Study of Mechanical and Durability Properties of High Performance Self Compacting Concrete with Varying Proportion of Alccofine and Fly Ash

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Abstract - The aim of this Study is to evaluate the performance of concrete (HPSCC) 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 mixtures in terms of Compressive strength, Flexural Strength, Split Tensile strength, Residual Compressive strength at elevated Temperature and Chloride Attack test at various ages. Result show that concrete incorporating Alccofine and fly ash have higher compressive strength and Alccofine enhances the durability of concretes and reduced the chloride diffusion.

KEYWORDS- Alccofine, durability, Compressive strength, Flexural Strength, Split Tensile strength, Residual Compressive strength, Chloride Attack tests.

I. INTRODUCTION

Concrete is a widely used construction material for various types of structures due to its structural stability and strength. The Ordinary Portland Cement (OPC) is one of the main ingredients used for the production of concrete and has no alternative in the civil construction industry. Unfortunately, production of cement involves emission of large amounts of carbon-dioxide gas into the atmosphere, a major contributor for green house effect and the global warming, hence it is inevitable either to search for another material or partly replace it by some other material(2). Fly ash is widely used in blended cements, and is a byproduct of coal-fired electric power plants. Utilization of waste materials such as fly ash in construction industry reduces the technical and environmental problems of plants and decreases electric costs besides reducing the amount of solid waste, greenhouse gas emissions associated with Portland clinker production, and conserves existing natural resources. Despite the benefits of fly ash, practical problems remain in field application. At early stages of aging, the strength of concrete containing a high volume of fly ash as a partial cement replacement is much lower than that of control concrete, due to the slow pozzolanic reactivity of fly ash.

Newly developed admixtures allow lowering the water/binder ratio to very low-levels without loss of workability. By incorporation of super plasticizers, the strength development of fly ash concrete can be accelerated to achieve the desired performance at early ages by adding accelerating agents such as Alccofine, metakaolin, slag, silica fume etc. ALCCOFINE 1203 is a specially processed product based on slag of high glass content with high reactivity obtained through the process of controlled granulation. Due to its unique chemistry and ultra fine particle size, ALCCOFINE1203 provides reduced water demand for a given workability, even up to 70% replacement level as per requirement of concrete performance. ALCCOFINE 1203 can also be used as a high range water reducer to improve compressive strength or as a super workability aid to improve flow. Alccofine1203 is known to produce a high-strength concrete and is used in two different ways: as a cement replacement, in order to reduce the cement content (usually for economic reasons); and as an additive to improve concrete properties (in both fresh and hardened states). Therefore, utilization of Alccofine1203 together with fly ash provides an interesting alternative and can be termed as high strength and high performance concrete. I n this paper cement has been replaced by varying proportion of fly ash varying from 24.5% to 36 % and Alccofine varying from 4 % to 10% at a constant water/cement ratio keeping the binder content constant at 600 kg/m^3 to obtain effective high performance self compacting concrete.

II. EXPERIMENTAL INVESTIGATION

2.1. Materials

2.1.1. Cement

Ordinary Portland cement (OPC) 53 grade conforming IS-12269-2013, manufactured by Hathi Cement Limited is used. Cement is tested as per above codes and properties are listed in table-1

Table 1 Properties of 53 grade Ordinary Portland cement

Specific gravity of Cement	**3.15**
Consistency of cement	31%
Initial setting time	45 mins
Final setting time	260 mins
Compressive strength at 7 days	40 N/mm^2
Compressive strength at 28 days	58 N/mm^2
Fineness (% passing 90 micron IS sieve)	3%
Soundness of cement (mm)	1.3 mm

2.1.2 Fly ash

Fly ash (ASTM Class F) was obtained from Wanakbori thermal power station, kheda, Gujarat, India, having a specific gravity of 2.4 and fineness 280 m^2/kg .

2.1.3 Aggregates

(A) Coarse aggregates (20 mm and 10mm size) from local quarry have been used. The properties of grit indicates that it is suitable for use to produce the concretes. The bulk density, fineness modulus and specific gravity were within permissible limits specified by the Indian standards IS:2386- [1963].

