantly reduce the technician time necessary to evaluate a particular concrete.

II. EXPERIMENTAL PROGRAM

Experimental program has been planned to provide sufficient information for ascertaining the quality of Alccofine based high performance concrete. To evaluate the behavior of Alccofine based high performance concrete, both compressive strength and durability aspects have been studied in this investigation.

A. MATERIAL

a) CEMENT

Ordinary Portland cement-53 grade (Abuja Cement) available in local market was used in investigation. The cement was tested according to IS 4031: 1988. It confirmed to IS 12269: 1987. Its Properties is given in Table I.

SR No	Properties		Value	As per IS: 12269-1976
1	Specific gravity		3.10	3.15
2	Normal consistency		31%	30% - 35%
3	Initial setting time		36	>30
4	Final setting time		450	<600
5	Fineness (%passing 90 IS sieve)		3%	<10%
6	Soundness (mm)		1.2	<10
7	Compressive strength	3 day	39	>27
		7 day	40	>37
		28 day	57	>53

Table. 1 :Properties Of Opc - 53 Grades Used

b) FINE AGREGATE

Natural sand as per IS: 383-1987 was used. Locally available River sand having bulk density 1860 kg/m3 was used The properties of fine aggregate are shown in Table II.

Sr. No.	Property	Result
1	Specific gravity	2.67
2	Fineness modulus	2.672
3	Grading zone	II

4	Water Absorption	1.5%

Table. 2 :Properties of Fine Aggregate

c) COARSE AGGREGATES:

Crushed aggregate confirming to IS: 383-1987 was used. Aggregates of size 20 mm and 10 mm of specific gravity 2.86 and fineness modulus 7.28 for 20 mm and 6.30 for 10 mm were used.

d) ALCCOFINE:

ALCCOFINE 1203 is a specially processed product based on slag of high glass content with high reactivity obtained through the process of controlled granulation. ALCCOFINE 1203 use in project conforming to ASTM C989-99. Physical & Chemical Properties of Alccofine is given in Table III

Physical Properties		
Fineness (cm^2/gm)		>12000
Specific Gravity		2.9
Bulk Density (Kg/m^3)		700-900
Particle Size Distribution	d10	1.5 micron
	d50	5 micron
	d90	9 micron
Chemical Properties		
C_aO		61-64%
SO_3		2-2.4 %
SiO_2		21-23 %
AL_2O_3		5-5.6 %
Fe_2O_3		3.8-4.4 %
M_gO		0.8-1.4 %

* As per Manufacturers booklet

Table. 3: Physical & Chemical Properties of Alccofine

e) SUPER PLASTICIZER:

In this investigation super plasticizer- GLENIUM SKY 784 is based on second generation polycarboxylic ether polymers, developed using Nano technology. Chemical Admixture GLENIUM SKY 784 is conforming to IS: 9103-1999. was used to improve the workability of concrete. The properties of super plasticizer are shown in Table IV.

Parameter	Specification(as per IS 9103)	Results
Physical state	Light brown liquid	Light brown liquid
Chemical name of active ingredient	Polycarboxylate polymers	Polycarboxylate Polymers
Relative density at 25 c	1.1±0.01	1.105
ph	Min 6	6.51
Chloride ion content (%)	Max 0.2	0.0017
Dry material content	34±5(%)	34.14

* As per Manufacturers booklet

Table. 4: Properties of Super Plasticizer

B. MIX PERPORRTION

In concrete mix design first find out optimum dosage of Alccofine and fly ash, Developed method by Dr.(smt) B.K.Shah.[15]. Alccofine is varies from 4% to 14% and fly ash varies from 20% to 35%. finally optimum dosages of alccofine and fly ash are 8% and 20% respectively. Mix proportion is found out by using Dr. (smt) B.K.Shah. in her PhD Thesis. The Table 5 Shows that final mix proportion of concrete in kg/m3

Sr No	Material	Quantity (kg/m^3)
1	Total binder	600 Kg
2	Water	180 Litre
3	Fine Aggregate	650 Kg
4	Coarse Aggregates	1080 Kg
5	Admixture	6 Litre

Table. 5: Final Quantity Of Concrete In $1m^3$

C. EXPERIMENTAL PROCESS:

The specimen of standard cube of (150mm x 150mm x 150mm) standard was used to determine the compressive strength. Three specimens were tested for 28 & 56 days with each proportion of Alccofine and Fly ash replacement. Totally 6 cubes, were cast for the strength parameters and 12 cubes for chemical attack test. and 100 Ø and 50 mm Thick disc used for finding out RCPT (Rapid Chloride penetration test) The constituents were weighed and the materials were mixed by machine mixing. The water binder ratio (W/B) (Binder = Cement + Partial replacement of Alccofine and fly ash) adopted was 0.30 and weight of super plasticizer was estimated as 1% of weight of binder. The concrete was filled in different layers and each layer was compacted. The specimens were demoulded after 24 hrs, cured in water for 28 & 56 days, and then tested for its compressive, Acid attack tests, Alkali test, Sea water test and RCPT (Repid chloride penetration test) as per Indian and ASTM Standards.

