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Durability Studies of Fiber Reinforced Self Compacting Concrete with Alccofine

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Abstract

Self Compacting Concrete is a recently developed concept in which the ingredients of the concrete mix are proportioned in such a way that it can flow under its own weight to completely fill the formwork and passes through the congested reinforcement without segregation and self consolidate without any mechanical vibration. Efforts for improving the performance of concrete over the past few years suggest that cement replacement materials such as Mineral admixtures can improve the strength and durability characteristics of concrete. Alccofine is pozzolanic material and the ultrafine particles of alccofine provide better workability, strength as well as economical one. In this study was carried out to study the effect of Alccofine on steel fiber reinforced self compacting concrete. SCC mixes incorporating different percentages (0%, 10%, 20%, 30% and 40%) of alccofine by weight of cement along with 1% of steel fiber. Super plasticizer Conplast SP430 was used to maintain workability with constant Water-cement ratio. Strength properties was determined such as compressive, split tensile, Impact Resistance and also the durability properties was determined such as water absorption, acid resistance, sulphate attack, sorptivity and microstructure analysis. This is done to determine the efficiency and optimum percentage of replacement at which maximum strength is achieved.
Keywords: SCC, Alccofine, steel fiber, Strength properties, Durability

I. INTRODUCTION

Self-compacting concrete (SCC), is defined as the concrete which can be placed and dense into every corner of formwork, purely by means of its self-weight, by eliminating the need of either external energy input from vibrators or any type of compacting effort.

Self Compacting Concrete has been developed in Japan to improve the durability and uniformity of concrete in 1988 by Okamura and Ozawa. The mix composition is chosen to satisfy all performance criteria for the concrete in both the fresh and hardened states. Self compacting concrete is a concrete which flows by its own weight. So it does not requires compaction at site or concrete plants. To achieve this, mineral admixtures and super plasticizers, viscosity modifying admixture are used in mix as chemical admixtures for design of concrete. The main difference between conventional concrete to self compacting concrete is the pore value in concrete mass i.e. highly eliminated pores. In this regards, mass of fine aggregate is typically equal or more compare to coarse aggregate. And selection of coarse aggregate size also gives impact on requirement of self compacting.

There are many advantages of using SCC especially when the material cost is minimized which include, Reducing the construction time and labour cost, Eliminating the need for vibration, Reducing noise pollution, Improving the filling capacity of highly congested structural member.

II. MATERIALS

Experimental program has been designed to provide sufficient information for ascertaining the quality of Alccofine based reinforced self compacting concrete. To evaluate the behavior of Alccofine based reinforced self compacting concrete, both mechanical strength and durability aspects have been studied in this investigatio

A. Cement

Ordinary Portland cement-53 grade have used in examination. The cement was tested according to IS 4031:1988. It confirmed to IS 12269:1987.

B. Fine Aggregate

The fine aggregate used in the experimental investigation was natural river sand confirming to Zone II of IS 383-1987. Sand used in the work which has particle size less than 4.75 mm.

C. Coarse Aggregate

Crushed granite aggregate particles passing through 12.5mm and retained on 10mm I.S sieve used as the natural aggregate which met the grading requirement of IS 383-1970.

D. Alccofine

ALCCOFINE 1203 is a particularly processed product based on slag of high glass content with high reactivity obtained through the process of controlled granulation. ALCCOFINE 1203 have used conforming to ASTM C989-99.

E. Steel Fiber

Steel fibers can improve the compressive strength, tensile strength and flexural strength of concrete. It is also enhance the durability properties of concrete. The crimped steel fibres are used in this study. The length of the fibre is 10mm and the aspect ratio is 25. The shape of the fibre helps in better bonding with the concrete.

F. Super Plasticizer

Generally super plasticizers are used to improve the workability and reduce water content. According to this the super plasticizer Conplast SP 430 is a high range water reducing agent. There are difficulties and limitations to obtain high workability in the field for a given set of conditions. Specific gravity and Chloride content of super plasticizer are 1.220 to 1.225 at 300ºC and Nil as per IS: 456 respectively.