Table 2 Properties of aggregates

Type of coarse Agg.	**Specific gravity**	**Void ratio**
20 mm single size	2.78	42.89 %
10 mm single size	2.73	44.27 %
Fine Aggregates<4.75 mm	2.64	29.19 %

2.1.4 Alccofine 1203

Ambuja cement Ltd., Mumbai.

ALCCOFINE 1203 is a specially processed product based on slag of high glass content with high reactivity obtained through the process of controlled granulation.

Table 3 Physical Properties of Alccofine 1203

Fineness (cm^2/gm)	**Specific gravity**	**Bulk Density (kg/m^3)**	**Particle size distribution (μ)**		
			d 10	**d 50**	**d 90**
12000	2.82	680	1.7 micron	4.4 micron	8.9 micron
Chemical Properties					
CaO	SO_3	SiO_2	Al_2O_3	Fe_20_3	MgO
33.6%	0.15%	33.6%	22.9%	1.8%	6.7%

2.1.5 Chemical admixtures

A new generation Poly-Carboxylic Ether (PCE) based super-plasticizer was used. This super-plasticizer is available as a medium brown colored aqueous solution. Its brand name is Glenium sky-784.Glenium sky-784 is free of chloride & has low alkali content. It is compatible with all types of cement.

2.2 Development of concrete mixes

After getting results from basic test of concrete ingredients like cement, fly ash, sand, coarse aggregate etc, a refernce mix design was finalized after several trials and errors. The binder content was kept constant at 600 kg/m^3 and water to cement ratio was also kept constant at 0.31 whereas proportion of cement, fly ash and Alccofine were varied as shown in the table 6. The super plasticizer dosage was kept constant at 1.5%.

Table 4 Trial Mix Design

Materials	**KG/Cubic meter**	**Sp Gravity**	**Volume**
CEMENT	450	3.15	142.85
FLY ASH	150	2.4	62.5
Sand <600 Micron	430	2.64	162.87
Sand >600 Micron to 4.75 mm	430	2.64	162.87
CA < 10 mm	650	2.78	233.81
CA-10 to 20 mm	150	2.73	54.94
Water	180	1	180
S.P Master Glenium 8784 (1.5%)	9		
			TOTAL = 1000

Table 5 Results Obtained

Slump Flow	L-Box	V funnel	T-50 time
660 mm	$H_2/H_1 = 0.91$	11 sec	4.5 sec

Compressive Strength	
7 days	28 days

32.88 MPa	54.37 MPa

Table 6 Varying contents of cement, fly ash and alccofine

Sr No (Mix Name)	Cement	Fly ash	Alccofine
A-0	**75%**	**25%**	**0%**
A-1	**67.5%**	**28.5%**	**4%**
A-2	**67.5%**	**26.5%**	**6%**
A-3	**67.5%**	**24.5%**	**8%**
B-1	**63.75%**	**32.25%**	**4%**
B-2	**63.75%**	**30.25%**	**6%**
B-3	**63.75%**	**28.25%**	**8%**
B-4	**63.75%**	**26.25%**	**10%**
C-1	**60%**	**36%**	**4%**
C-2	**60%**	**34%**	**6%**
C-3	**60%**	**32%**	**8%**
C-4	**60%**	**30%**	**10%**

2.3 Experimental Procedure

The specimen of standard cube of (150mm x 150mm x 150mm) and standard cylinders of (300mm x 150mm) and Prisms of (100mm x100mm x 550mm) were used to determine the compressive strength, split Tensile strength and flexural strength of concrete. Fresh properties of various mixes were determined based on the EFNARC guidelines for SCC. The specimens were demoulded after 24 hrs, cured in water for 7 & 28 days, and then tested for its compressive, split tensile and flexural strength as per Indian Standards. Chloride resistance test was performed after 28 days of normal curing for 56 days having 10 % of NaCl concentration. Also strength at elevated temperatures of 300°C AND 500°C were determined at 28 days at a heating rate of 5°C/min for a period of 2 hours.

