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Effect of Alccofine and GGBS Addition on the Durability of Concrete

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Abstract

Portland cement is the most important ingredient of concrete. A large scale production of cement plant consume large amount of energy and produce a number of undesirable products (CO_2) which negatively affect the environmental and depletion of natural resources. This treat to ecology has to lead to researchers to use industrial by-products as supplementary cementitious material in making concrete. In view this silica fume (SF), ground granulated blast furnace slag (GGBS), rice husk ash, fly ash (FL), metakolin, alccofine (AL), micro fine material, etc.; are tried out for replacing cement partially or fully in concrete, without compromising on its strength, also reduce greenhouse gases and sustainable way of management of waste. A new ultra-fine material emerged in market is called alccofine. This is available as a cementious material for replacing cement. Since this a new material, a study is tried out with the combination of Alccofine and GGBS. Ordinary Portland Cement 53 grade was used throughout the study and the grade of concrete is M20. Totally 108 cubes and 27 cylinder were cast and tested in the laboratory with nine different percentage combination of alccofine (A), GGBS (G) and cement (C) (C_{100}, $C_{70}A_0G_{30}$, $C_{90}A_{10}G_0$, $C_{60}A_{10}G_{30}$, $C_{30}A_{10}G_{30}$, $C_{40}A_0G_{60}$, $C_{85}A_{15}G_0$, $C_{55}A_{15}G_{30}$, $C_{25}A_{15}G_{60}$). Each case 3 nos. of specimen were used for repeatability. It is intended to study the compressive strength, and its durability properties like acid attack test, sulphate attack test and rapid chloride permeability test (RCPT). Among the nine different combination the maximum compressive strength of concrete is achieved by using AL10% and GGBS 30% is 38.08 N/mm^2. C60A10G30 is 28.76% higher than the control mix. Result shows that concrete incorporating alccofine and GGBS have higher compressive strength and alccofine enhanced the durability of concrete also.

Keywords: Alccofine; GGBS; Compressive Strength; Acid Attack Test; Sulphate Attack Test.

1. Introduction

1.1. General

Cement- based material is among the most important construction material, and it is most likely that they will continue to have the importance in the future. However, these construction and engineering materials must meet new and higher demands, these construction materials such as GGBS, SF, AL, and FA etc. GGBS and AL used as supplementary cementitious materials (SCM). When pozzolanic materials are incorporate to concrete, the GGBS present in this materials react with the calcium hydroxide released during the hydration of cement and forms additional C-S-H gel which improve the durability and the mechanical properties of concrete.

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1.2. Strength Properties of Concrete

Durability properties of concrete which include compressive strength, sulphate attack test, and acid attack test. The compressive strength is the capacity of a material or structure to withstand loads tending to reduce size. It can be measure by plotting applied force against deformation in a testing machine. Some materials fracture at their compressive strength limit; others deform irreversibly, so a given amount of deformation may be considered as the limit for compressive load. Compressive strength is a key value for designer of structure. The mass loss and strength of specimen due to sulphate attack acid attack, chloride attack.

1.3. Durability of Concrete

The durability of cement concrete is well defined as its ability to resist weathering action, chemical attack, or any other process of deterioration. Durable concrete will hold its original form quality, and serviceability when exposed to environment. One of the main reasons for deterioration of concrete in the past is that too much emphasis is placed on concrete compressive strength rather than on the performance criteria. The deterioration of reinforced concrete structures usually comprises the transport of aggressive substances from the surrounding environment followed by physical and chemical actions in its internal structure. As the permeation of concrete decreases its durability performance, in terms of physio-chemical degradation, increases. Therefore, permeation of concrete is one of the most acute parameters in the determination of concrete durability in destructive environments.

Since high resistance to chloride penetration can be directly related to low permeability that dominates the deterioration process in concrete structures, the resistance to chloride penetration is one of the simplest measures to determine the durability of concrete. Therefore, in this study sulphate attack test, acid attack test and rapid chloride permeability test method designated in ASTM C 1202(1997) were adopted.

1.4. Alccofine

Alccofine is a specially processed product based on slag of glass content with high reactivity obtained through the process of granulation. Alccofine provides reduced water demand for a given workability, up to 70% replacement level as per requirement of concrete performance. Alccofine can also be utilized as a high range water reduce to improve compressive strength or as a super workability aid to Improve flow.

1.5. Types of Alccofine

- Alccofine 1203
- Alccofine 1101

1.6. Alccofine 1203

Alccofine 1203 is a revolutionary material, used as a substitute to micro silica / silica fumes. Alccofine 1203 is useful in delivering better strength, but Apart from being environment friendly, Alccofine 1203 also economy since it is a major import substitute (Figure 1).

1.7. Ground Granulated Blast Furnace Slag

Blast furnace slag is a by-product of iron manufacturing industry. Iron ore, coke and limestone are fed in to the furnace, and the resulting molten slag floats above the molten iron at a temperature of about 1500^0c - 1600^0c. After the molten is tapped off, the remaining molten slag, it mainly consist of granulated siliceous and aluminous residues is then rapidly water quenched, resulting in the formation of a glassy granulate. This glassy granulate is dried and ground to the required size which is known as GGBS (Figure 2).