D. TEST METHODS

a) COMPRESSIVE STRENGTH

Concrete cubes of 150 X 150 X 150 mm dimension were cast for compressive strength. They were tested for compressive strength after 28 and 56 days of water curing. For each age, three specimens were tested and the mean value of these measurements is reported.

b) SULPHATE ATTACK TEST:

Cubes of sizes 150 X 150 X 150 mm were cast and cured for 28 days. After 28 days curing cubes were taken out and allowed for drying for 24 hours and weights were taken. For Sulphate Attack Test 5% dilute Na2So4 and 5% MgSo4 is used. The cubes were to be immersed in solution for a period of 30 days. The concentration is to be maintained throughout this period. After 30 days the specimens were taken from acid solution. The surface of specimen was cleaned and weights were measured. The specimen was tested in the compression testing machine under a uniform rate of loading 140Kg/cm2 as per IS 516. The mass loss and strength of specimen due to Sulphate Attack was determined.

c) ALKALI ATTACK TEST:

Cubes of sizes 150 X 150 X 150 mm were cast and cured for 28 days. After 28 days curing cubes were taken out and allowed for drying for 24 hours and weights were taken. For Alkali Attack Test 5% dilute NaOH is used. The cubes were to be immersed in solution for a period of 30 days. The concentration is to be maintained throughout this period.

After 30 days the specimens were taken from acid solution. The surface of specimen was cleaned and weights were measured. The specimen was tested in the compression testing machine under a uniform rate of loading 140Kg/cm2 as per IS 516. The mass loss and strength of specimen due to Alkali Attack was determined.

d) RCPT (Repid chloride penetration test)

The resistance of concrete to salt attack was assessed by Rapid Chloride Permeability Test (RCPT) at 28 and 56 days of water curing in conformity with ASTM C-1202. Three specimens of 100 mm in diameter and 50 mm in thickness which had been conditioned according to the standard were subjected to a 60-V potential for 6 h. The total charge passed through the concrete specimens was determined and used to evaluate the chloride permeability of each concrete mixture.

Sr. No.	Charge Passed (colombs)	Choride ion penetrability
1	> 4,000	High
2	2,000 - 4,000	Moderate
3	1,000 - 2,000	Low
4	100 - 1,000	Very Low
5	< 100	Negligible

Table. 6: Rapid Chloride Penetration Test (Rcpt) Ratings (Per ASTM C 1202)

III. RESULT AND DISCUSSION

A. OPTIMIZATION

The results of compressive strength were presented in Table II. The test was carried out conforming to IS 516-1959 to obtain compressive strength of concrete. The cubes were tested using Compression Testing Machine (CTM) of capacity 2000Kn. From Table 8 maximum compressive strength is observed at 20% replacement of Fly ash and 8% replacement of alccofine. So, optimum dosage of fly ash and alccofine is 20% and 8% respectively.