III. RESULTS

Various fresh properties considering specifications given by EFNARC guidelines such as Slump flow, V-funnel time, T-50 cm time and L-Box were checked for various mixes.

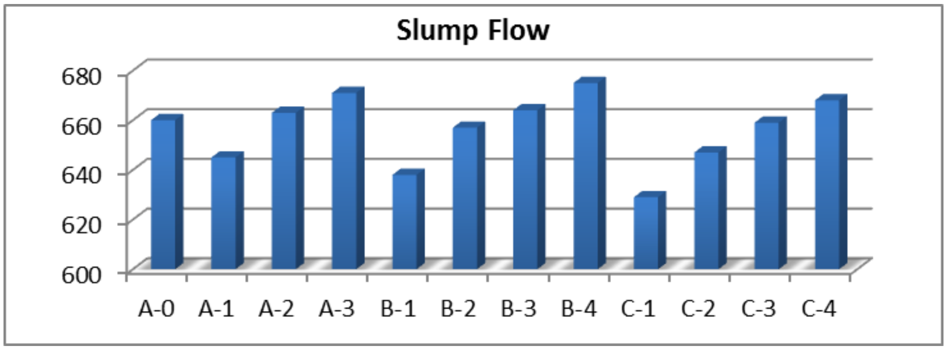

Figure 1 - Slump Flow Results

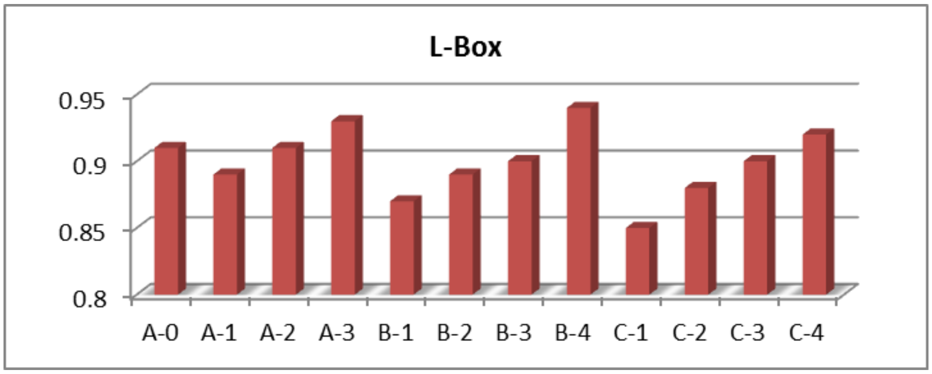

Figure 2 – L Box Results

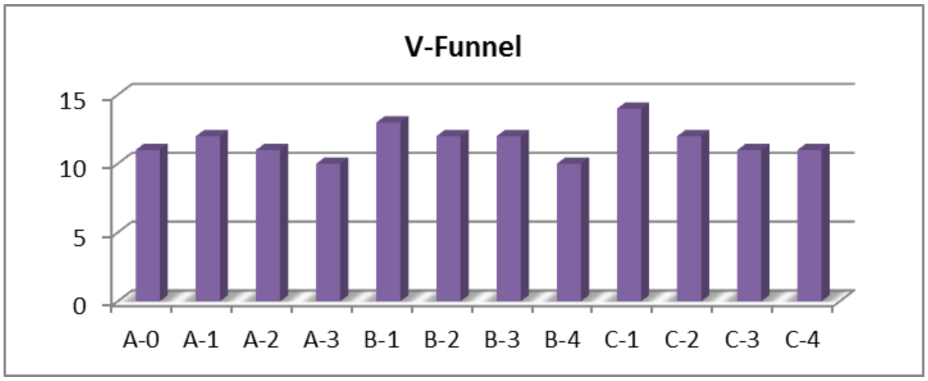

Figure 3 – V-Funnel Results

Compressive strength was determined for various mixes at 7 days and 28 days. Flexural strength and split tensile strength was determined at 28 days whereas strength at elevated temperature was determined at 28 days and chloride test was carried out at 56 days after normal curing.