Figure 1. Alccofine 1203

Figure 2. GGBS

Alccofine increases the particle packing and it increases the strength of concrete and fine aggregate increases the long term strength improvement of concrete [1]. The effect of Alccofine and fly ash addition is improving on the durability of high performance concrete [2]. The micro structure in the cement paste matrix enhanced due to pozzolanic action and micro filler effect of SF and GGBS, resulting and intermittent pore structure [3]. The compressive strength and flexural strength of concrete with 8% alccofine (AL) and16% fly ash (FA) gives the better results [4]. Strength relationship of concrete cube and cylinder using alccofine (3-18%) by weight of cement. It is observed that compressive strength of cube and cylinder. The 13% AL mix gives the higher strength and cube strength is higher than the cylinder strength [5]. Concrete made by use of GGBS (0-40%) as partial replaced by cement, to evaluate the compressive and flexural strength. It is observed from the investigation that the 20% replacement of GGBS are gave higher strength. It is concluded that increases in % of GGBS results in decreases in strength of concrete [6]. Self-compacting concrete (SCC) made by use of AL (5-10%) by partial replacement of cement. The result shows the SCC with 10% AL are superior to other combinations. It is concluded that addition of AL in SCC mixers increases the filling ability, passing ability and resistance to segregation [7]. In partial replacement of concrete 20% FA and 20% GGBS is highly significant to increase the compressive strength [8]. GGBS improved the pore structure of concrete, electrical resistivity of concrete was increased and the total coulombs passed during RCPT were significantly reduced, rate of carbonation for the samples with (30% and 50%) GGBS replacement increased however longer period of water curing for GGBS blended cement concrete reduced the carbonation rate [9]. The early strength gaining property by the addition of AL and that of FA showed long term strength. It is concluded that the ternary system that is (OPC+AL+FA) concrete was found to increase the compressive strength of concrete on all age when compared to concrete made with AL and FA alone [10].

Fire resistance defined as the ability of building components to perform their intended load-bearing functions under fire exposure [11]. Hybrid fiber reinforced proportions with Alccofine satisfies the durability aspects such as resistance to water permeability, water absorption, acid attack and fire resistance [12]. GGBS and Alccofine combination was witnessed to improve the mechanical and rheological characteristics of SCC which can results in high performance as well as high strength concrete [13]. The combination of GGBS and Alccofine as replacement for cement would not be useful in the formation of TBC, and hence alternative materials need to be sought for [14]. From the survey it is found the alccofine can achieve high strength when is replaced by cement at 0% - 20% compared to the traditional concrete [15]. Effect of alccofine with flyash and GGBS on high performance in ready mixed concrete is an effective way to save around 7.5-8.5% of the total cost of concrete mixtures supplied to construction projects [16]. 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 [17]. The partial replacement of cement by GGBS up to 15% and metakaoline 10% after this range starts reducing the strength [18]. High-Performance Concrete (HPC) that has a w/b ratio in the range of 0.25 to 0.35 is usually more durable than ordinary concrete. By the incorporation of supplementary cementing materials (SCMs) in high performance concrete (HPC) durability of concrete is significantly enhanced, as the ingress of deleterious chemicals is quite difficult and only superficial. The rate of hydration of Portland cement supplanted with SCMs is enhanced due to the physical phenomena or chemical reactions like nucleation effect and pozzolanic activity [19].

Considering economic and environmental issues, being cement costly and considering co_2 release due to cement it can be replaced by cementious property material GGBS and alccofine which reduced co_2 release by 40% [20]. Making concrete industry sustainable in the present scenario is very important, so as to reduce its adverse effects on environment. While choosing raw materials for construction it is necessary to go with eco-friendly materials. Alccofine (Ultra-fine form of slag) which are by-product from steel industry possess cementitious properties can be used as replacement of cement, which are causing a lot of environmental pollution [14]. Alccofine and ground granulated blast furnace slag (GGBS) mineral admixtures in the manufacturing of high strength concrete of M70 grade .In this, also polypropylene fiber has adopted as an additive to enhance the reactions in getting satisfactory compressive strengths with optimum volume fraction of 0.5% [21-26].

The focus of current study is to use of Alccofine and GGBS to improve the strength and durability properties of concrete and the objectives are to study the properties of materials such as cement, Alccofine and GGBS, to design the mix proportion of M20 grade of concrete incorporating Alccofine and GGBS, to determine the workability of M20 grade of concrete and its compressive strength, to carry out the durability studies such as acid test, RCPT, chloride and sulphate attack test.

1.8. Properties of Alccofine 1203

It is observed that the major chemical compositions of Alccofine 1203 is 34 percent calcium oxide, 35 percent silicon dioxide and 24 percent aluminum dioxide.

2. Experimental Investigations

The detailed experimental programme is shown in Figure 3.

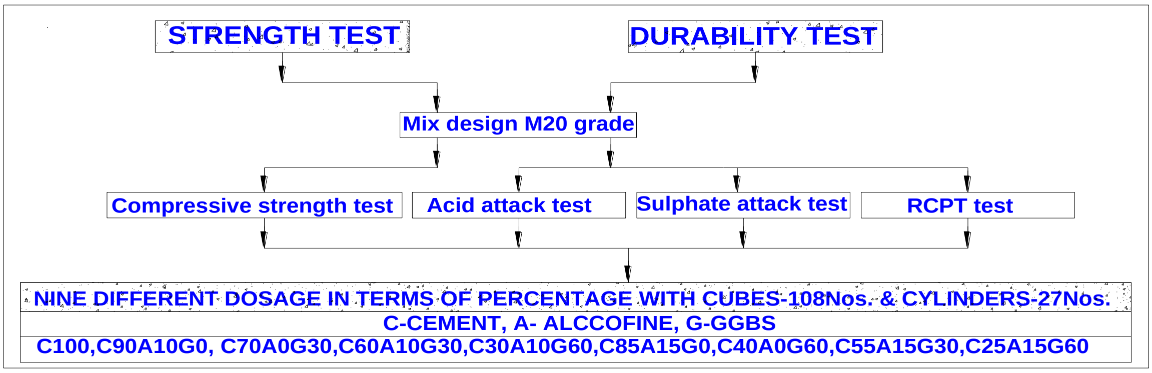

Figure 3. Experimental programme

2.1. Cement

OPC 53 confirming to IS 12269:2013 was used. The cement was procured from local markets and in one lot to maintain uniformly throughout the investigation.

2.2. Ground Granulated Blast Furnace Slag

It is made from a by-product of the production of iron in a blast furnace where iron ore, limestone and coke are heated to about 1500^0c. When these materials melt in the blast furnace slag.it is confirming to IS 12089:1987.

