PERFORMANCE OF CEMENT COMPOSITE WITH GGBS AND ALCCOFINE AS PARTIAL REPLACEMENT

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Abstract

The basic objective of any cement composite is to achieve high strength and improve durability to withstand a longer life span. The present work discusses, the behavior of cement composite with the replacement of cement by an ultrafine material called Alccofine (1203) at 0, 5, 10, 15, 20 % and ground granulated blast-furnace slag (GGBS) at 30 % for M60 grade of concrete. A constant water cement ratio of 0.3 is adopted, to enrich workability a super plasticizer is used. For casting and curing normal procedures are followed as per IS code. To access the mechanical properties, strength and durability tests are conducted on concrete specimens. The strength aspect is maximum at 15 % Alccofine and 30 % GGBS replacement. From the water permeability test it is concluded that there is no seepage of water in all mixes. Hence the concrete is highly durable by the addition of Alccofine. As per ASTM C1202 [1], the chloride permeability is very low in all the mixes.

Keywords: Alccofine; High performance concrete (HPC); High strength; Rapid chloride permeability test (RCPT); Water permeability.

1. INTRODUCTION

Concrete is one of the most extremely used man-made building material around the globe. The production and usage of concrete had led to a varied range of environmental and social significances. As the demand for the concrete is increasing continuously, the production of cement has been multifold during the last two decade. The CO_2 released from limestone in pyro-processing of clinker is responsible for the environmental issues. To address the CO_2 problem, an effective method is to reduce cement usage by replacing the cement with additives like mineral and chemical admixtures. Numerous experimental works are going on for evolution of high performance concrete (HPC), that posse's high strength and durability. Low water to cement ratio and high binder content are the two main features of HPC, but such concrete reports poor workability, thus, to overcome this issue, high range water reducing agents (HRWR) like super plasticizers are used in concrete to improve easy flow ability and comfort in placing and improves the withholding time which helps during transportation of concrete mix. In this study, super plasticizer was used in mix.

Alccofine 1203 is an ultrafine glass-based product, with low calcium silicate, factory-made product in India. It increases particle packing capacity in concrete and improves the performance of concrete at all stages, ensuing in production of high-performance ecological concrete. The use of Alccofine in concrete induces early strength and durability. Its unique characteristics and composition make it perform in a superior way compared to other supplementary materials. This material is used in high rise building structures, especially in marine structures, precast elements, bridges. The chemical composition for Alccofine is given in Table 6.

Ground granulated blast-furnace slag (GGBS) is a byproduct of iron and steel industry. As per IS: 455 (1989) [2] the typical range of GGBS used in concrete is 25 to 70 %. The initial rate of reaction between GGBS and water is slow, but as Alccofine is incorporated in the mix, the rate of reaction is faster. From recent studies it is established that the GGBS can protect the steel reinforcement more capably, thus it can resist the structure from chemical attack, reduce segregation and heat of hydration. The GGBS present in the composite reacts with the calcium hydroxide released during the hydration of cement and forms the additional calcium silicate hydrate gel, which improves durability and mechanical properties of concrete. The chemical composition for GGBS is listed in Table 6.

Durability of concrete is defined as the capability to withstand weathering action, chemical attack, and abrasion. The durability of concrete can be assessed by tests like acid attack, sorptivity, water permeability and rapid chloride permeability test (RCPT). In this study water permeability and RCPT tests are conducted to assess the durability.

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2. LITERATURE REVIEW

Rajesh Kumar S. [3], ***et al.*** **(2015),** worked on high strength concrete where cement was replaced by Alccofine with 5, 10, 15, 20 % for M60 grade of concrete. They have concluded that 10 % cement replacement by Alccofine has shown higher strength compared to other replacements.

Devol Soni [4], ***et al.*** **(2013),** reported study on Alccofine and fly ash as cement replacement for M80 grade of concrete. The percentage of replacements for Alccofine was 6 to 10 % with increase at 1 % interval and fly ash was 14 to 18 % with increase in 1 % were adopted. They have concluded that the maximum compressive and flexural strength was achieved at 8 % Alccofine and at 16 % fly ash.

Jigar N. Saiya [5] ***et al.*** **(2018),** reported that fly ash has better flow ability as compared to GGBS, while fly-ash based mix has lesser compressive strength as compared with GGBS based mixes. Thus using two separate admixtures in concrete mixes will optimize the performance.