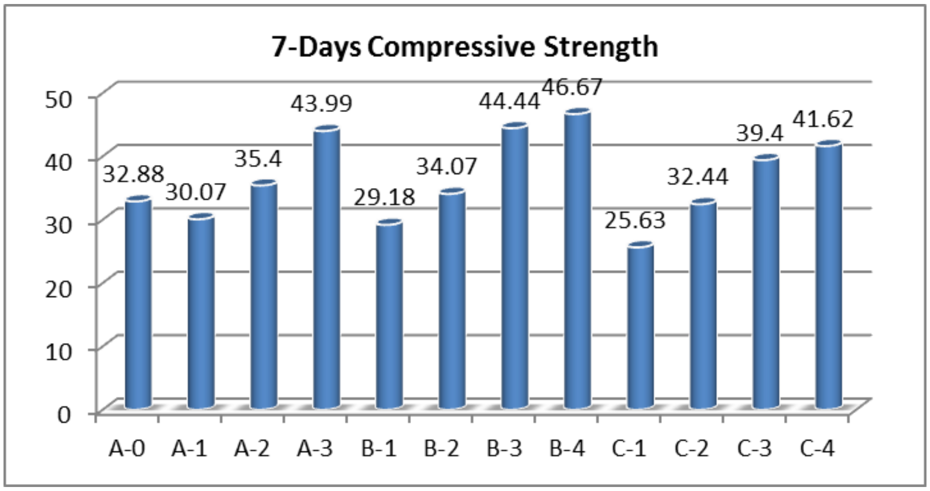

Figure 4-7 Days Compressive strength

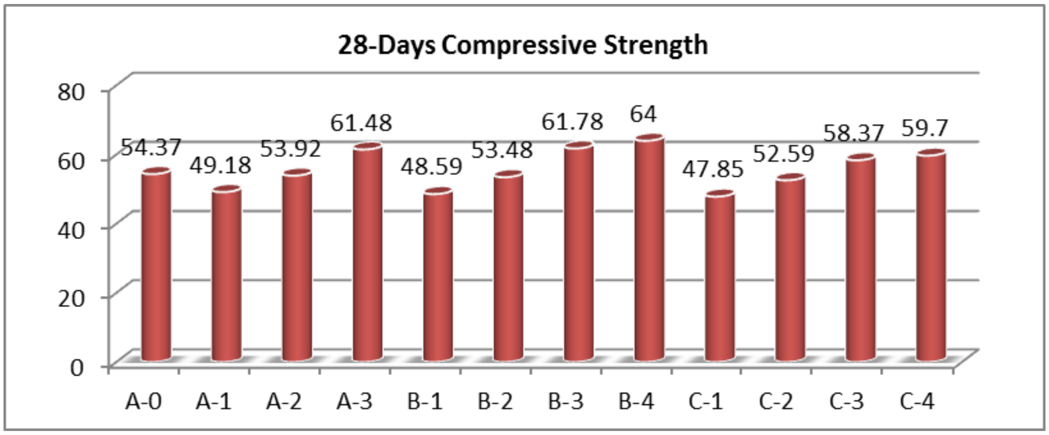

Figure 5 - 28 Days Compressive strength

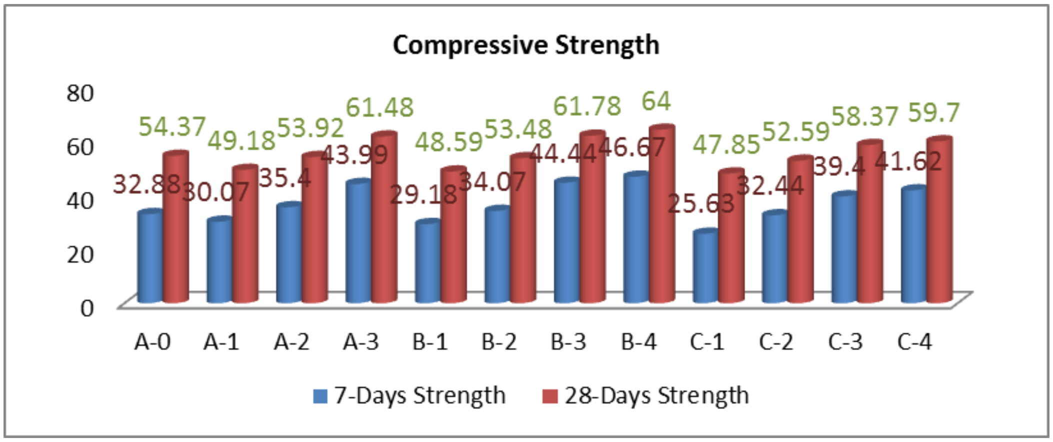

Figure 6 - Comparison of Compressive strength at different age

It can be observed that compressive strength increases to a great extent with increase in Alccofine content from 4 to 8 %. There isn't much variation in compressive strength from 8 to 10 %. From the above mixes most optimum mix is mix B-3 containing 28.25% of fly ash and 8 % Alccofine as it shows a maximum