III. MIX PROPORTION

The very first step to assure the flow requirement of SCC is to determine the optimum dosage of alccofine and super plasticizer. Various mixes were prepared and tested to satisfy the EFNARC guidelines. Finally a mix is chosen which gave fulfilling fresh properties. The addition of different percentage of admixtures would be done in this mix. The optimum dosage of alccofine is 30% and 1.5% of super plasticizer and 1% of steel fiber added to each mix.

The mix proportion was done based on the EFNARC guidelines. The mix design was carried out for M40 normal grade of self compacting concrete with alccofine as partial replacement of cement with a fraction of 0%, 10%, 20%, 30% & 40%.

Table - 3.1
Mix Ratio

WATER	*CEMENT*	*FINE AGGREGATE*	*COARSE AGGREGATE*
173 l/m^3	*496 kg/m^3*	*858 kg/m^3*	*841 kg/m^1*
0.35	*1*	*1.72*	*1.68*

Table - 3.2
Combinations of mixes

Concrete label	*Explanations*
SCC	*nominal mix*
SCC01	*Nominal mix + 1% fiber*
SCC02	*Nominal mix + 1% fiber + 10% alccofine*
SCC03	*Nominal mix + 1% fiber + 20% alccofine*
SCC04	*Nominal mix + 1% fiber + 30% alccofine*
SCC05	*Nominal mix + 1% fiber + 40% alccofine*

IV. EXPERIMENTAL WORKS

A. Fresh Properties

To study the fresh concrete properties of self-compacting concrete based on the parameters defining the fresh concrete. Many different test methods have been developed in attempt to characterize the property of Self-Compacting concrete.

Table - 4.1
Test Methods

Particulars	*Test methods*
Filling Ability	*Slump flow(diameter) Slump flow(time)*
Passing Ability	*L-box, J-Ring, U-box*
Segregation Resistance	*V-funnel*

According to EFNARC, a slump flow diameter varies from 650 to 800mm is acceptable for SCC. In slump flow ability and segregation resistance can be also resolute. Apart from slump flow L-Box test, U-Box test and V-Funnel test are also performed to evaluate flow ability, passing ability stability of SCC. The L-Box ratio is in range of 0.8-1.0. The V-Funnel time ranges from 8 to 12 seconds.

B. Durability Studies

1) Water Absorption

This test is done to know the relative porosity or permeability characteristics of the concrete. The test is carried out after 28 days of moist curing. The concrete specimens used for this test are 150 mm X 65 mm size cubes. The percentage absorption [6] is calculated using Eq. below.

$$\text{Absorption (\%)} = (W_2 - W_1)/W_1 X100$$

Where, W_1= weight of concrete specimen after complete drying at 105C

W_2= final weight of surface dry concrete specimen after immersion in water at least 24 hours

The concrete specimens are first dried for 24 hours at 105C in oven. The concrete specimens are removed from the oven and weighed which is considered as initial weight W_1. They are immersed in water again for 24 hours.

Fig. 4.1: Water Absorption Test

2) Sorptivity Test

The sorptivity can be determined by the measurement of the capillary rise absorption rate on reasonably homogeneous material. Water was used as the test fluid. The cylinders after casting were cured in heat curing chamber at 70°C for 24 hours. The specimen size 100mm dia X 50mm height after drying in oven at temperature of 100 + 10°C were drowned with water level not more than 5mm above the base of specimen and the flow from peripheral surface is prevented by sealing it properly with non-absorbent coating. The quantity of water absorbed in time period of 30 minutes was measured by weighting the specimen on a top pan balance weighting up to 0.1mg. The surface water on the specimen was wiped off with a dampened tissue and each weighting operation completed within 30 seconds. Sorptivity is material property which characteristics the tendency of a porous material to absorb and transmit water by capillarity. The cumulative water absorption (per unit area of the inflow surfaces) increases as the square root of elapsed time (t)

$I = S.t^{1/2}$

Therefore $S = I/ t^{1/2}$

Where,

S = Sorptivity in mm.

t = Elapsed time in mint.

I = $\Delta w/Ad$ Δw = change in weight = $W_2 - W_1$

W_1 = Oven dry weight of cylinder in grams.

W_2 = Weight of cylinder after 30 minutes capillary suction of water in grams.

A = Surface area of the specimen through which water penetrated.

d = Density of water.