Kavitha, S. [6], ***et al.*** **(2016),** have concluded that after addition of Alccofine and GGBS in self-compacting concrete the concrete gained high strength and shown high performance. The percentage of GGBS was kept constant at 30 % and Alccofine (AL) was varied from 5 to 10 % with 5 % increment in each batch. Optimum replacement level obtained at 10 % AL and 30 % GGBS.

Balamuralikrishna R. [7], ***et al.*** **(2019),** have studied the effect of Alccofine and GGBS in concrete. A total of nine different combinations of Alccofine and GGBS were investigated for both strength and durability test. Among nine combinations the maximum compressive strength is achieved by using AL 10 % and GGBS 30 % for M20 grade. The minimum loss of weight and compressive strength was reported for sulphate attack, and chloride penetration test. Thus, author concluded that the combination of Alcofine 10 % and GGBS 30 % mix gives better performance from both strength and durability point of view.

Kaviya, B. [8], ***et al.*** **(2019),** have experimented by replacing cement with 0, 5, 10, 15 % of Alccofine and reported the mechanical properties. The compressive strength and flexural strength of concrete at 7 and 28 days of curing were determined. The best properties were reported at 10 % replacement of Alccofine.

Ansari, U.S. [9,10], ***et al.*** **(2015),** have replaced cement partially with Alccofine and fly ash for M70 grade of concrete. The experimentation was done on two mix proportions, one with pure OPC and the other with combination of OPC with Alccofine and fly ash. They have concluded that the compressive strength of concrete made with Alccofine, OPC and fly ash has shown an increment up to 15-20 % than that of conventional mix.

Bhanavath Sagar, and Sivakumar, M. V. N. [11], **(2022),** has reported the influence of alccofine-1203 (alccofine) on mechanical and microstructure characteristics of high strength concrete (HSC) with 4-14 % of alccofine replacement. As alccofine replacement levels increased from 4 to 10 %, the compressive and tensile strengths of concrete have increased from 12 and 14 %. The SEM and EDS analysis demonstrated that, mix with 10 % alccofine had higher amount of C-S-H gel formation.

3. MATERIALS AND PROPERTIES

The physical properties and chemical composition of the materials used in the study are tabulated below.

3.1 Cement

Ordinary Portland cement (OPC) 53 grade was used. The properties of the cement are shown in Table1 and Table 2.

3.2 Fine aggregate

The fine aggregate confirming Zone-II (from Godavari river) is used as per IS: 383 (1970) [12]. Fine aggregate properties are tabulated in Table 3.

3.3 Coarse aggregate

The physical properties of 20 mm and 12.5 mm coarse aggregate confirming to IS: 2386 (1986) [13] are shown in Table 3.

Table 1: Properties of cement

S. NO.	TEST	RESULT	PERMISSIBLE LIMITS
1.	Specific gravity	3.05	≤ 3.15
2.	Consistency (%)	31	26-33 %
3.	Fineness (%)	2.87	<10 %
4.	Setting time: Initial (min) Final (min)	 30 220	 30 600

Table 2: Chemical composition of cement

SiO_2	Al_2O_3	Fe_2O_3	SO_3	CaO	MgO	Na_2O	LOI
21.25	4.33	3.86	2.25	62.60	0.87	0.21	1.05

Table 3: Properties of fine and coarse aggregates

S. NO.	TEST	FINE AGGREGATE	COARSE AGGREGATE
1.	Specific gravity	2.72	20 mm – 2.88 12.5 mm – 2.85
2.	Bulk density	1.51 g/cc	1.445 g/cc
3.	Void ratio	0.52	0.88
4.	Porosity	34.2 %	50.5 %
5.	Fineness modulus	2.75	7.43

3.4 Alccofine1203

Alccofine1200 series is of 1203, 1202, 1201 signify ultrafine, micro fine and fine particle size respectively. By using Alccofine 1203, the packing density of cement composition increases, thus the demand of water and admixture decreases and hence improving strength and durability of concrete. Alccofine 1101consists of high calcium silicate. It's a micro finer cementitious grouting material for rock anchoring and soil stabilization. The types of Alccofine are shown in table 4.