2.3. Alccofine

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

2.4. Fine Aggregate and Coarse Aggregate

Locally available the river sand used as fine aggregate in the present investigation. The sand is free from clay matter, silt and organic impurities. The specific gravity of F.A is 2.63.The crushed angular 20 mm nominal size angular granite metal from local source confirming to IS 383:1970 is used as coarse aggregate. It is free from impurities such as dust clay particles and organic matter, etc. The coarse aggregate has specific gravity 2.7 and fineness modulus 7.627 was used.

2.5. Concrete

M20 grade of concrete with Ordinary Portland Cement 53grade was adopted. The physical properties and test of cement are carried out. The maximum size of aggregate shall be 20 mm and the size of fine aggregates ranges between 0 and 4.75 mm after casting the specimens need to be allowed to cure in real environmental condition for about 28 days. So as to help the concrete to stabilize its own properties. The strength of concrete under axial compression is determined by loading on as standard cube a (150×150×150 mm), cylinder (150×300mm) confirming to IS 10262:2009.

- **M20 grade design mix proportion**

Cement = 387.5 kg/m^3, water =186 kg/m^3, Fine aggregate = 653.292 kg/m^3, coarse aggregate = 1148.16 kg/m^3, w/c = 0.48. The final mix ratio 1:1.73:2.96:0.48 (C: FA: CA: WB).

- **Mix proportion for C60A10G30 mix**

Cement =387.5 × 0.6 = 232.5 kg/m^3, water = 186 kg/m^3, Fine aggregate = 653.292 kg/m^3, Coarse aggregate = 1148.16 kg/m^3, w/c = 0.48, Alcofine = 0.1238 × 0.1 × 2.8 × 1000 =34.664 kg/m^3, GGBS = 0.123 × 0.3 × 2.69 × 1000 = 99.906 kg/m^3.

2.6. Laboratory Test and Chemical Properties

2.6.1. Specific Gravity

The Table 1 shows the specific gravity for various materials.

Table 1. Specific Gravity

Sl. No.	Materials	Specific gravity
1	Cement	3.13
2	GGBS	2.7
3	Alccofine	2.8
4	Fine aggregate	2.63
5	Coarse aggregate	2.7

2.6.2. Sieve Analysis

Fine aggregate confirming to grading zone - III of Table 2 of IS: 383:1970 and fineness modulus 2.23.

Table 2. Sieve Analysis

Sl. No.	Sieve Size in mm	Percentage of passing
1	4.75	99.4
2	2.36	97.2
3	1.18	93.6
4	600 micron	76.4
5	300 micron	53.1
6	150 micron	10.3
7	75 micron	0.3
8	Silt	0

The cementitious materials are analyzed for chemical properties to find the various constituent chemicals in the materials obtained values are presented in Table 3.

Table 3. Chemical properties of various materials

Sl. No.	Chemical properties	OPC	GGBS	Alccofine
1	SiO_2	61.55%	11%	34%
2	Al_2O_3	19.5%	10.18%	33.2%
3	Fe_2O_3	5.65%	2.02%	22.5%
4	CaO	5.40%	51%	1.4%
5	SO_3	2.4%	-	0.11%
6	MgO	3.9%	11.2%	6.2%

2.7. Workability

The concrete the slump value is 35 mm is measured. The cube mould (150 × 150 × 150 mm) is filled with fresh concrete in three stages, each time it is tamped using rod of standard dimensions (16 mm diameter 600 mm length) at the end of the third stage, concrete is struck off flush to the top of the mould 24 hours the cube was demoulded and cured. Table 4 shows the total number of specimen details for the present study.

Table 4. Specimen Details

S. No.	Mix	Cube	Cylinder	Total
1	C_{100}	12	3	15
2	$C_{70}A_0G_{30}$	12	3	15
3	$C_{90}A_{10}G_0$	12	3	15
4	$C_{60}A_{10}G_{30}$	12	3	15
5	$C_{30}A_{10}G_{30}$	12	3	15
6	$C_{40}A_0G_{60}$	12	3	15
7	$C_{85}A_{15}G_0$	12	3	15
8	$C_{55}A_{15}G_{30}$	12	3	15
9	$C_{25}A_{15}G_{60}$	12	3	15
Total Specimen (Note: C-Cement, A-Alccofine, G-GGBS)				135

2.8. Casting

In this research mainly prepare nine mix of M20 grade of concrete, namely conventional concrete (C100), concrete made by replacing of cement by 10% Alccofine (C90A10G0), concrete made by replacing of cement by 10% Alccofine and 30% GGBS (C60A10G30),concrete made by replacing of cement by 0% Alccofine and 30% GGBS (C70A0G30), concrete made by replacing of cement by 10% Alccofine and 60% GGBS (C30A10G60),concrete made by replacing of cement by 15% Alccofine (C85A15G0), concrete made by replacing of cement by 0% Alccofine and 60% GGBS (C40A0G60), concrete made by replacing of cement by 15% Alccofine and 30% GGBS (C55A15G30), concrete made by replacing of cement by 15% Alccofine and 60% GGBS (C25A15G60) (Figure 4). The cubes are demould after one day of casting and cubes are immersed into the normal water 28 days curing going on and then cube are taken out from the curing for test.

Figure 4. Casting of specimens

2.9. Strength and Durability

2.9.1. Compressive Strength

The test was carried out conforming to IS 516-1959 to obtain compressive strength of concrete at the age of 7 days. The cubes were tested using compressive testing machine (CTM) of capacity 2000 kN (Figure 5). The maximum compressive strength observed at replacement of Alccofine and GGBS. The result of compressive strength were presented in Table 5.