Fig. 4.2: Sorptivity Test

3) Acid Resistance

The plain concrete specimens are exposed in the acid tank for required ages in months. After completion of exposure, the specimens are taken out of the acid tank. The required exposure ages considered for plain concrete specimens are 21, 56, 90 Days respectively.

The acid which is used for the test is Hydrochloric acid (HCl) solution having 5% concentration by volume of water. The solution is stirred every week and pH value of solution is measured after every 15 days. Modification in the pH is done by adding acid or water in the tank if pH value differs from 1. All the specimens are weighed before keeping them into the acid tank. After removing from the tank of acid solution after completion of exposure, respective specimens are wiped clean and weighed. This weight is considered as a final weight of concrete specimens in kg. Change in mass of concrete specimens after completion of exposure of corresponding age is evaluated. For evaluating the change in compression strength of concrete specimen after completion of exposure age in acid, the specimens are kept in saturated surface dry (SSD) condition.

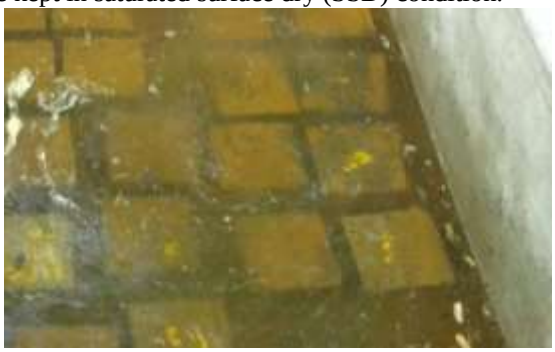

Fig. 4.3: Acid attack on concrete

4) Sulphate Attack

The plain concrete specimens are exposed in the acid tank for required ages in months. After completion of exposure, the specimens are taken out of the acid tank. The required exposure ages considered for plain concrete specimens are 21, 56, 90 Days respectively. The acid which is used for the test is Sulphuric acid (H_2SO_4) solution having 5% concentration by volume of water. The solution is stirred every week and pH value of solution is measured after every 15 days. Modification in the pH is done by adding acid or water in the tank if pH value differs from 1. All the specimens are weighed before keeping them into the acid tank. After removing from the tank of acid solution after completion of exposure, respective specimens are wiped clean and weighed. This weight is considered as a final weight of concrete specimens in kg. Change in mass of concrete specimens after completion of exposure of corresponding age is evaluated. For evaluating the change in compression strength of concrete specimen after completion of exposure age in acid, the specimens are kept in saturated surface dry (SSD) condition.

Fig. 4.4: Sulphate Attack

5) Rapid Chloride Penetration Test

The diffusion cell consists of two chambers. NaCl solution concentration 2.4M and NaOH solution concentration 0.3M are prepared. NaCl solution concentration 2.4M is filled in one chamber and in another chamber 0.3M NaOH solution is taken. The chloride ions were forced to migrate through the centrally placed vacuum saturated concrete specimen under an impressed DC voltage of 60 Volts as shown in the figure view of RCPT set up.

The procedure of this test method for measuring the resistance of concrete to chloride ion penetration has no bias because the value of this resistance can be defined only in terms of a test method. The method relies on the results from a test in which electrical current passes through a concrete sample during a six-hour exposure period. The interpretation is that the larger the Coulomb number, or the charge transferred during the test, the greater the permeability of the sample. The more permeable to the concrete, the higher the coulombs value; the less permeable to the concrete, the lower the coulombs value. The total charges passed through the cell in coulomb has been found in order to determine the resistance of the specimen to chloride ion penetration. The following formula, based on the trapezoidal rule can be used to calculate the average current flowing through one cell.

$$Q = \frac{1800}{2}(I_0+2I_{30}+2I_{60}+2I_{90}+2I_{120}+\ldots+2I_{300}+2I_{330}+I_{360}) \text{ (or)}$$

$$Q = 900(I_0+2I_{30}+2I_{60}+2I_{90}+2I_{120}+\ldots+2I_{300}+2I_{330}+I_{360})$$

Where,

Q = current flowing through one cell (coulombs)
I0 = Current reading in amperes immediately after voltage is applied, and
It = Current reading in amperes at t minutes after voltage is applied
The table 4.1 shows the rating of chloride permeability according to ASTM C 1202-97.