Due to the presence of high calcium oxide content the hydration process upholds two-way reaction i.e, hydraulic and pozzolanic, which results in denser composition and strength improvement. The properties of Alccofine are shown in Table 5.

3.5 GGBS (Ground granulated blast furnace slag)

GGBS is a byproduct of iron and steel industry. The molten iron slag from blast furnace of iron and steel manufacturing unit is stimulated with steam or water to produce a glassy and granular product which is dried and ground into a fine powder. It is one of the best mineral admixture which reduces heat of hydration, thermal cracking, permeability, alkali-silica reaction. The properties of GGBS are shown in the Table 5.

3.6 Water

In the present work, potable water has been used for both mixing and curing. Water with Ph equals to 7 is considered potable water conforming IS: 10500 (2012) [14].

3.7 Superplasticizer

Superplasticizer is used in all the mixes to improve workability and retention time of concrete. The dosage of superplasticizer was kept constant at 7 ml/kg pf cement for all the mixes.

4. METHODOLOGY

4.1 Mix design

The mix design is done as per IS: 10262 (2019) [15] (concrete mix proportioning-guidelines) to conquer high strength and durable concrete of M60 grade. The mix proportion for the control concrete was 1:1.1:2.31 with 0.3 as water to cement ratio. The experimental program is done with six mix proportions. The replacement of GGBS with cement was kept constant at 30 % for all the mixes and Alccofine replacement is varied from 0 to 20 % with 5 % increment in each mix. The mix proportions for the above said replacement are depicted in Table 7.

Table 4: Types of Alccofine

Alccofine	SCM (Supplementary cementious materials) ALCCOFINE–1203	Low calcium silicate	• High rise structures • Marine structures • Ports
	GROUTING ALCCOFINE–1101	High calcium silicate	• Tunnel • Dams • Bridges • Under groundwork

Table 5: Properties of Alccofine and GGBS

S. NO.	PHYSICAL PROPERTIES	ALCCOFINE	GGBS	CEMENT
1.	Particle shape	Spherical	Spherical	Spherical
2.	Colour	Gray	White	Grey
3.	Specific gravity	2.86 cm^2/gm	2.85 cm^2/gm	3.05 cm^2/gm
4.	Particle size	0.1– 17 microns avg. size - 4	13.8 microns	9 microns
5.	Bulk density	600-700 kg/m^3	1200 kg/m^3	1480 kg/m^3
6.	Fineness	-	>350 kg/m^2	2.87

Table 6: Chemical composition of Alccofine and GGBS

MATERIAL	SiO_2	Al_2O_3	Fe_2O_3	SO_3	CaO	MgO	LOI
Alccofine	35 %	24 %	2 %	-	34 %	-	-
GGBS	34.26	17.11	1.23	1.72	35.17	6.41	0.15

Table 7: Mix code and proportions

S. NO.	MIX DESIGNATION	CEMENT kg/m³	GGBS kg/m³	ALCCOFINE kg/m³	FINE AGGREGATE kg/m³	COARSE AGGREGATE kg/m³	WATER (LITER)
1.	M-1	462	0	0	508	1067	139
2.	M-2	323	139	0	508	1067	139
3.	M-3	300	139	23	508	1067	139
4.	M-4	277	139	46	508	1067	139
5.	M-5	254	139	69	508	1067	139
6.	M-6	231	139	92	508	1067	139

4.2 Workability test

The workability test is carried out using the slump cone method. Slump for all the mix codes for M60 grade concrete are done as per IS: 1199 (1959) [16].

4.3 Mechanical properties

4.3.1 *Compressive strength test*

Concrete cubes of size 150 × 150 × 150 mm are cast as per IS: 10262 [15] and cured. From each mix three specimens were tested for compressive strength on 100 ton compressive testing machine (CTM) after 7 and 28 curing days.

4.3.2 *Split tensile strength test*

Concrete cylinders of size 150 mm diameter and 300 mm height are cast as per IS: 5816 (1999) [17] and were cured. Three specimens of each mix were tested under compression testing machine after 7 days and 28 days of curing.

4.3.3 *Flexural strength test*

Concrete beams of size 100 × 100 × 150 mm were cast as per IS: 516 (1959) [18] and are cured. Three beam specimens of each mix were tested in flexural strength testing machine after 7 and 28 days of curing.