Figure 5. Compressive strength set up for cube

Table 5. Compressive Strength at 28 days for various mixes

S. No.	Mix	Compressive Strength in N/mm^2
1	C_{100}	31.80
2	$C_{90}A_{10}G_{0}$	35.66
3	$C_{70}A_{0}G_{30}$	34.08
4	$C_{60}A_{10}G_{30}$	38. 01
5	$C_{30}A_{10}G_{60}$	27.75
6	$C_{85}A_{15}G_{0}$	33.49
7	$C_{40}A_{0}G_{60}$	29.02
8	$C_{55}A_{15}G_{30}$	35.45
9	$C_{25}A_{15}G_{60}$	23.38

2.9.2. Acid Attack Test

Cubes of sizes 150×150×150 mm were cast and cured from 28 days. After 28 day curing were taken out and allowed for drying 1-3 days and weights were taken for Acid attack test 3% dilute HCL used. The cubes were to be immersed in solution for a period of 30 days. PH value to be maintained throughout the period. After 30 days the specimen were taken from the solution the specimen were cleaned and weight are measured (Figure 6). There was tested in the compression testing machine as per IS 516:1959. The mass loss and strength of specimen due to sulphate attack was determined. The test specimens are shown in Figure 7 a, b, c.

$$\text{Weight loss in percentage } = \frac{W_1 - W_2}{W_1} \times 100 \tag{1}$$

Where W_1 = Before immersion on solution (HCL, NaCl, Na_2So_4) and W_2 = After immersion on solution (HCL, NaCl, Na_2So_4).

Figure 6. Cubes are immersed in HCL Solution

(a)	(b)	(c)

Figure 7. Testing details; a) before immersion on HCL solution; b) After immersion on HCL solution(C/C); c) after immersion on HCL solution ($C_{60}A_{10}G_{30}$)

2.9.3 Sulphate Attack Test

Cubes of sizes 150×150×150mm were cast and curved for 28 days. After 28 days curing were taken out and allowed for drying 1-3days and weights were taken for sulphate attack test 5% dilute Na_2SO_4 used. The cubes were to be immersed in solution for a period of 30 days i.e., 15 wet and dry cycles. PH to be maintained throughout the period. After 30 days the specimen were taken from the solution the specimen were cleaned and weight are measured. There was tested in the compression testing machine as per IS 516:1959. The mass loss and strength of specimen due to sulphate attack was determined.

2.9.4. Chloride Attack Test

Cubes of sizes 150×150×150 mm were cast and cured for 28 days. After 28 days curing were taken and allowed for drying 1-3 days and weights were taken for sulphate attack test 3.5% dilute NaCl used. The cubes were to be immersed in solution for a period of 30 days i.e., 15 wet and dry cycles. PH value to be maintained throughout the period. After 30 days the specimen were taken from the solution the specimen were cleaned and weight are measured. There was tested in the compression testing machine as per IS 516:1959. The mass loss and strength of specimen due to sulphate attack was determined.

2.9.5. RCPT (Rapid Chloride Permeability Test)

The Rapid Chloride Permeability test for different mixes was carried out (Figure 8). Standard cylindrical disc specimens of size 100 mm diameter and 50mm thick after 90 days water curing were used. This test method covers the determination of the electrical conductance of concrete to provide a rapid indication of its resistance to penetration chloride ions. The chloride ions Apparatus consist of variable DC power supply which feeds constant stabilized voltage to the cells. The cells are made up of polymethyl methacrylate the concrete specimens are kept in between the cells. The cells connected to main instrument through 3pin plug and socket for voltage feeding. The charge of current flowing through the specimen is measured by using an accurate digital meter one cell is filled with NaCl 2.4 M concentration and other is filled with 0.3 M NAOH solution. The cylindrical specimen are coated with silica gel on their curved surfaces and the mounted on the on the open faces of the two cells. After checking the leak proofness a 60V potential differences is applied between the electrode. The current passed was noted at every 30 minutes over a period of 6 hrs and the total electric charge passed through the specimen is calculated using below expression. The test results are presented in Table 6.

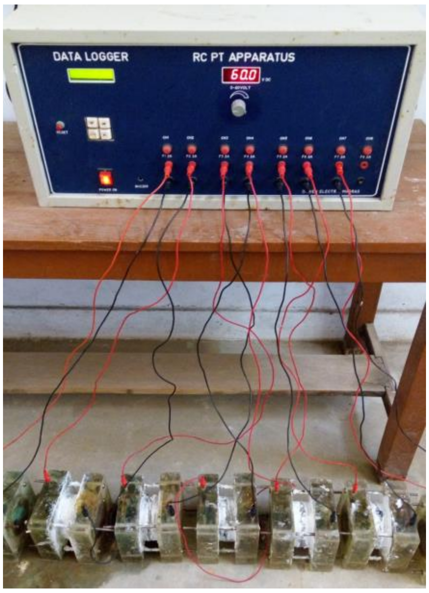

Figure 8. RCPT Setup

Table 6. Chloride penetration based on charge passed

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

The Following formula based on the trapezoidal rule can be used to calculate the average current flowing.

$$Q = 900[I_0 + 2I_{30} + 2I_{60} + \cdots + 2I_{330} + 2I_{360}] \quad (2)$$

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.

$$Qs = Q_X\,(95/X)^2 \quad (3)$$

Where Q_s = Charge passed (coulombs) through a 95 mm diameter specimen; X = Diameter of the non-standard specimen and Q_X Charge passed (coulombs) through a X mm diameter specimen.

3. Results and Discussion

3.1. Strength Properties

3.1.1. Compressive Strength

The test was carried out confirming to IS 516-1959 to obtain compressive strength of concrete at the age of 28 days is presented in Table 9. The cubes were tested using CTM. From Figure 8, it is found that the compressive strength is up to 38.01 N/mm^2 at 28 days. The maximum compressive strength is observed at C60A10G30 Mix. There is a significant improvement in the compressive strength of concrete because of the high pozzolanic nature of the alccofine and its voids filling ability.

