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Durability and Cementing Efficiency of Alccofine in Concretes

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***Abstract* - In the modern era, many research works are being carried out throughout the world for finding out a suitable cementitious material for the replacement of cement. In this order fly ash, silica fume, GGBS, Metakaoline, Micro materials, Quartz powder, etc. are tried out for replacing partially or full of cement in concrete. A new ultrafine material called Alccofine is tried out for replacing partially in this thesis. M20 grade of concrete is intended to study the Durability And Cementing Efficiency of Alccofine in concretes by replacing the cement with Alccofine of various percentages such as 5%, 10%, 15%, 20%. Design mix is made for M20 grade and cubes were cast with various percentage of alccofine as said above. In this phase-II, all the durability studies are carried out as per as per Indian standards to determine the properties. The results are presented and discussed. It is observed that 15% of alccofine replacement with the cement is yielding good strength as compared to other mix percentages. Also it is determined that the cementing efficiency of alccofine is good in earlier ages of concrete.**

Key words: Alccofine, cementing efficiency, Acid Resistant Test, Sulphate Attack Test, Chloride Attack Test, RCPT.

1. INTRODUCTION

1.1 General

Creating quality concrete in the present climate does not depend solely on achieving strength property. Improving the durability of the concrete and reduce porosity to sustain a longer life span and producing a greener concrete are becoming one of the main criteria in obtaining a quality concrete. Compressive strength of concrete is important because the main properties of concrete. Compressive test is the most common test conducted on the hardened concrete because it is an easy test to perform and most of the desirable characteristic properties of concrete are qualitatively related to its compressive strength. In this work the effect of ultra fine slag (Alccofine) replacement on the mechanical properties of high strength concrete is studied. It has been found that use of ultra fine slag not only improves the compressive strength of concrete but also improve the workability and fluidity of the mix. It also shows segregation resistance and improves reliability and durability of the reinforced concrete structures.

1.2 ALCCOFINE 1203

Alccofine-1203 is a specially processed product based on high glass content with high reactivity obtained through the process of controlled granulation. The raw materials are composed primary of low calcium silicates. The processed with other select ingredients results in controlled particle size distribution (PSD). The computed blain value based on PSD is around 12000cm^2/gm and is truly ultra fine. Due to its unique chemistry and ultra particle size, ALCCOFINE-1203 provides reduced water and 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.

1.2.1 Necessity of Alccofine 1203

- HSC is required as a construction material in special structures like tunnels in sea beds, off-shore piers and platforms, jetties and ports, and tall structures etc..,
- It can be used as an alternative material for cement.
- To reduce the usage of cement to certain limit.

Table1.1Chemical Composition and Physical properties

Chemical Analysis	Mass %	Physical Analysis	Range
CaO	30- 34	Bulk Density	600 -700 kg/m^3
Al_2O_3	18 -25	Surface Area	12000 cm^2/gm
Fe2O3	0.8 3.0	Particle Shape	Irregular
SO3	0.1-0.4	Particle Size,d10	<2mm
MgO	6-10	d50	<5mm
SiO2	30-36	d90	<9mm

2. EXPERIMENTAL INVESTIGATION

2 .1 Materials

Cement, fine aggregate, coarse aggregate and water are the common ingredients used. In addition ALCCOFINE 1203, this is to increase the strength of concrete which is provide workability and other advantages to the concrete.

2.1.2 Cement

Cement used for all specimen was ordinary Portland cement of 53 grade confirming to IS: 12269:2013 was used.

Fig 2.1 OPC-53 grade cement

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 05, May-2016

2.1.3 Alccofine 1203

As can be seen in the chemical composition and physical characteristics listed below, ALCCOFINE 1203 has got the unique chemical composition mainly of CaO 30-34% and SiO2 30-36%. Physically the product is unique with regards to its particle size distribution as shown.

Fig 2.2 Alccofine 1203

Table 2.1 Chemical Composition of Alccofine

Chemical Analysis	Mass %
CaO	33
Al2O3	22.1
Fe2O3	2.1
SO3	0.3
MgO	7.5
SiO2	35

2.1.4 Fine Aggregate

The fine aggregate is as per the IS 383-1970 code conforming that is coming under ZONE III.

2.1.5 Coarse Aggregate

The coarse aggregate conforming to IS: 383-1970 was used. The size of aggregate used was 12mm to 20mm.

2.1.6 Water

Potable water was used for mixing concrete and curing the specimen.

