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Experimental Studies on Durability Aspects of High Strength Concrete using Flyash and Alccofine

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Abstract: ***The experimental work is to study the influence of FLY ASH and ALCCOFINE 1203 in achieving High Strength Concrete (HSC). This study analyses the performance of various combinations of concrete in which cement is partially replaced with 30% fly ash with different proportions of alccofine of grade 1203, micro fine silica includes 0%, 4%, 8%, 12% respectively. Super plasticizer Conplast SP430 of 1.5% for every specimen is added in order to improve the workability of the mix. Specimens are casted for M 60 grade as per mix design using manufactured sand (M sand) as fine aggregate. Durability tests conducted includes rapid chloride penetration test, water absorption test, carbonation test and water permeability test. Scanning electron microscopic analysis was carried out to determine the development of micro structural configuration of the concrete.***

Keywords: ***High Strength Concrete, Rapid Chloride Penetration Test, Water Absorption Test, Carbonation Test, Water Permeability Test, and Scanning Electron Microscopy.***

I.INTRODUCTION

The term high strength concrete is generally used for concrete with compressive strength higher than 60MPa. The use of high strength concrete in the construction sector has increased steadily over the past years**.** Alccofine 1203 is a micro fine slag that preferably replaces silica fume which is used in high performance concrete and alccofine 1101 is a micro fine cement based product used for injection grout in underground tunnels and soil stabilization which have been enjoying a successful buy-in from its various customers ever since its launch. Because of its unique property and ultra-fine particle size. Alccofine1203is a high range water reducer to improve the compressive strength as well as workability of concrete. The major byproduct in electric power generating plants is fly ash. The two general classes of fly ash can be categorized as class F (low calcium fly ash) and class C (high calcium fly ash).

II.MIX PROPORTIONING

Table 1 Mix Proportion

Mix	Mix proportion	Cement kg/m³	Fine aggregate kg/m³	Coarse aggregate kg/m³	Fly ash kg/m³	Alccofine 1203 kg/m³	Water kg/m³
FAA0	30% fly ash & 0% Alccofine 1203	486	669.4	948.75	145.8	-	145
FAA4	30% fly ash & 4% Alccofine 1203	320.76	669.4	948.75	145.8	19.44	145
FAA8	30% fly ash & 8% Alccofine 1203	301.32	669.4	948.75	145.8	38.8	145
FAA12	30% fly ash & 12% Alccofine 1203	281.88	669.4	948.75	145.8	58.32	145

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III. MATERIALS USED

A. Cement

In this study, Ordinary Portland Cement (OPC) of 53 Grade confirming to I S specification is used. Properties of the cement are presented in Table 2.

Table 2 Properties of OPC 53 grade cement

Properties	Test results	Technical reference
Specific gravity	3.15	IS4031(PART 11): 1988
Consistency (%)	33	IS4031(PART 4): 1988
Fineness of cement (%)	8	IS4031(PART 2): 1996
Initial setting time (minutes)	75	IS4031(PART 5): 1988

B. Fine Aggregate

Manufactured sand (M-Sand) is an alternative to river sand for construction. M-sand is a product obtained from crushing of hard granite stone. The size of M-Sand is less than 4.75mm. Due to the scarcity of river sand, another alternate material manufactured sand has been used for construction purposes. Another reason for use of M-Sand is its ease of availability and less transportation cost. Also it is a dust free material, causing very less pollution. Properties of fine aggregate are presented in table 3.

Table 3 Properties of Fine Aggregate

Properties	Test results
Specific gravity	2.74
Water absorption (%)	0.4
Free surface moisture	Nil

C. Coarse Aggregate

Aggregates having particle size distribution greater than 4.75 mm, but generally ranges between10 mm to 40 mm in size. Coarse aggregate provide strength, toughness, and hardness properties to concrete and provides resistance to abrasion. Coarse aggregate used in the experimental study was confirming to IS 383:1970.Properties of coarse aggregate are listed in table 4.