Table - 4.1
Rating of Chloride ion permeability

Charge passing in coulombs	*Chloride permeability rating*
>4,000	*High*
2,000 to 4,000	*Moderate*
1,000 to 2,000	*Low*
100 to 1,000	*Very Low*
<100	*Negligible*

Fig. 4.5: Rapid chloride permeability test setup

V. RESULT AND DISCUSSION

A. *Fresh Properties of SCC*

The workability of the concrete was mainly influenced by the water requirement at the time of mixing. For conventional concrete, it was mainly based on the maximum size of the aggregate used. When mineral admixture was added to the concrete, their physical characteristics mainly influenced the water demand as well workability of the mix. The slump value obtained for river and sea sand mixes are presented in table 5.1

Table - 5.1
Workability values of self compacting concrete

Testing Methods	*Units*	*Workability Values*						
		Permissible limits	*SCC*	*SCC01*	*SCC02*	*SCC03*	*SCC04*	*SCC05*
Slump Flow(Diameter)	*mm*	*650-800*	*670*	*653*	*657*	*660*	*665*	*670*
Slump Flow(Time)	*Sec*	*2-5*	*3*	*3.5*	*3.2*	*3*	*2.8*	*2.8*
V-Funnel	*Sec*	*6-12*	*7*	*8*	*8*	*7.8*	*7.3*	*7*
L-Box	*-*	*0.8-1.0*	*0.84*	*0.93*	*0.93*	*0.91*	*0.9*	*0.9*
U-Box	*mm*	*0-30*	*22*	*20*	*20*	*22*	*22*	*22*
J-Ring	*mm*	*0-10*	*6*	*7.5*	*7*	*7*	*6.5*	*6.5*

According to EFNARC, a slump flow diameter varies from 650 to 800mm is acceptable for SCC. In slump flow ability and segregation resistance can be also resolute. Apart from slump flow L-Box test, U-Box test and V-Funnel test are also performed to evaluate flow ability, passing ability stability of SCC. The L-Box ratio is in range of 0.8-1.0. The V-Funnel time ranges from 8 to 12 seconds.

The results shows that it is possible to achieve self compaction with different percentage of alccofine by the tests of slump flow, J - ring, L - box, U – box and V - funnel. The fiber inclusion reduced the fluidity, but presence of alccofine enhance the flow properties. Although results obtained from all of the mixes satisfy the lower suggested by EFNARC, all mixes had good flow ability and possessed self-compaction characteristics. Increasing the percentage of alccofine gives the better flow ability than the previous mix. We concluded that if we increase the proportion of admixture it higher up the rheology properties.

B. *Tests on Durability of Concrete*

1) Acid Resistance

Table - 5.2
Acid Resistance of SCC made Alccofine based Concrete & Steel Fiber

Type Of Concrete	*Specimen Weight (Kg)*			*Compressive Strength (MPa)*		
	Before curing	*After curing*	*Reduction of weight %*	*Before curing*	*After curing*	*Reduction of Strength %*
SCC	*7.33*	*6.63*	*9.54*	*42.2*	*41.13*	*2.52*
SCC01	*8.45*	*7.74*	*8.40*	*44.0*	*43.04*	*2.18*
SCC02	*8.61*	*7.93*	*7.89*	*44.3*	*43.42*	*1.97*
SCC03	*8.77*	*8.12*	*7.41*	*45.6*	*44.77*	*1.80*
SCC04	*9.12*	*8.43*	*7.56*	*48.1*	*47.36*	*1.53*
SCC05	*9.23*	*8.55*	*7.36*	*46.2*	*45.46*	*1.59*