2.1.7 Concrete

Ordinary Portland Cement 53 grade is used. The physical properties and tests of cement are carried out in accordance with procedure laid down in IS: 1489. The maximum size of aggregate shall be 20mm and the size of fine aggregate ranges between 0 and 4.75mm. After casting the specimen need to be allowed to cure in real environmental conditions for about 28 days so as to help the concrete to stabilize its own properties like compressive strength. The strength of concrete under axial compression is determined by loading on a standard cube (150 x 150 x 150 size).

2.3 PRELIMINARY TESTS ON MATERIALS

Basic tests like specific gravity and sieve analysis were carried out on the materials used. Testing was done and the results were tabulated as given below.

2.3.1 Specific Gravity of Material

Table 4.2 Specific Gravity Test Result

Sl. No	Name of the Material	Specific Gravity
1.	OPC Cement	3.07
2.	Alccofine	2.8
3.	Fine aggregate	2.63
4.	Coarse aggregate	2.67

2.3.2 Sieve Analysis

The sieve analysis done by the soil mechanics lab. As per the IS 383-1970 Code conforming that fine aggregate is coming under ZONE III.

2.3.3 Slump Test

The trial mix get the suitable workability of slump value is 70mm.

Fig.2.3 Slump test on M20 grade of concrete

2.3.4 CastingofSpecimens

Fig.2.4 Casting of Cylinder

Fig.2.5 Casting of Cube

2.4 MIX DESIGN PROPORTIONS FOR M20 GRADE

Table 2.4 Mix Proportion for M20 Grade of Concrete

Sl. No	Cement	F.A	C.A	W/C
1	384 kg/m³	646 kg/m³	1167 kg/m³	0.5

2.5 COMPRESSIVE STRENGTH

The compressive strength is the capacity of a material or structure to withstand loads tending to reduce size.

International Journal of Engineering Research & Technology (IJERT)
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Vol. 5 Issue 05, May-2016

Fig. 2.6 Compression Test setup

2.6 DURABILITY PROPERTIES

2.6.1 Sulphate Attack Test

The sulphate attack testing procedure was conducted by immersing concrete specimens of the size 150 x150 x150mm and cured for 28 days. Then, they were cured in 5% sodium sulphate solution for 28 days respectively. The specimens are cured in water for 28 days. The cured specimens were weighted and immersed in water diluted with 5%sodium sulphate solution medium of 15 cycles (1 cycle = 24 hours wetting and 24 hours drying). After 15 cycle, alternate wet and dry process, the concrete specimens are taken out and exposed normal atmospheric condition so as to obtain surface dry and lightly crushed to remove the debris from the surface before weighing and the average percentage of loss of weight and compressive strength were calculated.

Fig.2.7 Specimens immersed in diluted Na_2SO_4

2.6.2 Chloride Attack Test

The Chloride attack testing procedure was conducted by immersing concrete specimens of the size 150 x150 x150mm and cured for 28 days. Then, they were cured in 5% sodium Chloride solution for 28 days respectively. The specimens are cured in water for 28 days. The cured specimens were weighted and immersed in water diluted with 5%sodium Chloride solution medium of 15 cycles (1 cycle = 24 hours wetting and 24 hours drying). After 15 cycle, alternate wet and dry process, the concrete specimens are taken out and exposed normal atmospheric condition so as to obtain surface dry and lightly crushed to remove the debris from the surface before weighing and the average percentage of loss of weight and compressive strength were calculated.

Fig.2.8Specimens immersed in diluted NaCl

2.7.3 Acid Resistant Test

To perform the acid attack studies in the present investigation immersion technique was adopted. After 28 days curing 150 x 150 x150 mm cube specimens were immersed in 3.5%of HCL solution. The solution was kept at room temperature and the solution was strirred regularly, at least three days to maintain uniformity. The solution was replace at regular intervals to maintain concentration of solution throughout the best period. The evaluations were conducted after 28 days from the date of immersion. After removing the specimens from the solution, the surface were cleaned with a soft nylon wire brush under the running tap water to remove weak products and loose material from the surface. The specimen were allowed to surface dry and the compressive strength of the specimens were found out and the average percentage of loss of weight and compressive strength were calculated.