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Table 4.Properties of Coarse Aggregate

Properties	Test results	Technical reference
Specific gravity	2.63	IS2386(PART 3): Clause 2.4.2
Water absorption (%)	1.2	IS383(PART 3): 1970
Free surface moisture	Nil	IS383(PART 3): 1970
Fineness modulus	2.6	IS383(PART 3): 1970 table 2

D. Alccofine 1203

Alccofine 1203 is manufactured in India and is one of the upcoming micro fine materials of particle size finer than cement, fly ash, silica fume etc. Alccofine 1203 has unique properties in influencing the performance of concrete in both fresh and hardened state due to its effective particle size distribution. In the concrete mix design with alccofine 1203, the early strength is found similar or increased as that of silica fume. The reason being, alccofine triggers the initial reaction during hydration of cement. Also, the latter age strength of concrete increases as the alccofine 1203 consumes the by- product calcium hydroxide that is released from the hydration of cement. Thus it forms extra amount of C-S-H gel which is similar to other pozzolans. The computed particle size distribution of alccofine (PSD) is approximately 12000cm²/g. It can be replacedwith cement even up to 70% for replacement level as per requirement. Properties of alccofine 1203 are presented in table 5.

Table 5.Properties of Alccofine 1203

Properties	Test results
Specific gravity	2.9
Bulk density (kg/m³)	700-900[8]
Fineness (cm²/g)	>1200[10]

E. Fly ash

Fly ash is a by-product of combustion of coal, composed of fine particles that are escaped out of the boiler along with the flue gases. Fly ash is generally captured by electrostatic precipitators and the bottom ash is removed from the bottom of the boiler. Fly ash is generally stored at coal power plant or dumped in landfills. Flyash which are recycled is often used as pozzolan to produce hydraulic cement and as a replacement or partial replacement for Portland cement in production of concrete. Fly ash particles are commonly spherical in shape and size ranges from 0.5 μm to 300 μm. This study involves the use of fly ash as a partial replacement of cement with the 30% addition. A property of Fly Ash is listed in table 6.

Table 6. Properties of Fly Ash

Properties	results	Technical reference
Specific gravity	2.2	IS 3812(PART I):2013
Moisture content (%)	0.12	IS 3812(PART I):2013 CLAUSE 6.2
Particles retained on 45μ sieve	0.31	IS 3812(PART I):2013 TABLE 2

F. Durability Aspect

Durability is the ability of the material to withstand significant deterioration. A reliable material helps in reducing wastes and the environmental impacts of repair and replacement. Durability properties of concrete are to measure the longevity and ability of concrete to withstand severe weathering condition. It is an important factor in identifying how sustainable the structure will ultimately be. Durable concrete is relatively impermeable as long as it remains un-cracked.

G. Durability Tests on Concrete

Durability test includes, rapid chloride penetration test (RCPT), water absorption test, carbonation test and water permeability test

a. Rapid Chloride Penetration Test

The resistance of concrete to salt attack is assessed by rapid chloride penetration test. Rapid chloride penetration test is done to estimate the amount of chloride ions penetration in concrete. The test set up is shown in figure 1. Cylindrical concrete specimen of size 100 mm long and 50mm diameter is casted and cured for 28 days in chloride free water. The test apparatus consists of two cell compartments, one cellis filled with 3% NaCl solution which is cathode and the other one is filled with NaOHsolution of 0.3 normality(N) serves as anode. Power source of 60V direct current is continuously supplied for 6 hours. The output is observed in terms of electric charge passed into the specimen measured in Coulombs from the computer. The standard penetration rate of chloride ion in presented in table 7.