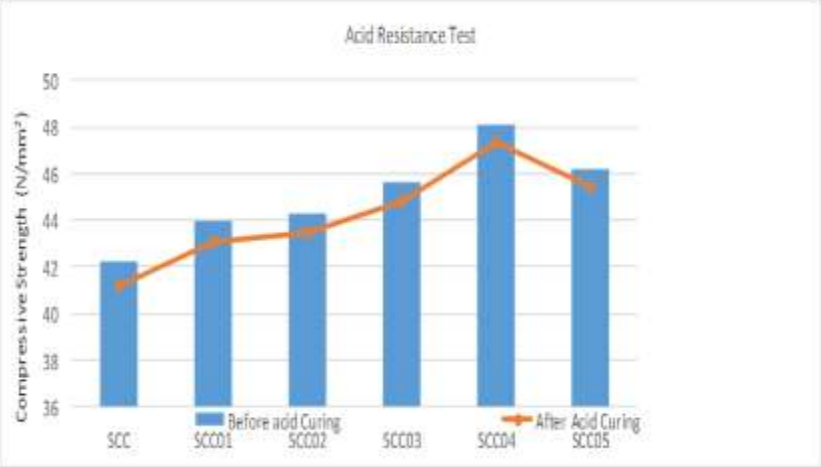

Fig. 5.1: Acid Resistance of SCC

From fig 5.1, it can be noted that the percentage loss of weight is less for all the mixes compared to control concrete mix SCC (Conventional) and SCC01. The minimum value of weight of weight loss was obtained for mix SCC04 at 90 days and it was 1.53% in acid attack solution. Adding steel fiber and alccofine to the normal concrete reduces the leaching of calcium salts from the impermeable surface there is increasing the acid resistance of SCC mix. There is slight increase in SCC05 concrete mix.

2) Sulphate Attack

Table - 5.3
sulphate Attack of SCC made Alccofine based Concrete & Steel Fiber

Type Of Concrete	*Specimen Weight (Kg)*			*Compressive Strength (MPa)*		
	Before curing	*After curing*	*Reduction of weight %*	*Before curing*	*After curing*	*Reduction of Strength %*
SCC	*7.542*	*6.810*	*9.679*	*42.3*	*41.14*	*2.73*
SCC01	*8.735*	*8.023*	*8.151*	*44.6*	*43.46*	*2.55*
SCC02	*8.818*	*8.110*	*8.029*	*44.8*	*43.86*	*2.09*
SCC03	*8.982*	*8.272*	*7.904*	*45.7*	*44.84*	*1.87*
SCC04	*9.227*	*8.545*	*7.391*	*48.0*	*47.21*	*1.64*
SCC05	*9.459*	*8.760*	*7.385*	*46.1*	*45.30*	*1.72*

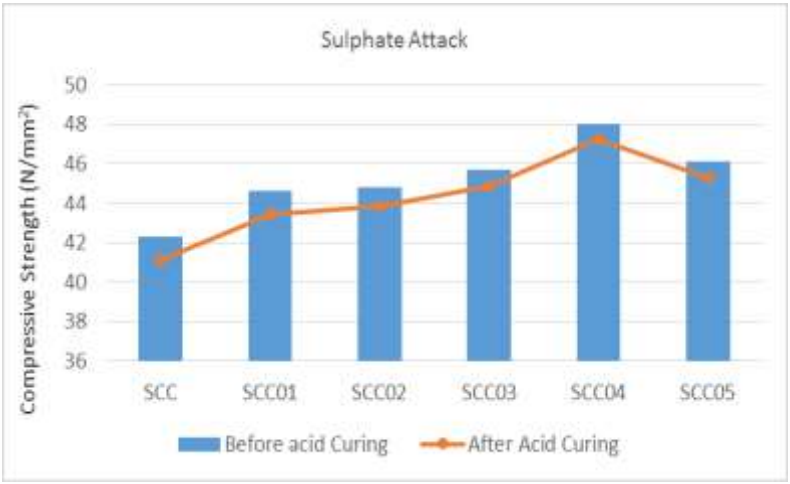

Fig. 5.2: Sulphate Attack on SCC

From fig 5.2, it can be noted that the percentage loss of weight is less for all the mixes compared to control concrete mix SCC (Conventional) and SCC01. It can be noted that the percentage loss in mass of reinforced self compacting concrete is higher than the conventional concrete mix. The percentage loss in mass of all the mixes is lower than the conventional and reinforced concrete. The lowest value of strength loss percentage for H_2SO_4 was obtained for SCC04 at 90 days and it was 1.64%, than all the concrete mixes. There is slight increase in SCC05 concrete mix.