4.4 Durability test

4.4.1 RCPT test (Rapid chloride permeability test)

RCPT test is conducted on the concrete specimens as per ASTM C1202 [1] for accessing the resistance of chloride ion penetration. The test setup is shown in Figure 1. In this test, a cylindrical concrete sample of size 50 mm thick, 100 mm diameter is subjected to a potential variance of 60 V DC voltage for 6 hours in which one surface of the specimen is exposed to 3 % of NaCl and the other surface is exposed to 0.3 N NaOH solution. The resistance of Cl^- ion penetration was calculated by the amount of charge passed (in Columbs) into the specimen.

4.4.2 Water permeability test

Water permeability test is also called water penetration test. The concrete durability depends on the permeability of the concrete. Concrete is a composition of cement, sand, and coarse aggregate. The voids present in these materials will allow the water or gases into the concrete, which cause corrosion of steel and finally damage the structure.

After curing the concrete cubes for 28 days, place it in a cell and fill the gap with a molten sealing of admixture of resin and bee-wax applied in hot condition to form an effective seal. Apply air pressure of 1 to 2 kg/cm² and allow the water to pass through the pipes into the cell. If any leakages or air bubbles are found, it indicates that the faulty sealing, in that case, remove the cube, and reseal it. Keep the water measuring jars in position and collect the water passing through the cube at the bottom of the cell as shown in Figure 2. Record the operating pressure and quantity of water collected and time of observation. The cube insertion position in the cell is shown in Figure 3.

The coefficient of permeability is calculated as, $K = \frac{Q}{(AT \times \frac{H}{L})}$

where, K = Coefficient of permeability in cm/sec.

Q = Quantity of water percolated over the entire period of test in milliliters.

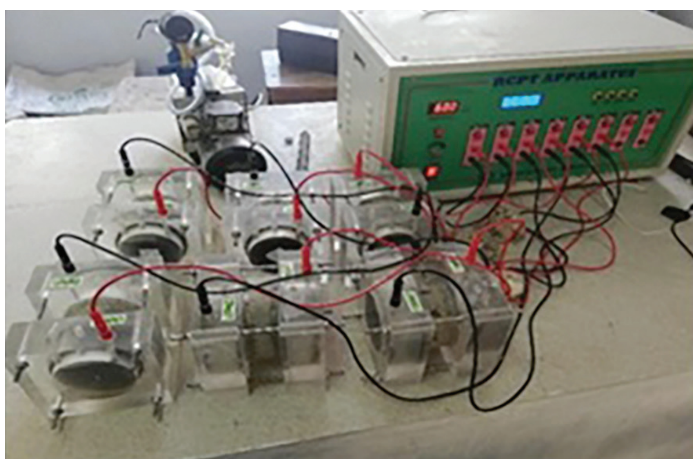

Figure 1: RCPT test set-up

Figure 2: Water permeability test set-up

Figure 3: Cube inserting position in a cell

A = Area of specimen in cm^2.

T = Time in seconds over which Q is measured.

$\frac{H}{L}$ = Ratio of the pressure head to the thickness of specimen both expressed in same units.

5. RESULTS AND DISCUSSIONS

5.1 Strength test

5.1.1 *Compressive strength test*

The compressive strength test was conducted for all mixes after 7 and 28 curing days and the results are shown in Table 8 and Figure 4.

From the obtained results, with the increase in Alccofine percentage, the strength got increased initially up to M-5 (Table 8) i.e., 15 % replacement for both 7 and 28 days and then decreased. The maximum compressive strength attained at M-5 (30 % GGBS and 15 % Alccofine) was 57.33 N/mm^2 and 77.14 N/N/mm^{2}f or both 7 and 28 days. The compressive strength of the M-5 mix improved by 19 % when compared to normal concrete.