increase of 13.43% in comparison to mix B-2 containing 30.25% fly ash and 6% Alccofine.

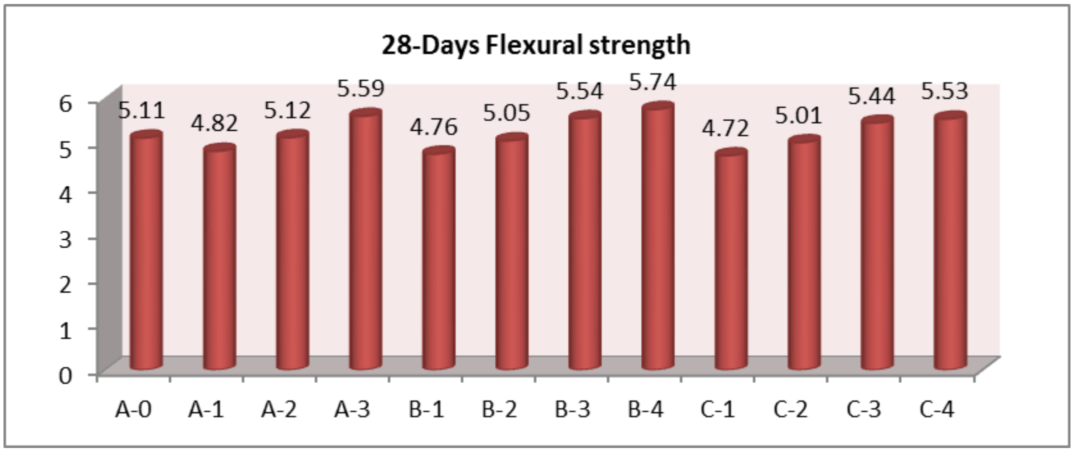

Figure 7 - 28 Days Flexural Strength

There is an increase in strength of 5.74%, 14.08% & 17.07% for mix B-2, B-3 & B-4 in comparison with mix B-1 for mixes having Alccofine percentages varying from 4% to 10% for mixes B-1 to B-4 which shows that Alccofine helps in increasing the Flexural strength. Also it can be observed that the rise in strength is tremendous from B-2 to B-3 which signifies that optimum percentage of Alccofine is 8%.