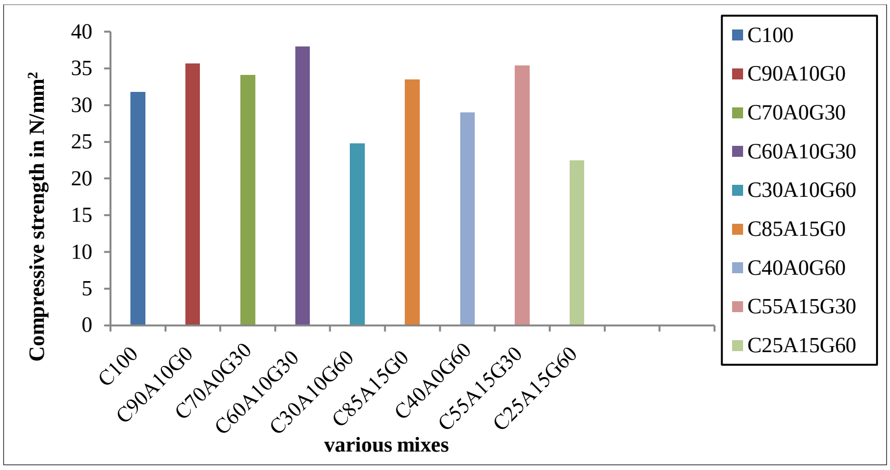

Figure 9. Compressive strength for various mixes at 28 days

3.1.2. Acid Attack Test

The acid attack test parameters observation was presented in Table 7. It shows the influence of acid attack on Al and GGBS. The average loss of weight and loss of compressive strength is considerably low. As the attack proceeds, all the cement compounds are evenly broken and leached away, together with carbonate aggregate material. This indicates that incorporation of Al in concrete could be reasonable in the aspects of more acid resistance.

Table 7. Compressive strength for acid attack test

Sl. No.	Mix	Compressive strength in N/mm^2 (Acid attack test)
1	C_{100}	25.76
2	$C_{90}A_{10}G_0$	32.13
3	$C_{70}A_0G_{30}$	30.12
4	$C_{60}A_{10}G_{30}$	36.16
5	$C_{30}A_{10}G_{60}$	18.84
6	$C_{85}A_{15}G_0$	30.08
7	$C_{40}A_0G_{60}$	23.02
8	$C_{55}A_{15}G_{30}$	32.59
9	$C_{25}A_{15}G_{60}$	17.29

From the Figure 10 shows Compressive strength for acid attack test. The strength varies from 17.29 to 36.16 N/mm^2. C25A15G60 mix lower than all other mixes.C60A10G30 is 28.76% higher than the control mix. The C70A0G30 mix compressive strength is higher than C40A0G60 mix.

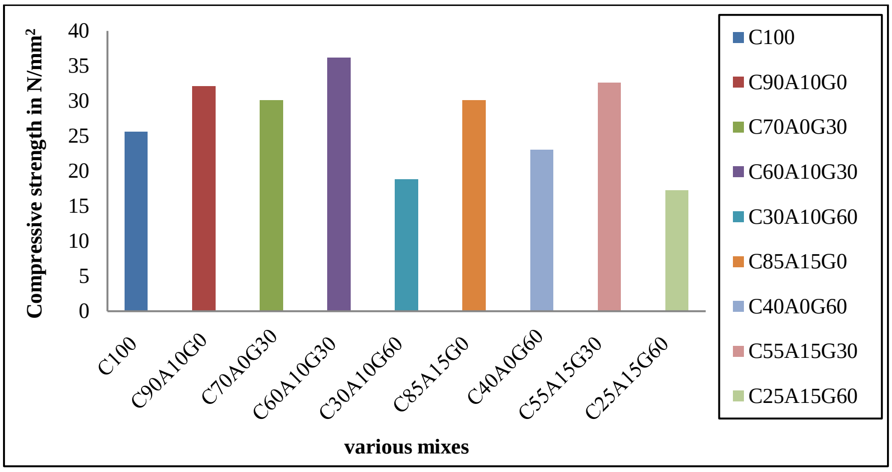

Figure 10. Compressive strength for acid attack test

Comparison of before and after acid attack test are presented in Table 8.

Table 8. Comparison of compressive strength for various mixes

Sl. No.	Mix	Compressive strength for before acid attack (N/mm^2)	Compressive strength for after acid attack (N/mm^2)
1	C_{100}	31.8	25.76
2	$C_{90}A_{10}G_0$	35.66	25.76
3	$C_{70}A_0G_{30}$	34.08	30.12
4	$C_{60}A_{10}G_{30}$	38. 01	36.16
5	$C_{30}A_{10}G_{60}$	27.75	18.84
6	$C_{85}A_{15}G_0$	33.49	30.08
7	$C_{40}A_0G_{60}$	29.02	23.02
8	$C_{55}A_{15}G_{30}$	35.45	32.59
9	$C_{25}A_{15}G_{60}$	23.38	17.29

From the Figure 11 shows that comparison of before and After Acid Attack. C60A10G30 loss of compressive strength is very lower than all other mixes.

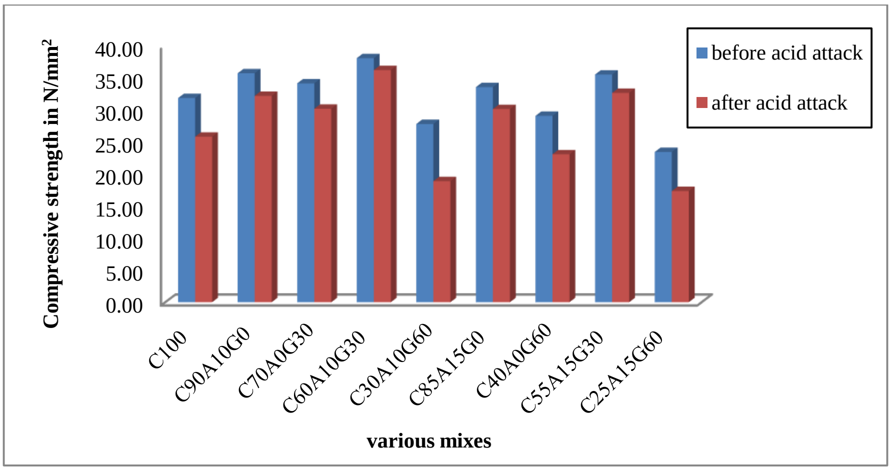

Figure 11. Comparison of before and after acid attack test result

3.1.3. Weight Loss for Acid Attack Test

From the Table 9 shows weight loss for acid attack test. The weight loss varies from 0.463 to 5.7%. C25A15G60 mix higher weight loss than all other mixes. C60A10G30 mix weight loss is lower than the control mix.

