EXPERIMENTAL STUDY ON ECO-FRIENDLY CONCRETE BY PARTIAL REPLACEMENT OF CEMENT USING ALCCOFINE

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Abstract : **Supplementary cementitious materials (SCM) are becoming popular in the construction industry as these materials are bringing technical revolution in the field of civil engineering. Alccofine is a new generation micro fine concrete material for high Strength Concrete which is important in respect of workability as well as strength. The aim of this paper is to highlight the importance of Alccofine as Supplementary cementitrious materials in construction industries. This can be used as a SCM due to its ultrafine size and high content of calcium oxide (Cao), Alccofine1203 is essential in terms of reducing heat of hydration and strength at all stages whereas Alccofine 1101 can be used as a grouting purpose. Because of the demands in the construction industry, the necessity of high performance concrete is also increased. Over the past few years, the efforts which are made for improving the performance of concrete suggest that cement replacement materials along with the minerals and chemical admixtures can improve the strength and durability characteristics of concrete. For high strength, Alccofine is a new generation micro fine concrete material and which is important in respect of workability as well as strength. The advantage of Alccofine other than strength is that it also lowers the water/binder ratio. Alccofine material increases the strength both in compression and flexure to a large extent. The design mix executed for this project is M70grade concrete. The cement is replaced by 0%, 5%, 10% and 15% by Alccofine. The compressive strength, flexural strength and split tensile strength were carried out with different proportioned Alccofine at different curing days for 14,28 and 56 days. The strength obtained from the Alccofine concrete is compared with the conventional concrete. The results showed that a high strength value is given for 15% replacement and it enhanced the strength of concrete making it to be the highest of any other replacement.The optimum compressive strength achieved is 83.26N/mm^2.The durability test were conducted using Na_2SO_4 and HCl at 28 day curing.The percentage loss of weight and strength is found to be less for 5% replacement of Alccofine aftr durability tests.**

Keywords: Alccofine,Compressive strength,Split Tensile Strength,Durablity

I. INTRODUCTION

High strength and high performance concrete are gaining popularity day by day in the construction industry worldwide. Practically high strength concrete is generally said to be high strength concrete having high cement content and very low water cement ratio.cement-based materials are among the most important construction materials, and it is most likely that they will continue to have the same importance in the future[4] However, these construction and engineering materials must meet new and higher demands. When facing issues of productivity, economy, quality and environment, they have to compete with other construction materials such as plastic, steel and wood. The durability of cement concrete is defined as its ability to resist weathering action, chemical attack, or any other process of deterioration. [4].Durable concrete will retain its original form quality, and serviceability when exposed to environment. These materials include traditional Portland cement and other cementitious materials, such as fly ash, ground granulated blast furnace slag (GGBS), limestone fines and silica fume[8]. These materials are either combined at the cement works or at the concrete mixer when the concrete is being produced. Cementitious materials for concrete are fine mineral powders. When these materials are mixed with water, they react chemically

to form a strong rigid mass that binds aggregate particles together to make concrete. This paper gives information on the standards of cementitious materials for concrete, provides guidance to the selection of cementitious materials for various applications[4].Conplast 430 is used as superplasticizer.

1.1 Alccofine

Alccofine is a new generation, micro fine material of particle size much finer than other hydraulic materials like cement, fly ash, silica etc. being manufactured in India. Alccofine has unique characteristics to enhance performance of concrete in fresh and hardened stages due to its optimized particle size distribution. It can be used as practical substitute for Silica Fume as it has optimum particle size distribution not too coarse, not too finer either per the results obtained by Counto Micro fine products Pvt. Ltd (A joint venture with ambuja cement ltd and alcon developers). It is manufactured in the controlled conditions with special equipments to produce optimized particle size distribution which is its unique property.

Alcofine 1203 and Alcofine 1101 are two types of Alccofine with low calcium silicate and high calcium silicate respectively. Alccofine 1200 series is of which represents fine, micro fine, ultrafine particle size respectively. Alccofine 1203 is slag based SCM having ultra fineness with optimized particle size distribution whereas Alcofine 1101 is a micro finer cementitious grouting material for soil stabilization and rock anchoring. The performance of Alcofine is superior to all the other admixtures used in India. Due to high Calcium oxide (Cao) content.[4,10]

There are two types of Alccofine:-

1.1.1 Alccofine 1203:-

It is an alccofine with low calcium silicate. Alccofinee 1200 series is of 1201, 1202, 1203 which represents fine, micro fine, ultrafine particle size respectively. Alccofine 1203 is a slag based SCM having ultrafineness with optimized particle size distribution. [10] Alccofinee 1203 provides reduced water demand for a given workability, even up to 70% replacement level as per requirement of concrete performance.