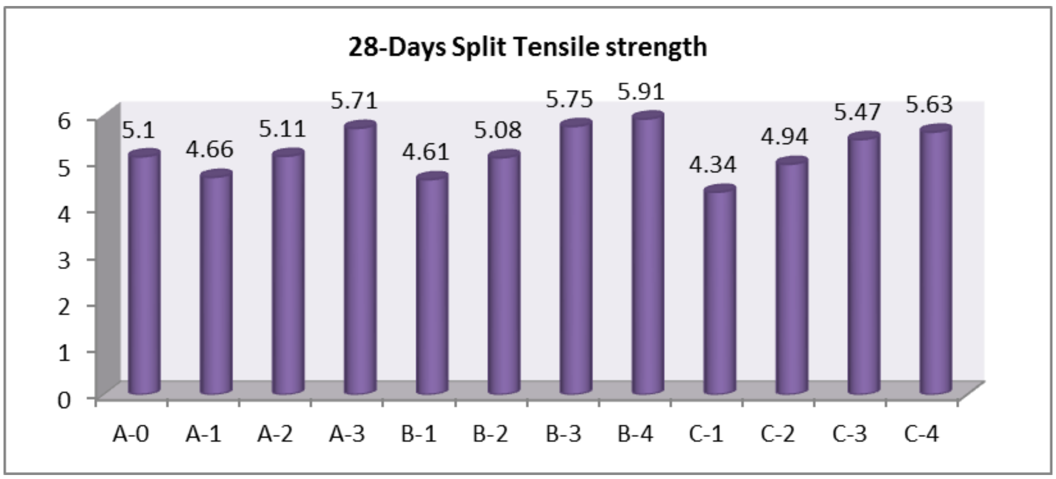

Figure 8 - 28 days Split Tensile Strength

Maximum tensile strength was obtained for mix B-4 containing 10% Alccofine and 26.25% fly ash. Results show that with increase in Alccofine percentage the value of Split tensile strength increases.