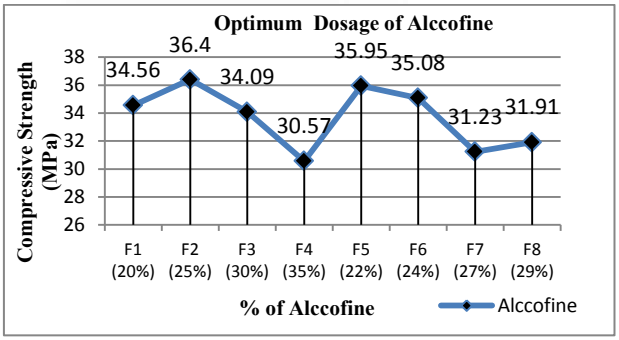

Fig. 1: Optimum Dosage of the fly Ash

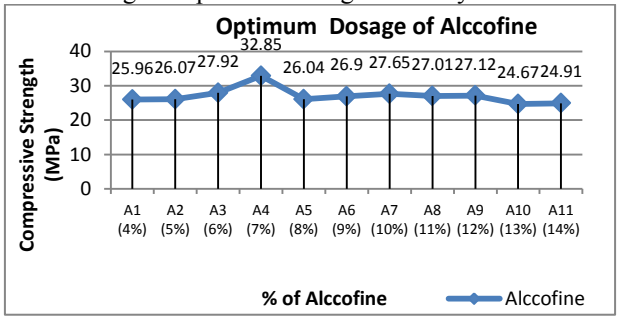

Fig. 2: Optimum Dosage of the Alccofine

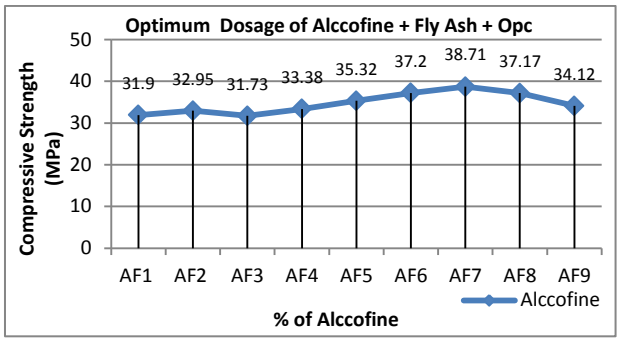

Fig. 3: Optimum Dosage of the Alccofine

MIX	AF 1	AF 2	AF 3	AF 4	AF 5	AF 6	AF 7	AF 8	AF 9
%Fly ash	20 %	25 %	30 %	20 %	25 %	30 %	20 %	25 %	30 %
%Alcco fine	6%	6%	6%	7%	7%	7%	8%	8%	8%

Table. 7: Optimum Dosage Of The Alccofine + Fly Ash + Opc

B. COMPRESSIVE STRENGTH:

The results of compressive strength were presented in Table VIII. The test was carried out conforming to IS 516-1959 to obtain compressive strength of concrete at the age of 28 and 56 days. The cubes were tested using Compression Testing Machine (CTM) of capacity 2000Kn. From Fig 4 the compressive strength is up to 54.89 MPa and 72.97 MPa at 28 and 56 days. The maximum compressive strength is observed at 8% replacement of Alccofine. There is a significant improvement in the compressive strength of concrete because of the high pozzolanic nature of the Alccofine and its void filling ability.

Days/types of concrete	7 days (MPa)	14 days (MPa)	28 days (MPa)	56 days (MPa)
AL1	44.06	50.65	54.89	72.97

Table. 8: Result Of Compressive Strength At 28 & 56 Days

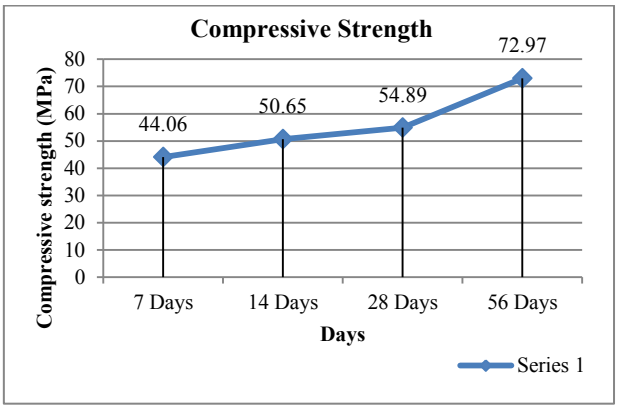

Fig. 4: Result of Compressive strength at 28 & 56 Days

C. SULPHATE ATTACK TEST:

The Sulphate attack test parameters observation was presented in Table IX. shows the influence of sulphate attack on Alccofine. The average loss of weight and loss of compressive strength of concrete is considerably low.

This indicates that incorporation of Alccofine in concrete could be considered to be reasonable in the aspects of more Sulphate resistance.

Mix Proportion	loss of weight in %	Loss in Strength %
AL1	1.03	2.46

Table. 9: $Mgso_4$ & Na_2so_4 Solution For 56 Days

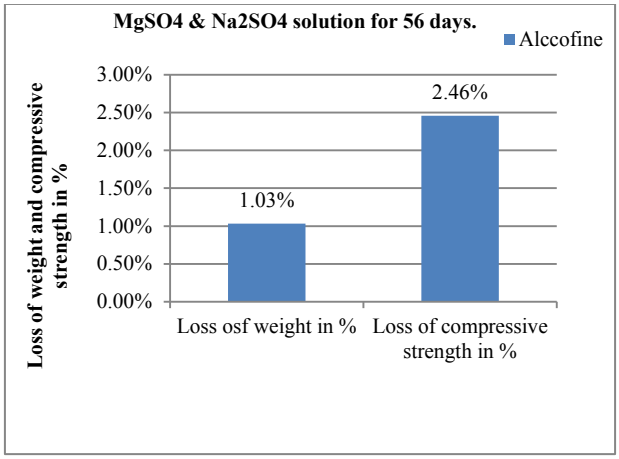

Fig. 5 : Loss of Weight & Compressive Strength at 56 Days in %

D. ALKALI ATTACK TEST

The alkali attack test parameters observation was presented in Table X. shows the influence of alkali attack on Alccofine. The average loss of weight and loss of compressive strength of concrete is considerably low.