1.1.2 Alccofine 1101:-

It is an Alccofine with high calcium silicate. It is a micro finer cementitious grouting material for soil stabilization and rock anchoring. The performance of Alccofinee is superior to all other admixtures used in India due to high calcium oxide (Cao) content.

II. MATERIALS AND METHODOLOGY

2.1 Materials

In this stage the collection of materials required for the mix design as per the data obtained from the sieve analysis and specific gravity tests. Sieve analysis is done for both fine aggregate and coarse aggregate and the fineness modulus is obtained and the sample which suits the requirement is selected. Specific gravity tests were also conducted for both FA and CA. The initial material tests were performed as per Indian Standard specifications.

The materials that are needed for the casting operations are cement, fine aggregate, coarse aggregate, Alccofine, Superplasticizer and water.

2.1.1 Cement

The most commonly used cement is ordinary Portland cement of 53 grade conforming to IS: 12269- 1987 is been used. The tests which were conducted on cement are fineness test, specific gravity, initial and final setting time.

2.1.2 Alccofine

Alccofine 1203 is a slag based SCM having ultra fineness with optimized particle size distribution. Alccofinee 1203 provides reduced water demand for a given workability, even up to 70% replacement level as per requirement of concrete performance. Based on analysis, physical properties of Alccofine is carried out.The specific gravity of Alccofine is found to be 2.9 and the fineness is found to be 3%.

The physical properties of the cementitious materials are shown in Table 2.1.

Fig 2.1 Alccofine 1203

Table 2.1 Properties of cementitious materials

Sl.no	Property tests	Cement	Alccofine
1	Normal Consistency	34%	-
2	Specific Gravity	3.13	2.9
3	Fineness	6%	3%
4	Initial Setting Time	30	-
5	Final Setting Time	530	-

2.1.3 Aggregates

The crushed coarse aggregate (CA) of maximum size 10mm and natural river sand (Zone II) conforming to IS 383:1970 was used as fine aggregates.The aggregate tests are performed and the results are shown in Table 2.2..

Table 2.2 Physical properties of CA and FA(IS 380-1970)

Properties	Fine Aggregate	Coarse Aggregate
Maximum Size(mm)	4.75	10
Water Absorption	1.5%	0.5%
Specific Gravity	2.615	2.57
Fineness modulus(from Sieve Analysis)	3.52	4.08
Aggregate Impact Value	-	4.8%

2.2 Methodology

2.2.1 Mix Proportion

An experimental investigation was planned on utilization of alccofine in developing high strength concrete and carried out to determine the mechanical and durability properties of M70 grade of concrete mix. The mix was designed as per IS 10262:2009 [15] with a water/cement ratio of 0.3 and a targeted slump of 100mm by partially replacing the cement with 0%, 5%,10% and 15%. Concrete mixes prepared by substituting cement with 0%,5%, 10%, 15% have been named as M1, M2, M3 and M4 respectively.and is shown in Table 2.3. A set of 9 specimen cubes of size 150mm x 150mm x150mm for compressive strength test and a set of 6 specimen cylinders of size 150mm x 300mm for split tensile strength were casted, cured and tested after the curing age of 14, 28 and 56 days. A set of 8 cubes of 150mm x 150mmx 150mm were casted for sulphate attack and acid resistance tests.The mix proportion details are shown in Table 2.3

Table 2.3 Mix proportion

Mix	% replacement of Alccofine	Cement (kg/m^3)	Fine aggregate (kg/m^3)	Coarse aggregate (kg/m^3)	Superplasticizer (kg/m^3)
M1	0	508	750	829	7.08
M2	5	482.44	750	829	7.08
M3	10	459.60	750	829	7.08
M4	15	431.62	750	829	7.08

2.2.2 Casting of specimens

For the tests to be conducted, cubes, cylinders and beams were casted. Filling the Moulds and Compacting the Concrete. After the sample has been remixed, immediately fill the cube moulds and compact the concrete, either by hand or by vibration. Any air trapped in the concrete will reduce the strength of the cube. Hence, the moulds must be fully compacted. It actually takes it about 28 days to reach its full strength and hardness. After the concrete is poured and floated, the curing process ensures it hardens properly.