Fig.2.9 Specimens immersed in diluted HCL

2.7.4 Rapid Chloride Penetration Test

The test method consist of monitoring the amount of electrical current passed through 50 mm thick slices of 100 mm nominal diameter cores or cylinders during 6 hours at 30 minutes interval. The rapid chloride penetration test line diagram is shown in Fig.2.10

International Journal of Engineering Research & Technology (IJERT)
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Vol. 5 Issue 05, May-2016

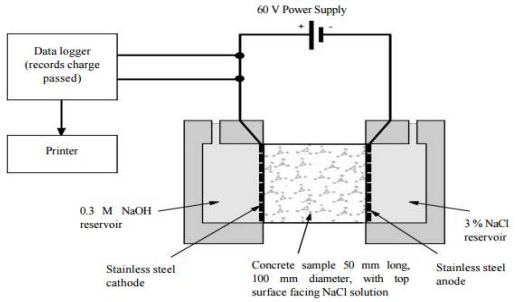

Fig.2.10 Line diagram of RCPT

A potential difference of 60v dc is maintained across the ends of the specimens, one of which is immersed in a sodium chloride solution, the other in a sodium hydroxide solution. The total charge passed in coulombs, has been found to be related to the resistance of the specimen to chloride ion penetration. The left hand side (-) of the test cell is filled with a 3% NaCl. The right hand side (+) of the test cell is filled with a 0.3N NaOH solution. AASHTO T277,'' standard method of test for rapid determination of the chloride permeability of concrete''. The test results are compared to the values in cart below. This cart was originally referred in FHWA/RD-81/119 and is also used in AASHTO T277-83 and ASTM C 1202 specifications. If the current is recorded at 30 minutes intervals, the following formula, based on the trapezoidal rule, can be used with an electronic calculator to perform the integration. The RCPT specimens and RCPT test setup as shown in Fig.2.10 and 2.11.

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

Where,

Q – Charge passed (coulombs)

I_0 – Current (amperes) immediately after voltage is applied

I_t – Current (amperes) at t min after voltage is applied

$$\mathbf{Q_s = Q \times (95/x)^2}$$

Where,

Q_s – Charge passed (coulombs) through a100 mm diameter specimen

Q_x – Charge passed (coulombs) through x (mm) diameter specimen

x – Diameter of the nonstandard specimen.

Table 2.7 Recommended Values from ASTM C 1202

Charge passed (coulombs)	Chloride penetration
>4000	High
2000-4000	Moderate
1000-2000	Low
100-1000	Very low
<100	Negligible

Fig.2.11 RCPT Specimens

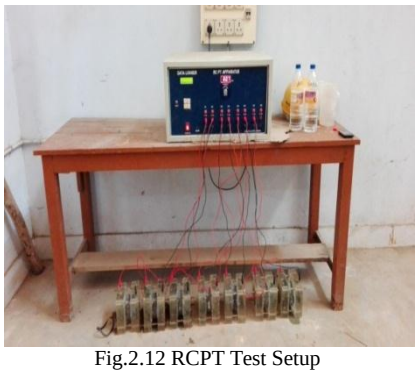

Fig.2.12 RCPT Test Setup

2.7.5 Cementing Efficiency

The value of cementing efficiency can be used to assess the overall quality, durability and performance of concrete. In other words, ''k'' is a factor that explains the difference between the contribution of the Portland cement and the contribution of the mineral admixtures in the development of a specific property. The cementing efficiency factor as show in the following equation:

$$(W/C)_{no\_\ Alccofine} = (W/C+kAl)_{\%\ 0f\_\ Alccofine}$$

Where,

W/C - Water/Cement ratio

k - Cementing efficiency factor

Al - Alccofine

3. RESULTS AND DISCUSSIONS

3.1 General

The aim of the study is to determine the compressive strength, Durability (RCPT) ,Acid Resistant Test ,Sulphate Attack Test, Chloride Attack Test of concrete with various mix proportions. The results of test specimens are presented in the form of bar charts and graphs.

3.2. MECHANICAL PROPERTIES

The mechanical properties of concrete such as compressive strength. Durability Properties such as Acid Resistant Test, Sulphate Attack Test, Chloride Attack Test are determine from the standard experiments. They are as follows.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 05, May-2016

3.2.1 Compressive Strength

The results obtained from the compressive strength of the concrete with various mix proportions are presented in the in the form of bar charts and graphs as shows in Figure 3.1

Table 3.1 Compressive Strength at 28days

Sl. No	% of Alccofine	Compressive strength 28 days in N/mm²
1	A0	31.24
2	A5	33.27
3	A10	37.63
4	A15	42.16
5	A20	41.49

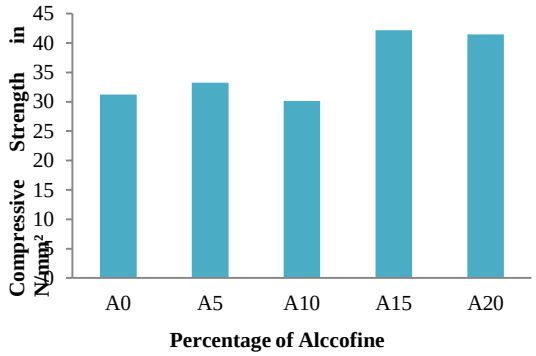

Fig.3.1 Compressive Strength at 28 days.