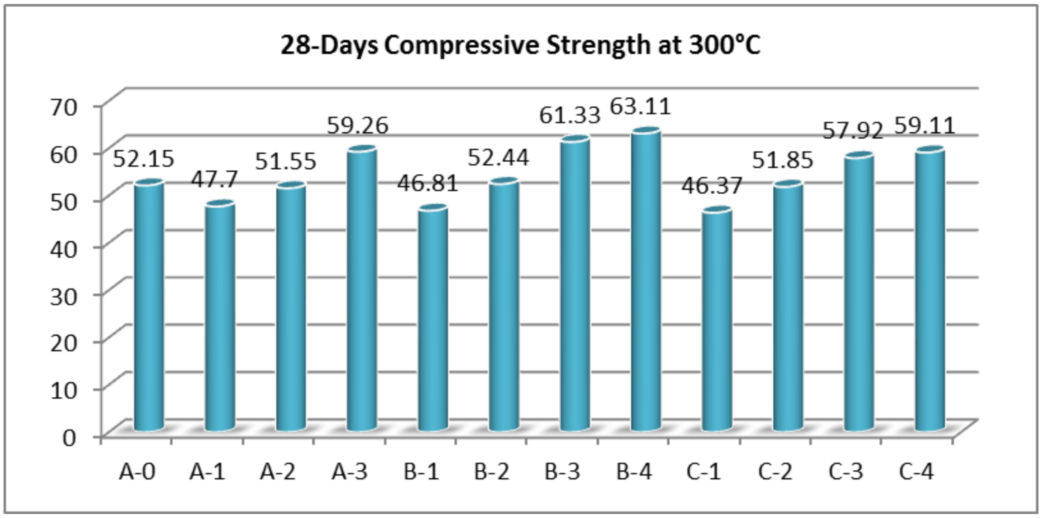

Figure 9 - 28-Days Compressive Strength at 300°C

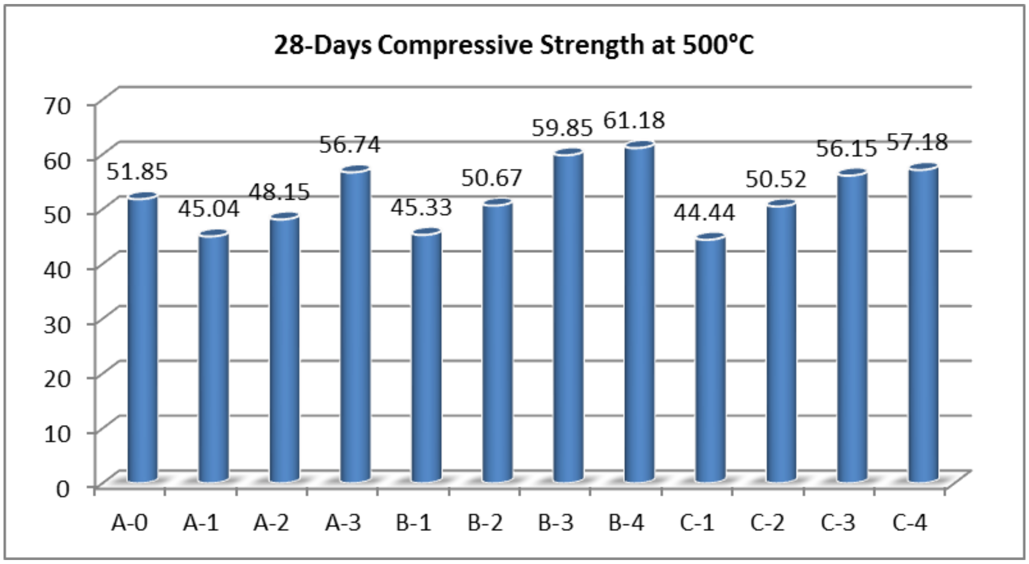

Figure 10 - 28-Days Compressive Strength at 500°C

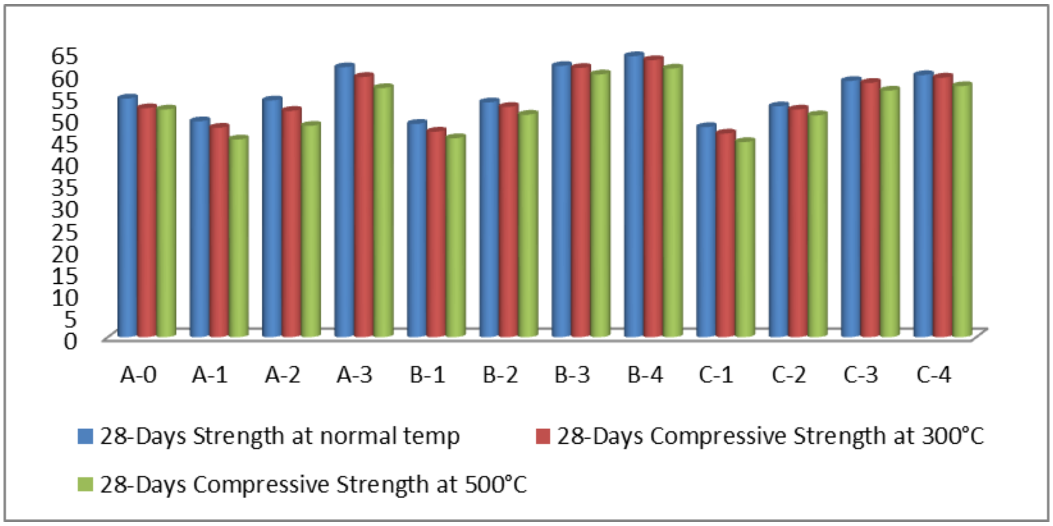

Figure 11 - Comparison of Compressive strength at varying Temperature

It can be concluded that with rise in temperature the compressive strength of cubes decreases gradually as shown in figure 11. Concrete subjected to rise in temperature at a rate of 5°C/min and maintained at a temperature of 300°C or 500°C for a period of 2 hours doesn't show much susceptibility to loss of strength, which indicates the durability of such concrete to heating at high temperature. At 500°C Maximum reduction in strength is observed for mix A-2 having a strength reduction of 10.72% whereas minimum loss of strength is observed for mix B-3 having a strength loss of 3.12%. This result further indicates that mix B-3 can be classified as most optimum mix having 8% of Alccofine and 28.25% fly ash. There is not much loss of strength for concrete specimens subjected to heating at 300°C. Maximum loss of strength is observed for mix A-2 having a compressive strength of 51.55 N/mm^2 showing a decrease in strength of 4.4%.