2.2.3 Curing of specimen

The casted specimens were cured for 14 days, 28 days and 56 days. The cured specimens are taken out and proceeded for testing. Compressive strength of cubes, split tensile strength of cylinders and tensile strength of beams were carried out at the required curing days and average strength were calculated.

2.2.4 Slump Test

The concrete slump test measures the consistency of fresh concrete before it sets. It is performed to check the workability of freshly made concrete, and therefore the ease with which concrete flows.The targeted slump have been analysed as per the IS code IS 1199-1959.The slump value have been observed as increasing as compared to the conventional concrete mix as alccofine is finer than cement.

2.2.5 Compressive Strength Test.

Compressive strength or compression strength is the capacity of a material or structure to withstand loads tending to reduce size, as opposed to tensile strength which withstands loads tending to elongate. Compression tests assumed that a pure state of uniaxial loading.

The test is conducted on the 14th day, 28th day and 56th day curing with replacement for cement by Alccofine with 0%, 5%, 10% and 15%.The compressive strength values were computed using the equation (1)

$$\text{Compressive strength} = \frac{P}{A}\ \text{N/mm}^2 \qquad (1)$$

where, P = load in N

A = area of cube in mm^2

2.2.6 Split Tensile Strength Test

Splitting tensile strength test on concrete cylinder is a method to determine the tensile strength of concrete. It is necessary to determine the tensile strength ofconcrete to determine the load at which the concrete members may crack. The test is conducted on 14th day, 28th day and 56th day. The cylinder is held in horizontal position and the load is applied gradually and value is recorded if the cylinder fails while applying the load in it. Values are taken for conventional concrete and 0%,5%, 10% and 15%.[8].The split tensile strength were calculated using the equation (2)

$$\text{Split tensile strength, } f_t = \frac{2P}{\pi DL} \qquad (2)$$

where,

P = compressive load at failure in N

D = diameter of cylinder in mm

L = length of cylinder in mm

2.2.7 Sulphate Attack test

The test was carried out on the 150*150*150 mm Concrete cube. Total 8 cubes are casted and demoulded after 24 hours and at the ends of 28 days of normal curing period tested. The specimens were taken out from the curing tank and initial weight was taken. 5% of sodium sulphate (Na_2SO_4) by weight of water was added with water. The specimens were taken out from the sulphate solution after 28 days of continuous soaking. The surface of the Cube were cleaned, weighed & then tested in the compressive testing machine.The percentage loss in weight is calculated from the equation (3)

$$\text{Weight Loss} = \frac{W_i - W_f}{W_f} \times 100 \qquad (3)$$

Where, W_i – Weight of specimen before sulphate attack

W_f - Weight of specimen after sulphate attack

The loss in compressive strength is computed from the equation (4)

$$\text{Strength loss} = \frac{F_i - F_f}{F_f} \times 100 \qquad (4)$$

Where, F_i = compressive strength after 28 days normal curing

F_f = compressive strength after 28 days Na_2SO_4 curing

2.2.8 Acid Resistance Test

The concrete cubes of size 150mm were cast and cured for a period of 28 days. After 28 days curing of specimens, cube surfaces were cleaned using standard preliminary surface cleaning process and weighed. The identified specimens were immersed in prescribed acid(HCl) solution. The solution was checked periodically. After the prescribed duration, the specimens were removed from the solution. Using weight loss method, percentage weight loss was determined.

III. RESULTS & DISCUSSIONS

3.1 Slump Test

The targeted slump have been analysed as per the IS code IS 1199-1959. The Fig 3.1 shown that the mix of Alccofine and Super plasticizer can improve the workability and because of the ultra fineness of alccofine the slump value is improved as compared to the conventional concrete mix.