Table 9. Weight loss for acid attack test

Sl. No.	Mix	Weight loss in %
1	C_{100}	5.45
2	$C_{90}A_{10}G_0$	2.92
3	$C_{70}A_0G_{30}$	3.23
4	$C_{60}A_{10}G_{30}$	0.463
5	$C_{30}A_{10}G_{60}$	5.22
6	$C_{85}A_{15}G_0$	3.38
7	$C_{40}A_0G_{60}$	4.06
8	$C_{55}A_{15}G_{30}$	1.505
9	$C_{25}A_{15}G_{60}$	5.7

3.1.4. Sulphate Attack Test

The Sulphate attack test parameters observation was presented in Table 10. It shows the influence of Sulphate attack on Al. From the Figure 12 shows compressive strength for sulphate attack test. The strength varies from 19.26 to 37.76 N/mm^2. C60A10G30 mix higher than all other mixes.

Table 10. Compressive strength for sulphate attack

Sl. No.	Mix	Compressive strength in N/mm^2 (Sulphate attack test)
1	C_{100}	28.92
2	$C_{90}A_{10}G_0$	34.23
3	$C_{70}A_0G_{30}$	32.03
4	$C_{60}A_{10}G_{30}$	37.76
5	$C_{30}A_{10}G_{60}$	21.36
6	$C_{85}A_{15}G_0$	32.07
7	$C_{40}A_0G_{60}$	26.15
8	$C_{55}A_{15}G_{30}$	37.03
9	$C_{25}A_{15}G_{60}$	19.26

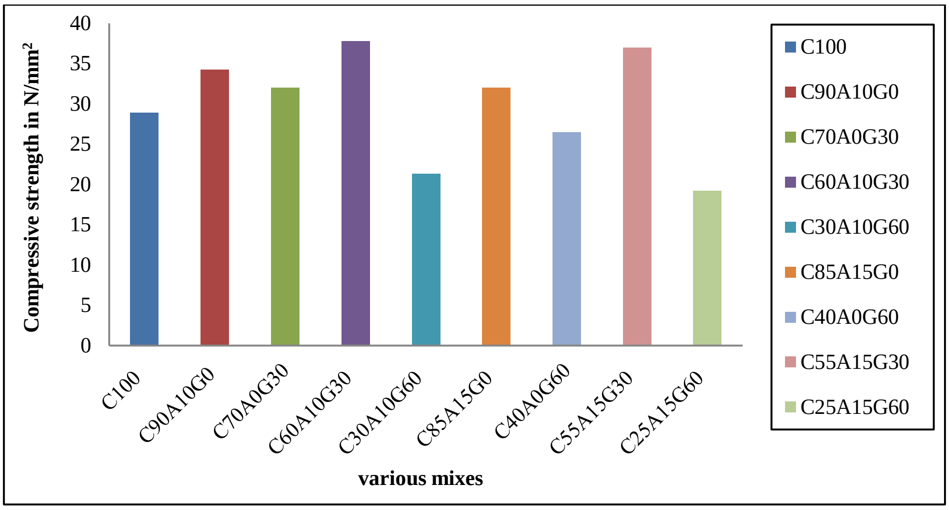

Figure 12. Compressive strength for sulphate attack test

3.1.5. Comparison of before and after Sulphate Attack Test

Comparison of before and after acid attack test are presented in Table 11.

Table 11. Comparison of compressive strength for various mixes

Sl. No.	Mix	Compressive strength for before sulphate attack (N/mm^2)	Compressive strength for after sulphate attack (N/mm^2)
1	C_{100}	31.8	28.92
2	$C_{90}A_{10}G_0$	35.66	34.23
3	$C_{70}A_0G_{30}$	34.08	32.03
4	$C_{60}A_{10}G_{30}$	38. 01	37.76
5	$C_{30}A_{10}G_{60}$	27.75	21.36
6	$C_{85}A_{15}G_0$	33.49	32.07
7	$C_{40}A_0G_{60}$	29.02	26.15
8	$C_{55}A_{15}G_{30}$	35.45	37.03
9	$C_{25}A_{15}G_{60}$	23.38	19.26

From the Figure13 shows comparison of before and after sulphate Attack. C60A10G30 loss of compressive strength is very lower than all other mixes.

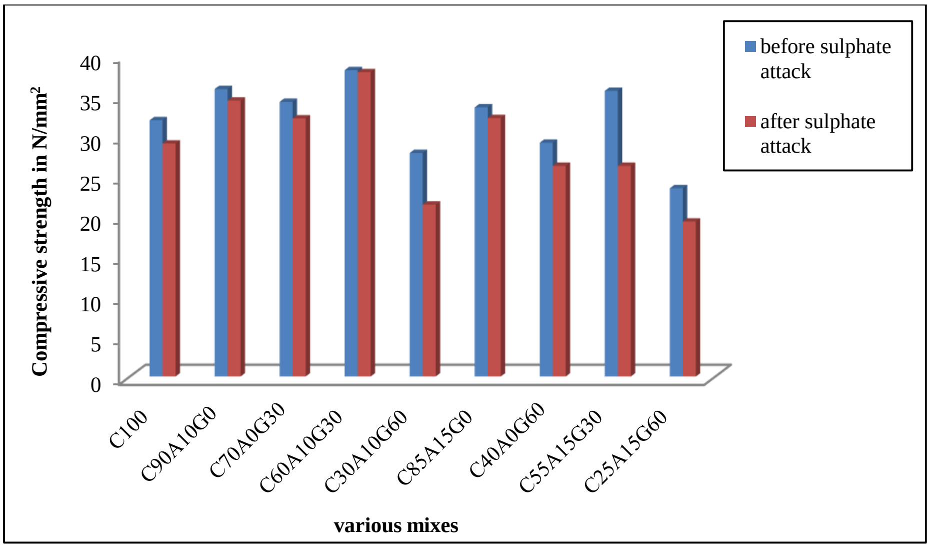

Figure 13. Comparison of before and after sulphate attack

3.1.6. Weight Loss for Acid Attack Test

From the Table 12 shows weight loss for sulphate attack test. The weight loss varies from 0.15 to 0.812%. C25A15G60 mix higher weight loss than all other mixes. C60A10G30 mix weight loss is lower than the control mix.