Table 7. Rapid Chloride Penetration Rate

Charge passed (Coulombs)	Chloride ion permeability
> 4000	High
2000-4000	Moderate
1000-2000	Low
100-1000	Very Low
< 100	Negligible

Fig.1.Rapid Chloride Penetration Test

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b. Water Absorption Test

Moisture penetration is one of the factors affecting the durability of concrete. Concrete as a porous material which can allow water to migrate through it, corroding steel reinforcement, bringing in harmful chemicals. So it is a predominant factor to be determined to assess the quality of concrete. For water absorption test, cube specimen of size of 150 mmx150 mmx150 mm was casted and immersed in water for 28 days. The specimens are ovendried for 24 hours at the temperature of 110˚C until the mass becomes constant and again weighed at room temperature.

$$\%\text{water absorption} = \frac{w_1 - w_2}{w_2} \text{ x } 100$$

w_1= oven dried weight of specimen

w_2 = final weight of specimen

Fig. 2.Water Absorption Test

c. Carbonation test

Carbonation directly relates with the corrosion of steel reinforcement and shrinkage. To avoid the future corrosion of steel reinforcement and the development of shrinkage cracks, carbonation test is very important. This test involves measuring the depth of carbonation of concrete. Specimen with size 150 mmx150 mmx150 mm cube was casted with 0%, 4%, 8% and 12% alccofine 1203. Measuring the depth of carbonation of the sample at different percentages of alccofine. Phenolphthalein is used as an indicator and specimen tester turns pink color it was denoted as Un-Carbonated and if it colorless implies that the specimen is carbonated.

d. Water Permeability Test

Evaluating the resistance of concrete against the penetration of water under hydrostatic pressure is determined by water permeability test. Depth of water penetration is measured by using water permeability test apparatus. Specimens of size 150 mm x 150 mm x 150 mm were used. This method is used to measure the resistance of concrete against penetration of water under a pressure of 0.5 N/mm² continuously for 48 hours. After the pressure is released the cube is split with the help of compression testing machine and depth of penetration of water is marked and measured. Water permeability test set up is shown in figure 3.

Fig. 3. Water Permeability Test

IV. RESULT AND DISCUSSION

In this section, the results of different tests performed to assess the durability aspects of concrete are presented.

A. Rapid Chloride Penetration Test

Rapid chloride penetration test on concrete is done to estimate the amount of chloride ion penetration. Table 8 indicates the results of total charge passed to assess the chloride ion penetration into concrete specimens.

Table8. Rapid Chloride Penetration Test

Mix	Voltage (V)	Charge passed (Coulomb)	Test duration (hours)	Permeability class
FA0	60	1159	6	Low
FA4	60	325	6	Very low
FA8	60	297	6	Very low
FA12	60	258	6	Very low

From RCPT results, the charge passed in coulombs get reduced that is permeability class changed from low to very low for 30% fly ash with 12% alccofine 1203 combination of the mixture.

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B. Water Absorption Test

Table 9 indicates the amount of water absorbed in percentage which is the difference in weight of specimen and oven dried weight.

Table 9.Water Absorption Test Results

Mix	Oven dried weight (kg)	Weight of specimen (kg)	% Water absorption
FA0	8.85	8.9	0.56
FA4	8.559	8.581	0.256
FA8	8.551	8.572	0.244
FA12	9	8.829	0.23

From water absorption test results, 30% fly ash with 12% alccofine 1203 mix has low percentage water absorption compared to other mix proportions.

C. Carbonation test

Measuring the depth of carbonation at the different sections of the sample with different percentages. Phenolphthalein is used as an indicator and specimen tester turns pink color it was denoted as un-carbonated and if it colorless implies that the specimen is carbonated. From the figure 4, it is clearly seen that the specimen remains pink color indicating the un-carbonated specimen.

Fig.4. Carbonation Test

D. Water Permeability Test

This method is used to measure the resistance of concrete against penetration of water under pressure of 0.5 N/mm^2. After the pressure is released it is divided and depth of penetration of moisture is measured. Moisture penetration depth of concrete specimen at different percentages of fly ash and alccofine mix is listed in table 10.

Table 10.Water Permeability Test Results

Mix	Depth of Penetration (cm)
FA0	2.16
FA4	1.625
FA8	1.53
FA12	1.4

From the results, it is clear that permeability gets reduced for 30% fly ash with 12%alccofine 1203 combination. This may be attributed to increased addition of fines content in the mix.