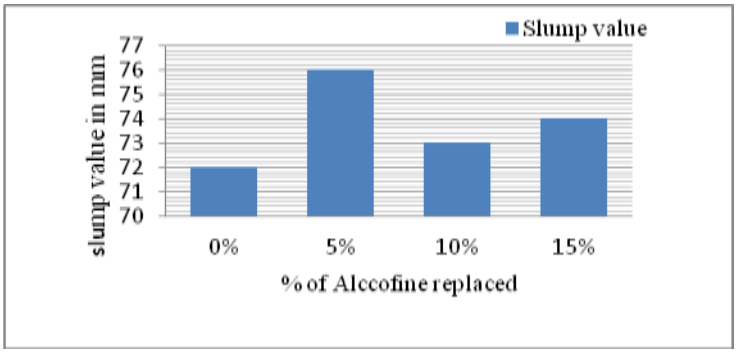


Fig 3.1 slump values

3.2 Compressive strength

The test is conducted on the 14th day, 28th day and 56th day curing and its observation are listed below in the form of a Table 3.2 and variations are shown in fig3.2. Compressive strength values with replacement for cement by Alccofine with 0%, 5%, 10% and 15%.All concrete mix exhibited higher CS than that of M1(conventional mix) at all curing ages. M4 mix exhibited maximum CS of 72.14, 80.73 and 83.26 after curing of 14, 28 and 56 days respectively than other mixes [4]. These results are almost consistent with Sharma et al [4] and Vijendar [8] Rate of development of CS was found to be increasing for all the curing days.The optimum compressive strength is reached at M4 at 56 day curing of 83.26 N/mm^2.A percentage increase of 29.69 % has been achieved from 14 day to 28 day and it is reduced to 12.8% from 28 to 56 day curing for conventional mix(M1).At the end of 28 day curing, the compressive strength increased at 2.16% for the mix M2 compared to M1 and 8.16% increment when it comes to M3.It has increased to 11.5% for M4. Optimum Strength is achieved at 15% replacement with 10.64% increment from 14 to 28 day curing and 3.38% increment for 56 day curing.The same trend was reported by VIjendar [8].

Table 3.2 Compressive Strength of Alccofine concrete at various days

Mix	Slump (mm)	% replacement of Alccofine	Compressive strength(N/mm^2) 14 days	Compressive strength (N/mm^2) 28 days	Compressive strength (N/mm^2) 56 days
M1	72	0	50.22	71.43	81.92
M2	76	5	61.03	73.01	82.10
M3	73	10	69.92	77.78	82.51
M4	74	15	72.14	80.73	83.26

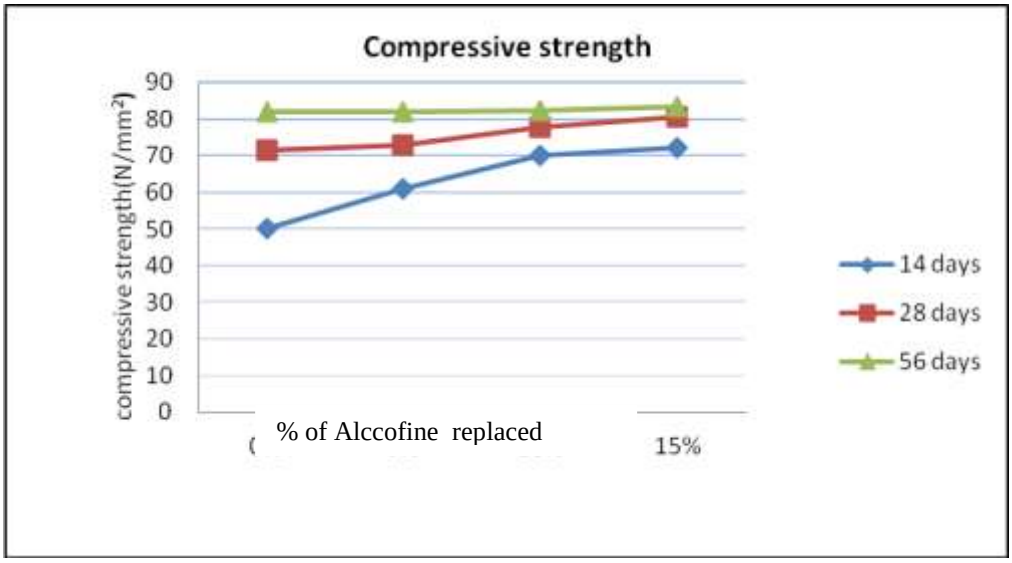


Fig 3.2 Compressive strength variations

3.3 Split tensile strength of cylinders

The test is conducted on 14th day, 28th day and 56th day. Values are taken for conventional concrete, 5%, 10% and 15%. 150 mm x 300 mm cylindrical specimens (24 specimens) of varying % ages of Alccofine have been used for tensile strength (TS) test of HSC [4]. The results of M4 seems to be higher in strength as compared to other mixes with a percentage increase of 25.89%.The strength increase is consistent with the existing results of Vijendar [8]. The minimum split tensile strength is found to be 1.2 to 2.4 N/mm^2. The tensile strength at 28 days is found tob increasing at a rate of 9.4% from 0% to 5% replacement of Alccofine, 12.3% increment from 0% to 10% replacement and 15.5% increment for 0% to 15% replacement.