It is observed that,

- A15 mix shows higher strength than all other mixes.
- 15% replacement of alccofine yields good strength by 25% as compared to conventional concrete mix.
- A15 mix slightly higher than by 5% than A20 mix.

3.2.2 Sulphate Attack Test

The results from the compressive strength and percentage of weight loss of the concrete with various mix proportions are presented in the form of bar charts and graphs as shown in figures.

Table 3.2 Compressive Strength after Sulphate Attack Test

Sl. No	% of Alccofine	Compressive strength in N/mm²
1	A0	30.5
2	A5	39.6
3	A10	42.14
4	A15	42.85
5	A20	40.21

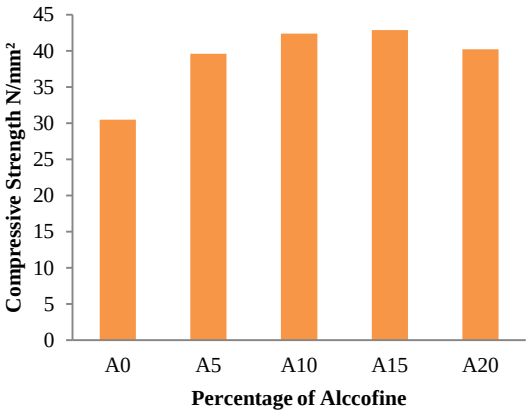

Fig. 3.2 Compressive Strength after Sulphate Attack Test

From the Fig 3.2 the following points are observed:

- A15 mix give higher strength than all control mix (A0).
- A15 mix give higher strength when compared to A5, A10 and A20 mix.

Table 3.3 Percentage of weight loss for Sulphate Attack Test

Sl. No	% of Alccofine	% of weight loss
1	A0	0.72
2	A5	2.1
3	A10	1.5
4	A15	1.2
5	A20	1.1

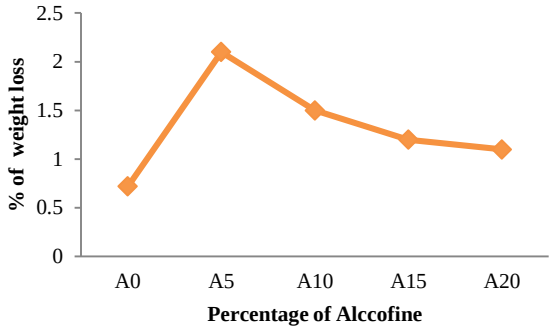

Fig.3.3 % of weight loss for Sulphate Attack Test

It is observed that

- A10 and A15 mixes are almost 29% higher than the control mix (A0) when compared its compressive strength.
- When compared to weight loss of the concrete after sulphate attack, A5 mix gives higher percentage of weight loss than A10, A15 and A20 mixes.
- As compared with control mix A0, the alccofine replaced concrete shows higher weight loss.

3.2.3 Chloride Attack Test

The results from the compressive strength and percentage of weight loss of the concrete with various mix proportions are presented in the form of bar charts and graphs as shown in figures.

Table 3.4 Compressive Strength after Chloride Attack Test

Sl. No	% of Alccofine	Compressive strength (N/mm²)
1	A0	40.92
2	A5	39.64
3	A10	38.99
4	A15	41.73
5	A20	40.98

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 05, May-2016

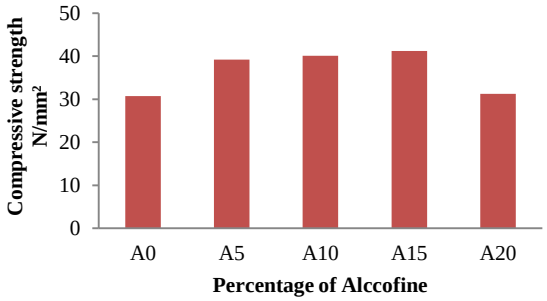

Fig 3.4 Compressive Strength after Chloride Attack Test

Table 3.5 Percentage of Weight Loss for Chloride Attack Test

Sl No	% of Alccofine	% of weight loss
1	A0	0.055
2	A5	0.19
3	A10	0.05
4	A15	0.03
5	A20	0.29