V. SCANNING ELECTRON MICROSCOPE

A scanning electron microscope is an important analysis to examine old and deteriorated concrete quality assurance scanning electron microscopy provides important information about:

Degree of hydration of cement

Formation and distribution of hydration products

Adhesion to aggregates

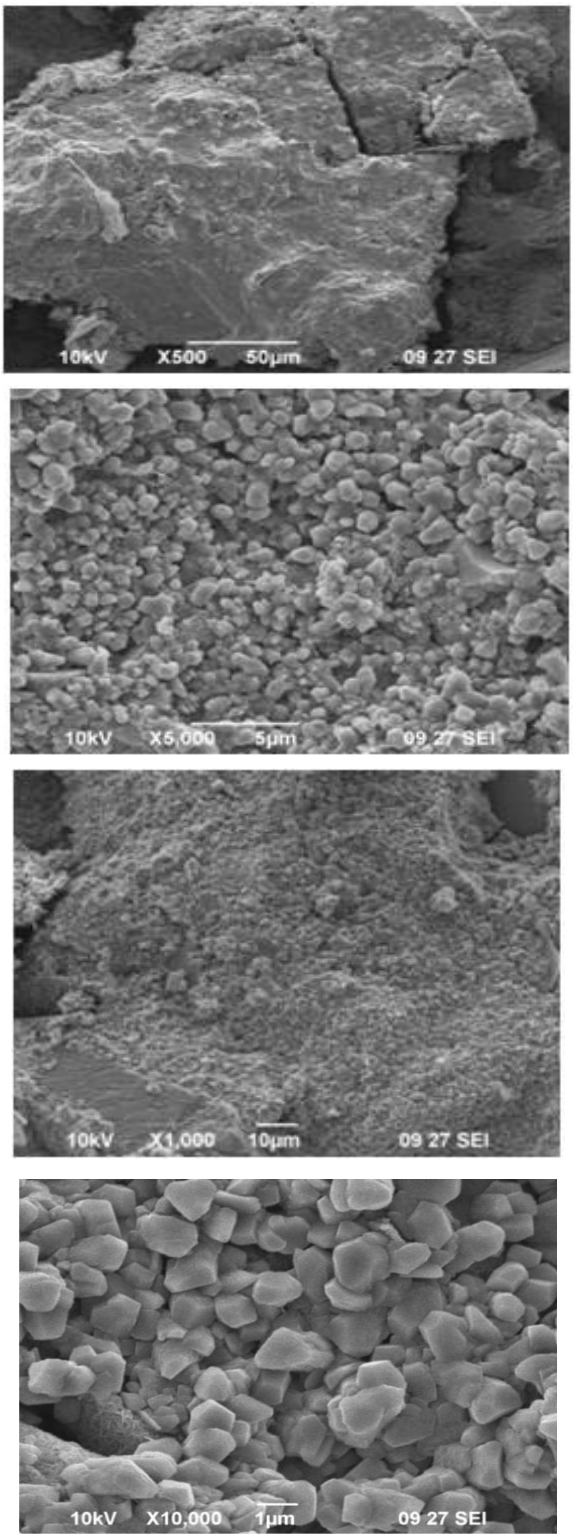

Fig. 7.Scanning Electron Microscope Analysis

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The collected samples were carbon coated and analyzed using a scanning electron microscope (SEM) in the back scattered electron mode with an accelerating voltage of 20Kev. The back scattered Intensity was set to the same parameter for each sample. The SEM analysis of concrete with 30% replacement of fly ash and 12% alccofine 1203 is shown in the Fig.8. From the picture, it is inferred that a surface coating of the hydrated reaction products are seen and it forms a dense structure in the mix. Also it is seen a needle like structure is formed as reaction product as indicated by the arrow.

VI. CONCLUSIONS

Major conclusions drawn from this study are presented as below.

1. Fly ash and alccofine replaced partially with cement, in concrete improves the durability aspects of concrete compared with the nominal mix.

2. The water absorption and permeability decreases with increase in alccofine content.

3. From RCPT results, the charge passed in Coulombs get reduced that is permeability class changed from low to very low.

The durability aspects of concrete for a mix proportion consisting of 30 % fly ash and 12 % alccofine replaced with cement was best among all other combinations.

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