The better results were shown for M4 which is 5.33N/mm^2.The increase in tensile strength improves the resistance against tension after sges.

The variation in split tensile strength are shown in fig 3.3

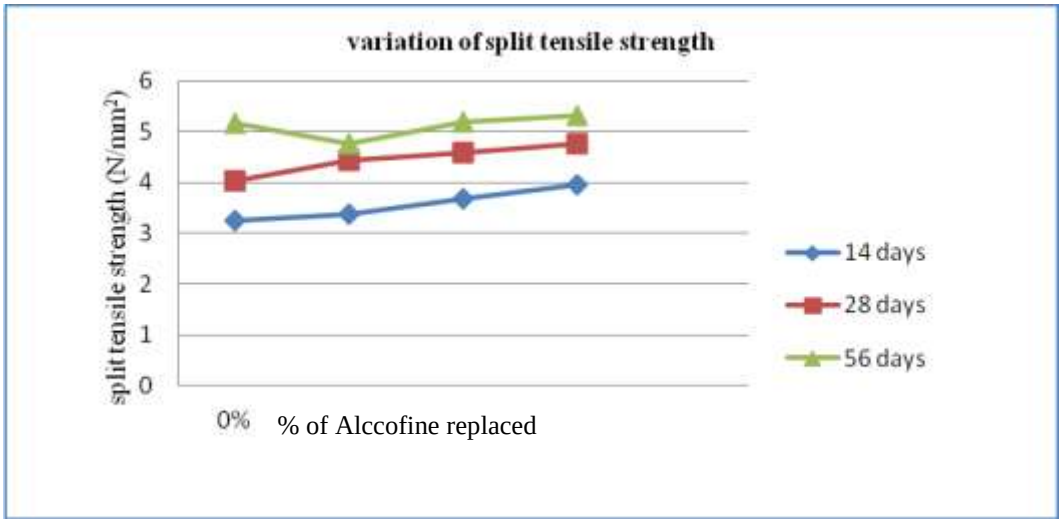


Fig 3.3 Split Tensile Strength Variations

Table 3.3 Split Tensile Strength on cylinders

Sl.no.	% replacement of Alccofine	Tensile strength (N/mm^2) 14 days	Tensile strength (N/mm^2) 28 days	Tensile strength (N/mm^2) 56 days
1	0	3.25	4.03	5.16
2	5	3.39	4.45	4.77
3	10	3.67	4.60	5.20
4	15	3.95	4.77	5.33

IV. DURABILITY OF ALCCOFINE CONCRETE

4.1 Sulphate attack test

4.1.1 Weight Loss

The best mix after this sulphate attack is found to be M1 which exhibits only 1.48% % loss in weight and 0.78 % loss in compressive strength.At 10% replacement,the percentage loss in weight is 2.21% which is higher among all the mixes. On the whole, all the mixes shown comparatively less variations in weight losses which makes the Alccofine concrete durable.Variation in strength loss is shown in fig 4.2.

4.1.2 Strength loss

The mix which exhibits minimum strength loss is M1 which is 0.78% only while M4 shows higher strength loss of about 3.65%. In the case of strength loss also, the Alccofine mix showed better results and made its way for durability properties.Compressive strength variations ara shown in fig 4.1.