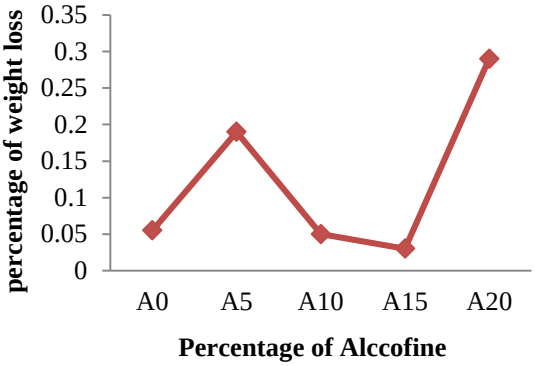

Fig 3.5 % of Weight Loss for Chloride Attack Test

It is observed that

- A15 mix shows higher strength than all control mix (A0).
- A5 and A10mix got almost equal strength than other mixes.
- A15 mix is almost 28% higher than the control mix(A0) when compared its compressive strength.
- When compared to weight loss of the concrete after chloride attack, A15 mix shows very less percentage of weight loss than other mixes including A0.
- As compared with control mix A0 and A15, A20 mix shows higher weight loss and it is severely affected by chloride.

3.2.4 Acid Resistant Test

The results from the compressive strength and percentage of weight loss of the concrete with various mix proportions are presented in the form of bar charts and graphs as shown in figure

Table 3.6 Compressive Strength after Acid Resistant Test

Sl. No	% of Alccofine	Compressive strength (N/mm²)
1	A0	30.71
2	A5	39.23
3	A10	40.08
4	A15	41.25
5	A20	31.28

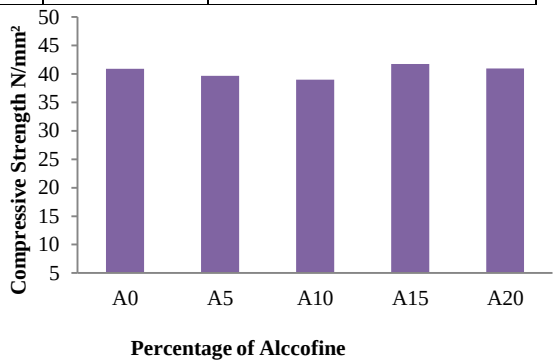

Fig.3.6 Compressive strength after Acid Resistant Test

Table 3.7 Percentage of weight loss

Sl No	% of Alccofine	% of weight loss
1	A0	1.02
2	A5	0.38
3	A10	0.45
4	A15	0.36
5	A20	0.7

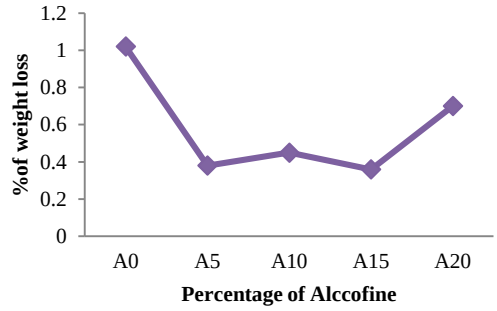

Fig 3.7 % of weight loss for Acid Resistant Test

It is observed that

- A10 and A15 mixes are showing lower and higher strength than all other mixes respectively after acid attack.
- All mixes including control mix got almost equal strength with smaller variation.
- A15 mix is only 5 to 7% higher than the control mix (A0) when compared its compressive strength.
- When compared to weight loss of the concrete after acid attack, A15 and A5 mixes show very less percentage of weight loss than other mixes including A0.
- As compared with control mix A0, A15 mix shows 60% of weight loss lesser than that and it reveals that alccofine well resisting the acid than conventional cement.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 05, May-2016

3.2 5RapidChloridePenetration Test (RCPT)

The result obtained from the RCPT, the chloride permeability of various mix proportions are presented in the form of Table 3.9. The Fig.3.6 shows the chloride penetration for various replacements of Alccofine concretes.