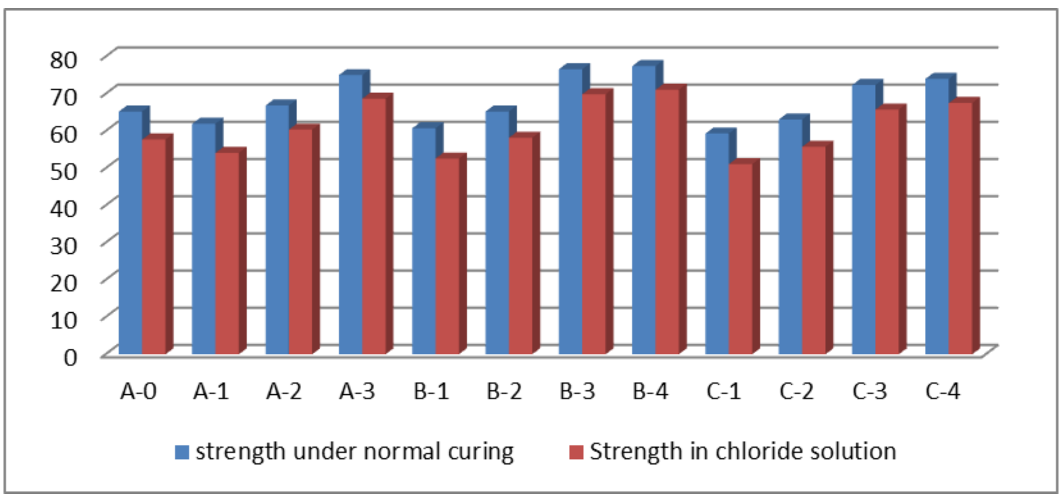

Figure 12 - Effect of chloride attack on compressive strength

Results show that with increase in percentage of Alccofine the resistance to chloride attack increases and thus one can say that Alccofine helps in reducing the susceptibility of concrete to reduction of strength under chloride attack. It can be also noted that with higher percentages of fly-ash the resistance to chloride attack reduces, which signifies that fly ash results in reduction of strength under chloride attack.

IV. CONCLUSION

Results show that with increase in percentage of Alccofine the resistance to chloride attack increases and thus one can say that Alccofine helps in reducing the susceptibility of concrete to reduction of strength under chloride attack. It can be also noted that with higher percentages of fly-ash the resistance to chloride attack reduces, which signifies that fly ash results in reduction of strength under chloride attack. It is observed that Alccofine helps to increase the slump flow in concrete. It can be further observed that higher the percentage of fly ash lesser is the slump flow. With the increase of fly ash percentage in concrete compressive strength decreases except for B-3 mix. Early age compressive strength is lower for mixes containing higher fly ash percentages. Maximum increase of 23.33% at 7 days is observed for mix B-2 to B-3 which shows that optimum percentage of Alccofine is 8%. Maximum compressive strength of 64 N/mm^2 at 28 days is observed for mix B-4 containing 26.25 % fly ash and 10 % Alccofine. Maximum increase of 13.43% is observed from mix B-2 to B-3 at 28 days. With rise in temperature the compressive strength of concrete cubes decreases gradually with a maximum decrease in strength of 4.4% and minimum loss of strength of 0.72 % at 300°C & maximum strength reduction of 10.72% along with minimum loss of strength of 3.12% at 500°C. With increase in percentage of Alccofine the resistance to chloride attack increases and thus one can say that Alccofine helps in reducing the susceptibility of concrete to reduction of strength under chloride attack. Fly ash results in reduction of strength under chloride attack. From the above concrete mixes concrete with 8% Alccofine and 26.25% fly ash can be considered most optimum related to all aspects and thus can be effectively utilized for mass concrete production.

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