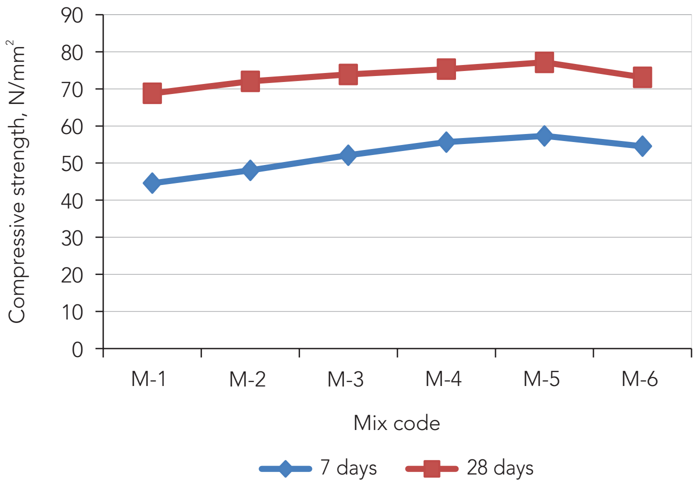

Figure 4: Variation of compressive strength with age

5.1.2 *Split tensile strength*

Concrete should withstand tensile stresses resulting from shrinkage in concrete. The split tensile test is conducted on all specimens after 7 and 28 days of curing. The test results are shown in shown in Table 8 and Figure 5.

Table 8: Compressive, split tensile, flexural strength test results

S. NO.	MIX CODE	REPLACEMENT OF CEMENT BY %		SLUMP (mm)	COMPRESSIVE STRENGTH (N/mm^2)		SPLIT TENSILE STRENGTH (N/mm^2)		FLEXURAL STRENGTH (N/mm^2)	
		GGBS	ALCCOFINE		7 DAYS	28 DAYS	7 DAYS	28 DAYS	7 DAYS	28 DAYS
1.	M-1	0	0	185	44.57	68.80	3.22	3.49	7.57	8.36
2.	M-2	30	0	180	48.04	72.03	3.34	3.62	7.87	8.97
3.	M-3	30	5	182	52.12	73.89	3.70	3.81	8.19	9.52
4.	M-4	30	10	185	55.65	75.30	3.76	3.93	8.78	9.79
5.	M-5	30	15	187	57.33	77.14	3.80	4.17	9.11	10.45
6.	M-6	30	20	175	54.53	73.12	3.63	3.77	8.36	9.65

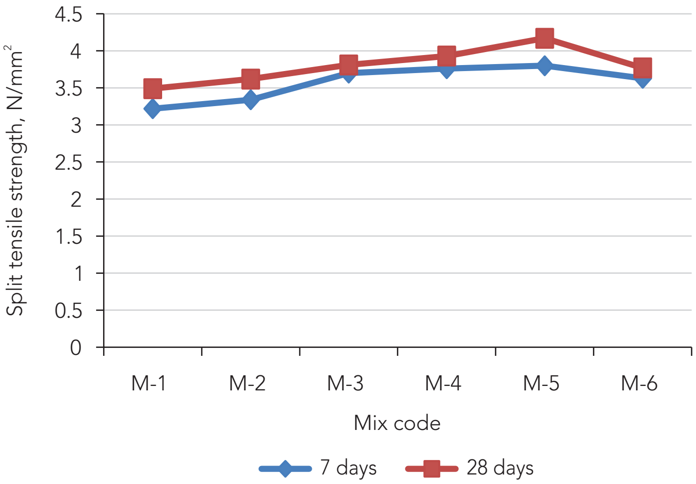

Figure 5: Variation of split tensile strength with age

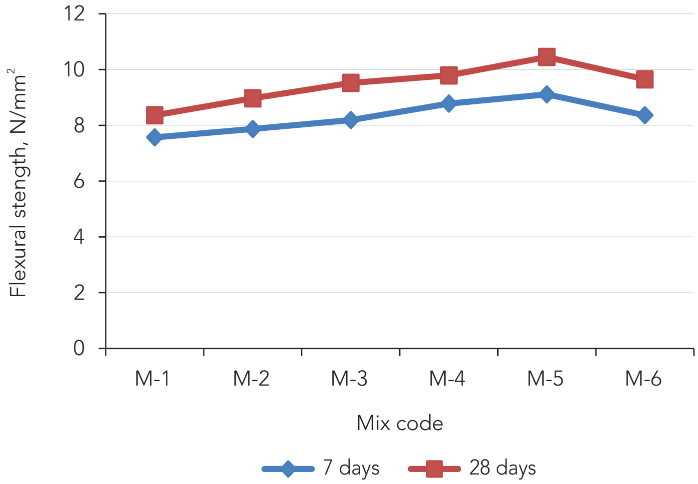

Figure 6: Variation of Flexural strength with age

From the obtained test results, it is observed that the maximum split tensile strength of concrete was achieved for M-5 mix for both 7 days and 28 days. (3.80 N/mm^2 and 4.17 N/mm^2). The split tensile strength of the M-5 mix has improved by 19 % compared to normal concrete.