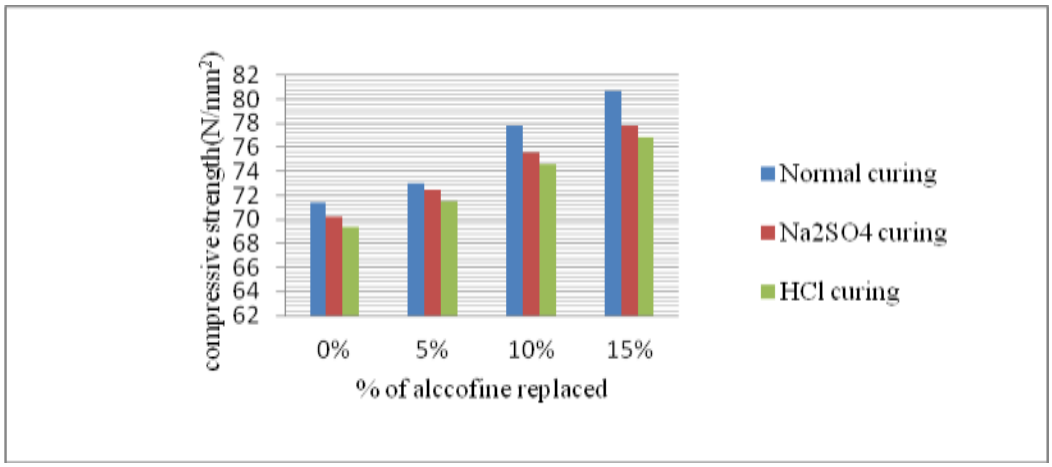
4.*2 Acid Resistance test*

4.2.1 Weight Loss

In this test also, M1 shown the best results compared to other mixes. Only 1.95% of weight loss and 1.99 % of strength loss is given by M1. Using weight loss method, percentage weight loss was determined. At 15% replacement,the percentage loss in weight is 4.76% which is higher among all the mixes.

4.2.2 *Strength Loss* .

M1 shown the best results compared to other mixes with 1.99% of strength loss. At 15% replacement,the strength loss is 4.76% which is higher among all the mixes.The variation in compressive strength aft normal curing, Na_2SO_4 curing and HCl curing is shown in fig 4.1.



. Fig 4.1 Variation in compressive strength

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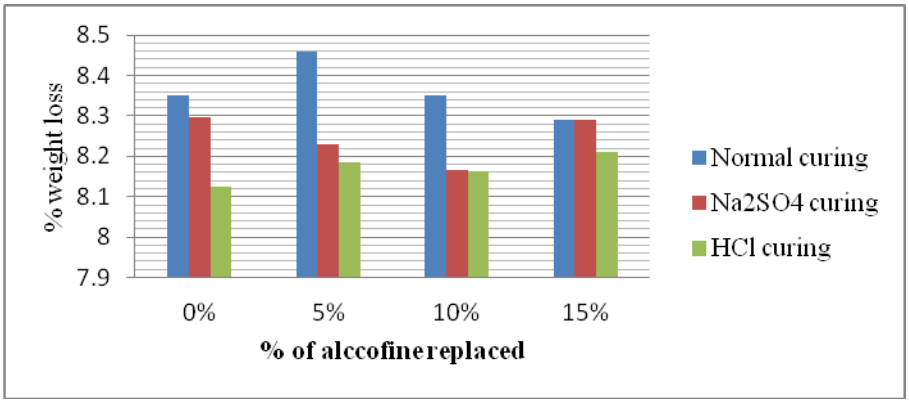

Fig 4.2 variations in weight loss

Table 5.1 Sulphate Attack Test on cubes

% replacement of Alccofine	Weight before sulphate attack (kg)	Weight after sulphate attack (kg)	% loss in weight	Load (KN) (concrete in Na_2SO_4 solution)	28 days Compressive strength (N/mm^2)	% loss in strength
0	8.35	8.295	0.65	1580	70.22	1.69
5	8.46	8.23	1.43	1630	72.44	0.78
10	8.35	8.165	2.21	1700	75.55	2.86
15	8.29	8.290	0.72	1750	77.78	3.65

Table 5.2 Acid Resistance test Results

% replacement of Alccofine	Weight before acid attack (kg)	Weight after acid attack (kg))	% loss in weight	Load (KN) (concrete in HCl solution)	28 days Compressive strength (N/mm^2)	% loss in strength
0	8.35	8.125	2.69	1560	69.33	2.93
5	8.29	8.185	1.95	1610	71.55	1.99
10	8.31	8.163	2.19	1680	74.66	4.01
15	8.35	8.210	1.67	1730	76.88	4.76

CONCLUSIONS

The effects in concrete with the partial replacement of cement by Alccofine is investigated and conclusions were achieved.

- The addition of Alccofine as partial replacement of cement increases the compressive strength of concrete at 15% by 10.64% as compared to conventional concrete from 14 to 28 day curing
- A percentage of tensile strength of concrete with replaced Alccofine increases at 15% of about 25.89% than conventional concrete.
- In the Sulphate Attack Test % weight loss of Alccofine specimen for 28 days are 0.65, 1.43,2.21 and 0.72 respectively.M1 exhibits the best results with only 0.78% strength loss and 1.48% weight loss.
- In acid attack test the % weight loss of Alccofine specimen for 28 days are 2.69, 1.95,2.19 and 1.67 respectively M1 exhibits the best results with only 1.99% strength loss and 1.98% of weight loss.

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