3) Water Absorption

Table - 5.4
Water absorption at 28 days

S.no	*Combination*	*Dry weight (kg)*	*Wet weight (kg)*	*Percentage of water absorption*
1	*SCC*	*8.335*	*8.511*	*2.32*
2	*SCC01*	*8.731*	*8.932*	*2.21*
3	*SCC02*	*8.806*	*8.985*	*2.04*
4	*SCC03*	*8.761*	*8.923*	*1.85*
5	*SCC04*	*9.065*	*9.210*	*1.60*
6	*SCC05*	*8.981*	*9.109*	*1.43*

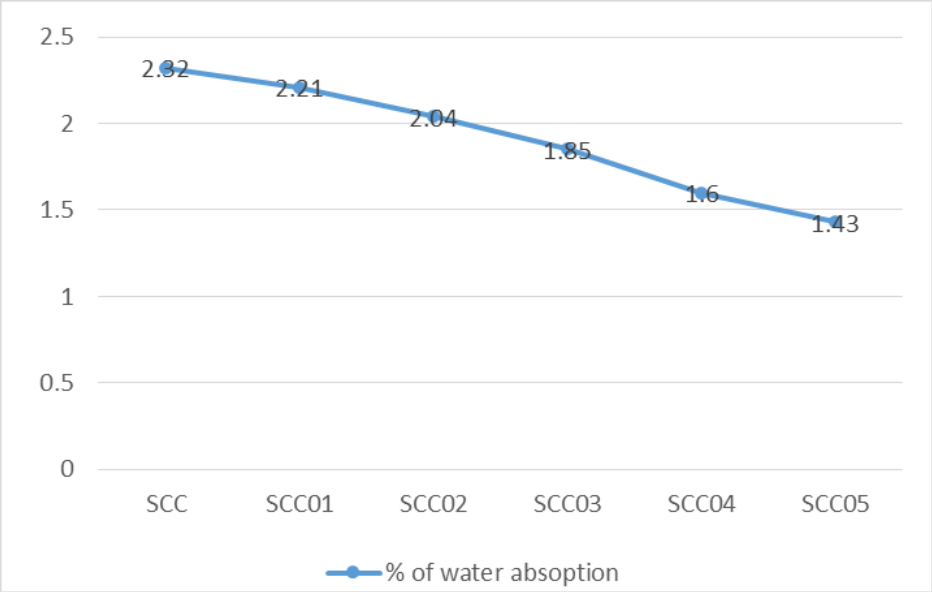

Fig. 5.3: Water Absorption at 28 days

From figure 5.3 the test result it is observed that the percentage of water absorption is 2.32% for reinforced self compacting concrete higher than the conventional concrete (2.12%). The SCC05 has the lowest water Absorption percentage than all combination mixes also conventional mix. Addition of admixture act as a filler to increase the density of concrete.

4) Sorptivity Test

Table - 5.5
Sorptivity at 28 days

S.No	*Combination*	*Dry weight in grams (W1)*	*Wet weight in grams (W2)*	*Sorptivity value in 10^{-8}mm/min $^{0.5}$*
1	*SCC*	*1184 .2*	*1185.8*	*2.63*
2	*SCC01*	*1218.5*	*1220.1*	*2.46*
3	*SCC02*	*1245.4*	*1246.3*	*1.47*
4	*SCC03*	*1397.2*	*1397.98*	*1.28*
5	*SCC04*	*1464.1*	*1464.75*	*1.06*
6	*SCC05*	*1480.4*	*1481.09*	*1.13*