Table 12. Weight loss for sulphate attack test

Sl. No.	Mix	Weight loss in % (sulphate attack test)
1	C_{100}	0.76
2	$C_{90}A_{10}G_{0}$	0.33
3	$C_{70}A_{0}G3_{0}$	0.39
4	$C_{60}A_{10}G_{30}$	0.15
5	$C_{30}A_{10}G_{60}$	0.69
6	$C_{85}A_{15}G_{0}$	0.45
7	$C_{40}A_{0}G_{60}$	0.49
8	$C_{55}A_{15}G_{30}$	0.27
9	$C_{25}A_{15}G_{60}$	0.812

3.1.7. Chloride Attack Test

The acid attack test parameters observation was presented in Table 13. It shows the influence of acid attack on Al. The average loss of weight and loss of compressive strength is considerably low. This indicates that incorporation of Al in concrete could be reasonable in the aspects of more acid resistance.

Table 13. Compressive strength for chloride attack

S. No.	Mix	Compressive strength in N/mm^2 (Chloride attack test)
1	C_{100}	29.20
2	$C_{90}A_{10}G_{0}$	34.13
3	$C_{70}A_{0}G_{30}$	33.08
4	$C_{60}A_{10}G_{30}$	37.88
5	$C_{30}A_{10}G_{60}$	23.20
6	$C_{85}A_{15}G_{0}$	32.04
7	$C_{40}A_{0}G_{60}$	27.80
8	$C_{55}A_{15}G_{30}$	34.23
9	$C_{25}A_{15}G_{60}$	21.16

From the Figure 14 shows compressive strength for Chloride attack test. The strength varies from 21.16 to 37.88 N/mm^2. C60A10G30 mix higher than all other mixes. C60A10G30 is 22.91 % higher than the control mix.

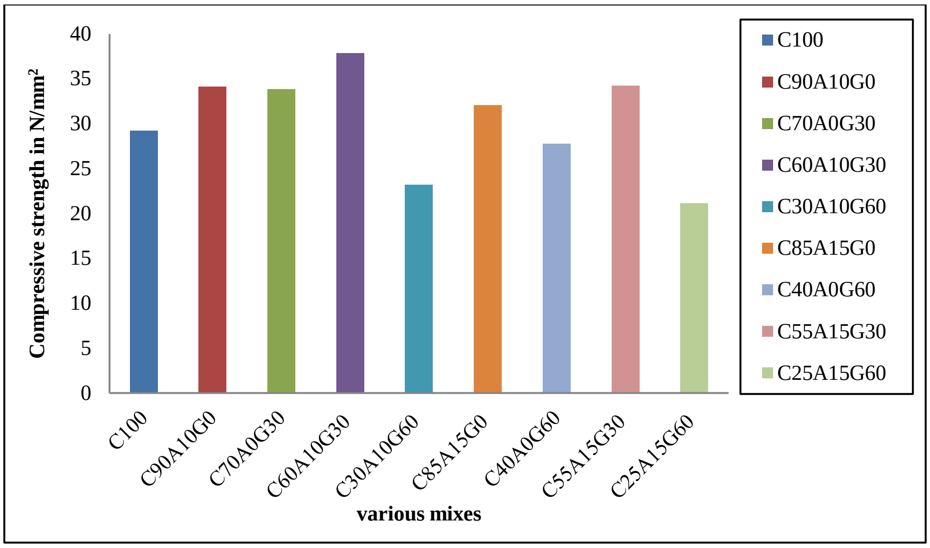

Figure 14. Compressive strength for chloride attack

3.1.8. Comparison of before and after Chloride Attack

Comparison of before and after acid attack test are presented in Table 14.

Table 14. Comparison of Compressive strength for Various Mixes

S. No.	Mix	Compressive strength for before chloride attack (N/mm^2)	Compressive strength for after chloride attack (N/mm^2)
1	C_{100}	31.8	29.20
2	$C_{90}A_{10}G_0$	35.66	34.13
3	$C_{70}A_0G_{30}$	34.08	33.08
4	$C_{60}A_{10}G_{30}$	38. 01	37.88
5	$C_{30}A_{10}G_{60}$	24.75	23.20
6	$C_{85}A_{15}G_0$	33.49	32.04
7	$C_{40}A_0G_{60}$	29.02	27.80
8	$C_{55}A_{15}G_{30}$	35.45	34.23
9	$C_{25}A_{15}G_{60}$	22.75	21.16

From the Figure 15 shows comparison of before and after chloride Attack. C60A10G30 loss of compressive strength is very lower than all other mixes.