This indicates that incorporation of Alccofine in concrete could be considered to be reasonable in the aspects of more alkali resistance.

Mix Proportion	loss of weight in %	Loss in Strength %
AL1	2.48	4.93

Table. 10: NaOH Solution For 56 Days

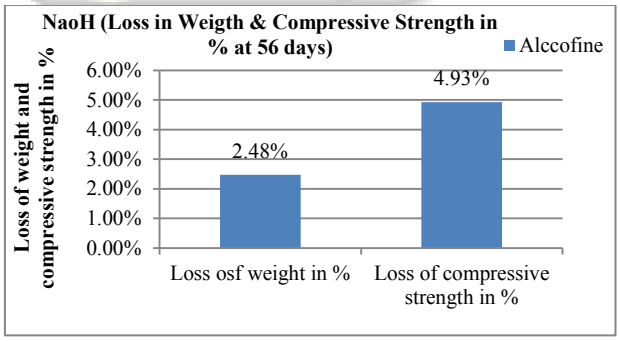

Fig. 6: Loss of Weight & Compressive Strength at 56 Days in %

E. RCPT (Repid chloride penetration test):

As w/c ratio increases permeability increases which results in high chloride penetration in any type of cement. On addition of Alccofine in OPC system, RCPT value decreases, this is due to (1) proper particle size distribution resulting in lower permeability.(2) addition of alumina decreases RCPT value because alumina reacts with chlorine preferentially to calcium (Fidder reaction).

On addition of Fly ash in Alccofine based cement, there is further reduction in RCPT value, this is due to the higher amount of pozzolona and proper particle size distribution resulting in further reduction in permeability and amount of liberated lime.

Mix Proportion/ RCPT	28 Days RCPT(Coulombs)	56 Days RCPT(Coulombs)
AL1	405	108

Table . 11 :Rcpt Result At 28 And 56 Days

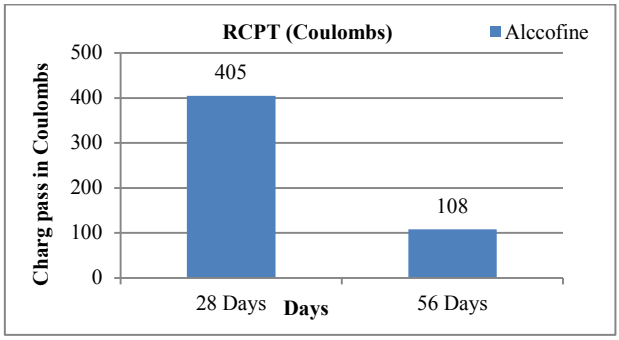

Fig. 7: Comparison of RCPT value of different concrete mix

IV. CONCULUSIONS

In this study, the effect of local Alccofine as supplementary cementing materials and filling materials on the strength and durability of concretes was investigated. From the results obtained in this study, the following conclusion can be drawn:

- We concluded that compressive strength achieved by using Alccofine (8%) + Fly Ash (20%) is 54.89Mpa, 72.97 Mpa, at 28 and 56 days respectively. Due to its particle size is smaller than cement so its helps to reduce voids so indirectly increase in strength.
- The minimum loss of weight and loss of compressive strength of concrete in Alccofine. Due to its more compactness and less permeability of concrete effect of Sulphate Attack is reduce. This is converts leachable calcium hydroxide into insoluble non- leachable cementanious product. This pozzolanic action is responsible for impermeability of concrete. Secondly, the removal of calcium hydroxide reduces the susceptibility of concrete to attack by magnesium sulphate.
- The minimum loss of weight and loss of compressive strength of concrete in Alccofine. Due to its more compactness and less permeability of concrete effect of alkali is reduce. This is due to more fineness of mineral admixtures such as Alccofine.
- It is possible to make M_{70} concrete having RCPT value lower than 500 coulombs. It is observed that in Alccofine, RCPT value is less. Due to its pore filling and pore refining of particle.

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