5.1.3 *Flexural strength test*

This test was performed on concrete beams after curing for 7 and 28 days. As per IS: 51 (1959) [17]. The beams are subjected to a two-point loading. The results are shown in Table 8 and Figure 6.

The maximum flexural strength of concrete prism is attained at M-5 (30 % GGBS and 15 % Alccofine) for both 7 days and 28 days is 9.11 N/mm^2 and 10.45 N/mm^2. When compared to conventional concrete the flexural strength increased by 25 %.

5.2 Durability test

5.2.1 RCPT (Rapid chloride permeability test)

RCPT test is conducted for all the mixes and the results are tabulated in Table 8 and Figure 7.

Corrosion of steel occurs when the chloride ingresses into the concrete which leads to the deterioration of concrete structures. The ingression of chloride ions into the concrete depends upon pore structure. The results indicated that pore structure of the concrete have improved for all the mixes i.e., M1 to M6, indicating the availability of free Calcium hydroxide (CAOH) in conventional concrete as drastically reduced due to addition of GGBS and Alccofine. The chloride ion permeability is very low in the concrete due to the presence of Alccofine component which is having a very good interlocking capacity that makes the concrete pore structure denser. The results of RCPT are listed in Table 9. The values are compared with the specifications recommended by ASTM 1202 [1] as shown in Table 10 the chloride permeability for all the mixes is very low.

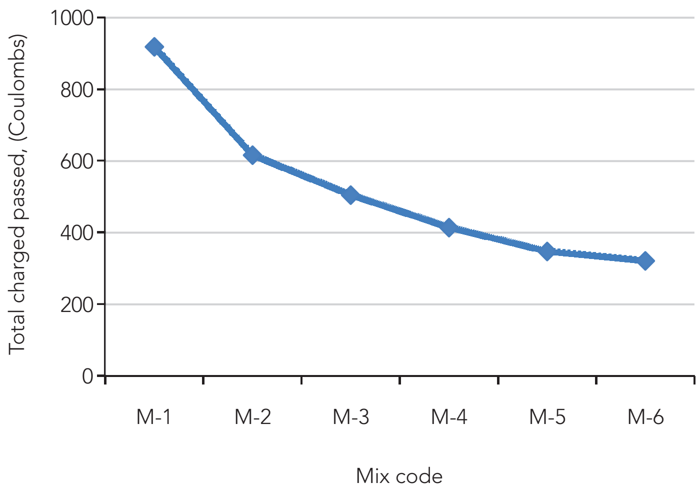

Figure 7: Variation of chloride permeability

5.2.2 Water permeability test

Water permeability test was conducted for all the mixes. The test results indicated no seepage of water from the concrete specimens for both conventional and modified mixes (with GGBS and Alccofine). The microstructure of the concrete made with Mineral admixtures like Alccofine and GGBS are proved to be good.

Table 9: RCPT result

S. NO.	MIX CODE	TOTAL CHARGE PASSED (COULOMBS)
1.	M-1	918.63
2.	M-2	616.23
3.	M-3	504.99
4.	M-4	414.36
5.	M-5	347.49
6.	M-6	321.48

Table 10: Values recommended from ASTM C1202[1]

CURRENT PASSED (COULOMBS)	CHLORIDE PERMEABILITY
>4000	High
2000-4000	Moderate
1000-2000	Low
100-1000	Very low
<100	Negligible

6. CONCLUSIONS

1. The high early strength is reported by the addition of Alccofine as partial cement replacement.
2. The compressive strength, split tensile strength and flexural strength of concrete cast with 30 % GGBS and 15 % Alccofine is 12, 19 %, and 25 % higher compared to conventional concrete respectively.
3. The combination of 15 % Alccofine and 30 % GGBS for M60 grade concrete yielded better results in terms of strength and durability
4. As per ASTM C1202 [1], the chloride permeability for all the mixes is very low.
5. From the water permeability test it is concluded that there is no seepage of water in all the mixes. Hence, the concrete is highly durable by the addition of Alccofine.

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