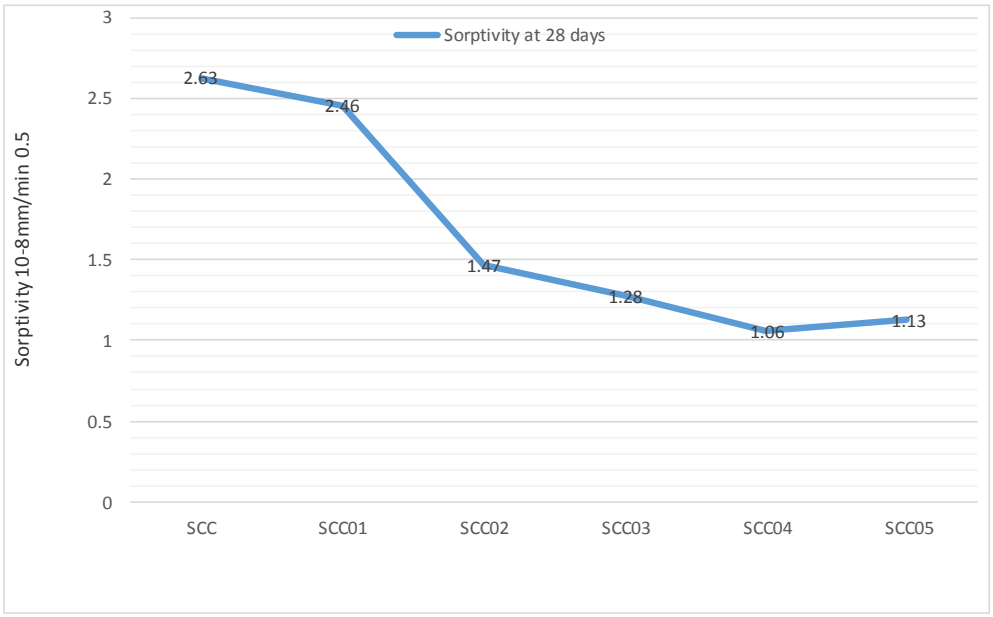

Fig. 5.4: Sorptivity results at 28 days

From figure 5.4 present the results obtained for all mixes including nominal mix for 28 days. The sorptivity values for all the mixes are lesser when compared to the control concrete mixes SCC (Nominal) and SCC01. The performance of the mixes SCC04 and SCC05 is found to be better compared to other mixes with sorptivity values about 1.06% which is lower than the conventional concrete mix.

5) Rapid Chloride Permeability Test

The permeability of concrete to the penetration of chloride ions is an important parameter influencing the durability properties. The presence of chloride ion in concrete adversely affects the concrete as well as reinforcement. The ingression of these chloride ions leads the expansion of concrete by 2 to 2.5 times than that caused by the penetration of water. This test is conducted to evaluate the resistance of concrete to chloride ion penetration.

Table - 5.6
Rapid Chloride Permeability Test result

S.No	*Sample*	*Chloride permeability (Coulombs)*	*Remark*
1	*SCC*	*5582*	*High*
2	*SCC01*	*4985*	*High*
3	*SCC02*	*2985*	*Moderate*
4	*SCC03*	*3554*	*Moderate*
5	*SCC04*	*3985*	*Moderate*
6	*SCC05*	*5661*	*High*

From the result, it can be seen that the charge passed to concrete decreases due to the presence of alccofine. At the age of 28 days up to 20% and 30% of alccofine and 1% of steel fiber there is a lower level of chloride ion penetration and the corrosion rate is moderate compared to other mix.

VI. CONCLUSION

The following conclusions are drawn for feasibility study conducted on reinforced self compacting concrete with alccofine as partial replacement of cement includes,

The conclusion based on the limited observations from the present investigation on study of compressive, split tensile, flexural strength, water absorption and acid resistance of the concrete made using alccofine as partial replacement of cement at different percentages with steel fiber (1%) and constant dosage of super plasticizer (1.5%).

1) In fresh properties that is possible to achieve self compaction with different percentage (10%, 20%, 30% and 40%) of alccofine by the results of slump flow, J - ring, L - box, U – box and V - funnel. FRSCC mix (SCC01) also satisfy the rheology properties but lower than control mix. However, the fiber inclusion reduced the fluidity, but presence of alccofine enhance the flow properties.
2) Water absorption and sorptivity is found to be lower in case of reinforced mix (SCC01) when compared to the nominal (SCC) mix and the other mixes gave lower results which has alccofine. Addition of alccofine enhance the durability of self compacting concrete particularly the resistance to acid attack as well as sulphate attack.
3) In RCPT, the rate of corrosion decreases and chloride penetration also decreases for 20% and 30% replacement of cement by alccofine so that durability of the concrete increases.

4) In summary, by comparing all the observed properties, 30% of cement replacement by Alccofine provided the best performance. Use of this admixture is eco- friendly also economical one.

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