Table 3.9 Chloride Penetration Result

Sl.No	Type of mix	Coulombs
1	CON	1951.84
2	AL5	966.57
3	AL10	1779.64
4	AL15	807.33
5	AL20	1516.47

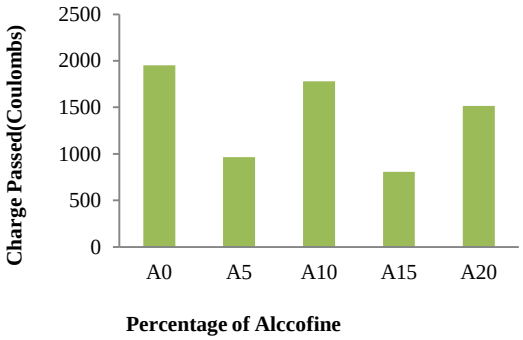

Fig. 3.8 Durability by RCPT Test

It is observed that

- The chloride penetration of conventional concrete was found to be 1951.84 coulombs.
- In chloride penetration test, A15 mix shows very low chloride penetration than other mixes.
- The chloride penetration even higher for conventional mix A0.
- Chloride penetration in A15 mix almost 42% lower than A0. But abnormal variation in A10 and A20.

3.2.6 Cementing Efficiency (k- factor)

In the present investigation cementing efficiency of Alccofine was calculated for the water/cement ratio of 0.5 can be found that when15% replacement of cement by Alccofine is giving strength to conventional concrete without Alccofine. Thus the corresponding cementing efficiency factor is a useful parameter in the mix design of Alccofine concretes. The German standards value of k factor was as 0.3 for 10 – 25% replacement. The higher value of k- factor reported in this investigation may be because of higher reactivity of the Alccofine. However some more confirmatory tests are needed to specify this value. Form of Table 3.10, Fig.3.9 shows the k factor for various replacements of Alccofine with concretes.

Table 3.10 k - Factor Value

Sl No	MIX	K- FACTOR
1	A0	0
2	A5	0.94
3	A10	1
4	A15	1
5	A20	1

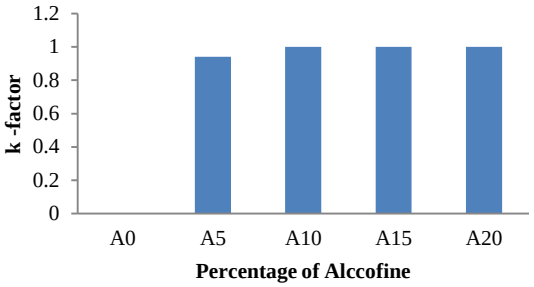

Fig.3.9 Cementing Efficiency

From Fig 3.9 the following points are observed:

- Cementing efficiency factor for control mix is 0 because of no admixture.
- Cementing efficiency factor for A5 mix is 0.94.
- Cementing efficiency factor for A10, A15 and A20 mix is 1.

4. CONCLUSIONS

The Conclusions the experimental from the investigations are as follows

- From the experimental results, A15 mix gives higher compressive strength than all other mixes (A0, A5, A10 and A20). It shoes that the addition of alccofine in concrete increases the compressive strength by 20 to 30%.
- It is observed that the Alccofine based concrete, RCPT value is less due to its pore filling and pore refining of particles, and this behavior resulting good performance in durability.
- If the percentage level of alccofine is increased more than 15% then it acts as a filler material only and the strength gradually decreases by increasing the percentage of alccofine.
- From the Sulphate attack test it is observed that A15 mix shows better performance in the compressive strength but weight loss is more compared with A0.
- From the test it is found that the alccofine addition increases, the weight loss decreases. But there is a limitation that strength will be decrease in the increase of alccofine.
- From chloride attack test, it is observed that it is well resistant against chloride attack. Because the percentage of weight loss is well below the conventional concrete mix whereas in compressive strength, A15 mix gives more strength than conventional mix.
- From the acid resistant test, it is observed that the compressive strength slightly higher than the conventional concrete. But percentage of weight loss is very less when compare to conventional concrete mix and it shows that the alccofine is very good against the acid attack.
- From RCPT, it is observed that the concrete incorporated with alccofine shows better performance than the control concrete mix.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 05, May-2016

- By increasing the percentage of alccofine in concrete as replacement of cement, the value of cementing efficiency increases.
- It is concluded that the alccofine 1203 is good replacement cementitious material for cement to certain extent that up to 15%. It is good against durability aspects also.
- Also further more research required to standardize the use of alccofine in concrete in practice.

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