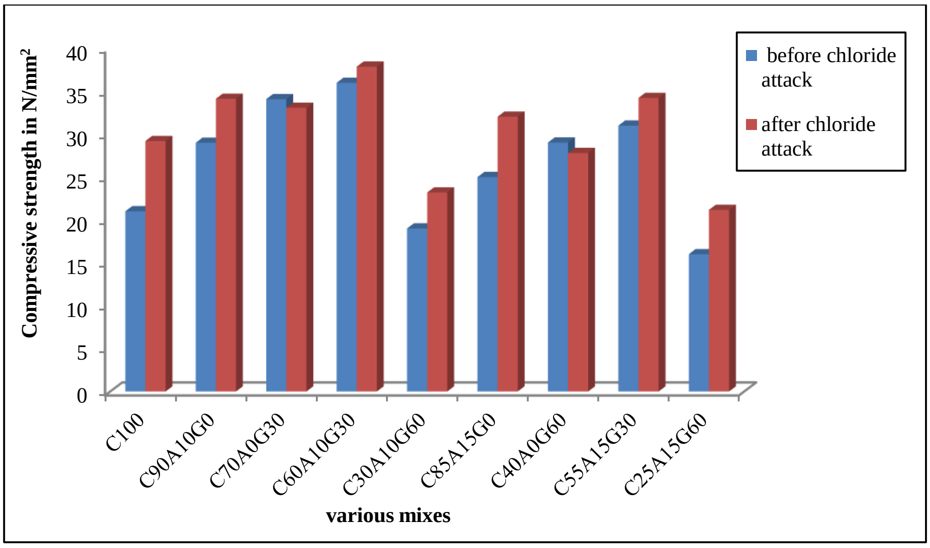

Figure 15. Comparison of before and after chloride attack

3.1.9. Weight Loss for Chloride Attack Test

From the Table 15 shows weight loss for chloride attack test. The weight loss varies from 0.21 to 1.41%. C25A15G60 mix higher weight loss than all other mixes. C60A10G30 mix weight loss is lower than the control mix.

Table 15. Weight Loss for Chloride Attack Test

S. No	Mix	Weight Loss In %
1	C_{100}	1.23
2	$C_{90}A_{10}G_0$	0.76
3	$C_{70}A_0G_{30}$	0.83
4	$C_{60}A_{10}G_{30}$	0.21
5	$C_{30}A_{10}G_{60}$	1.25
6	$C_{85}A_{15}G_0$	0.82
7	$C_{40}A_0G_{60}$	0.97
8	$C_{55}A_{15}G_{30}$	0.55
9	$C_{25}A_{15}G_{60}$	1.41

3.1.10. RCPT

On addition of Al in OPC system, RCPT value decreases, this is due to particle size is smaller other two materials resulting in lower permeability. Addition of alumina decreases RCPT value because alumina react with chlorine preferentially to calcium. On addition of GGBS in al based cement, there is further reduction in RCPT value, this due to the higher amount of pozzolana. RCPT values are presented in Table 14 and the corresponding Figure 16.

Table 16. RCPT test result

S. No	Mix	Total Charge Passed Through in Coulombs @ 28 DAYS
1	C_{100}	2155.5
2	$C_{90}A_{10}G_0$	322.56
3	$C_{70}A_0G_{30}$	523
4	$C_{60}A_{10}G_{30}$	204.6
5	$C_{30}A_{10}G_{60}$	2054.99
6	$C_{85}A_{15}G_0$	356.29
7	$C_{40}A_0G_{60}$	620.53
8	$C_{55}A_{15}G_{30}$	397.8
9	$C_{25}A_{15}G_{60}$	2277.0

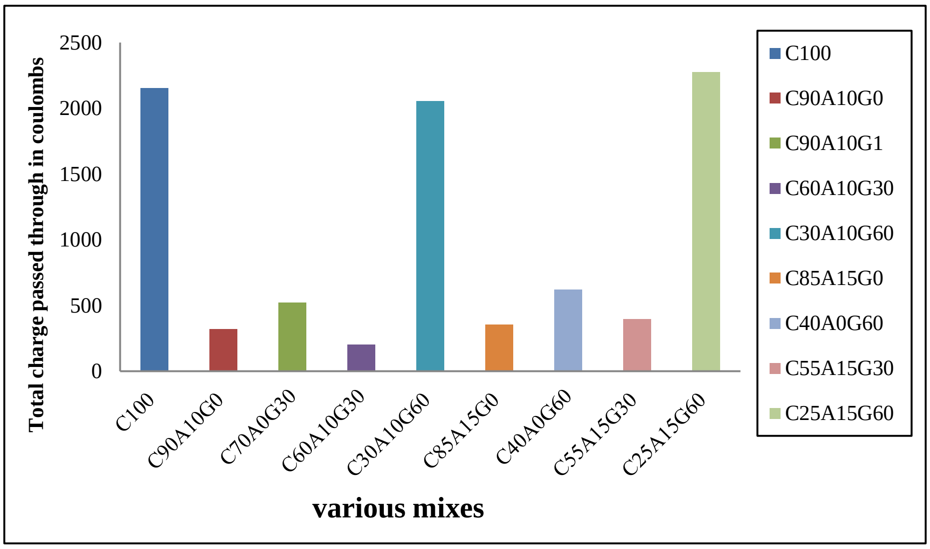

Figure 16. RCPT test result

4. Conclusions

In this study the effect of AL and GGBS as supplementary cementitious materials and durability of concrete was investigated. Based on the experimental investigation the following conclusions are drawn.

- Total nine different combination were investigated for both strength and durability test.
- All the different combination as a partial replacement of cement using alccofine and GGBS.
- Among the different nine combination the maximum compressive strength of concrete is achieved by using AL10% and GGBS 30% is 38.08 N/mm^2. C60A10G30 is 28.76% higher than the control mix.
- The minimum losses of weight and loss of compressive strength is achieved by C60A10G30 mix for acid attack test, sulphate attack test and chloride attack test.
- From the acid attack test results, loss of compressive strength is 28.76% is lower than the c/c and mass loss is 4.987% is lower than c/c.
- From the sulphate attack test results, loss of compressive strength is23.41 % is lower than the c/c and mass loss is 0.61% is lower than c/c.
- From the chloride attack test results, loss of compressive strength is 22.91% is lower than the c/c and mass loss is 1.02% is lower than c/c.
- From the RCPT test results reveals that the C60A10G30 mix total charge passed in coulombs is very lower than all other mixes.
- The combination C60A10G30 mix gives better performance in both strength and durability aspects.
- It recommended to utilize the AL material with cement after checking its other durability properties and flexural studies on beams.

5. Conflicts of Interest

The authors declare no conflict of interest.

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