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Concrete Experimentation using GGBS and Alcofine Elements Partially Substituted for Cement

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Abstraction: The most crucial ingredient in concrete is Portland cement. The manufacture of cement plants on a large scale uses a lot of energy and results in a lot of waste products (CO_2) that harm the environment and deplete natural resources. Researchers are now using industrial by-products as additional cementitious ingredients for concrete production as a result of this environmental treatment. Because of this, efforts are being made to replace some or all of the materials found in concrete, such as silica fume (SF), ground granulated blast furnace slag (GGBS), fly ash, rice husk ash, metakaolin, alcofine (AL), micro fine materials, etc., without sacrificing cement strength. This will help to reduce greenhouse gas emissions and provide a sustainable method of waste management. Alcofine is a brand-new ultra-fine substance that has entered the market. It can be used in place of cement as a cementitious substance. The combination of GGBS and Alcofine is being explored because it is a novel material. Throughout the investigation, regular Portland cement grade 53 was utilized, and the concrete grade was M20. Nine distinct percentage combinations of Alcofine (A), GGBS (G), and cement (C) were used to cast and test 108 cubes and 27 cylinders in the lab (C100, C70A0G30, C90A10G0, C60A10G30, C30A10G30, C40A0G60, C85A15G0, C55A15G30, and C25A15G60). Three specimens were utilized for repetition in each instance. This is to investigate its durability and compressive strength using tests such the rapid chloride permeability test (RCPT), sulfate attack test, and acid attack test. Out of the nine possible combinations, the concrete with AL10% and GGBS30% has the highest compressive strength, measuring 38.08 N/mm2. The difference between C60A10G30 and the control mix is 28.76%. The findings indicate that concrete combining GGBS and Alcofine has a higher compressive strength and is more durable.
Keywords: compressive strength, GGBS, acid attack test, sulfate attack test, and alcofine.

I. INTRODUCTION

In general, cement-based building materials are the most crucial and are probably going to remain such in the future. However, these engineering and construction materials—such as GGBS, SF, AL, and FA, among others—will need to satisfy new and increased requirements. As supplemental cementation materials (SCM), GGBS and AL are employed. Concrete's durability and mechanical qualities are enhanced when pozzolanic additives are added because the GGBS in these materials combines with the calcium hydroxide that is generated during cement hydration to create more CSH gels.

A. Concrete's Strength Characteristics

Concrete's strength characteristics Compressive strength, sulfate attack test, and acid attack test are examples of concrete's durability characteristics. The capacity of a material or structure to bear a load that causes it to shrink in size is known as compressive strength. Plotting the force applied against the deformation in a testing machine allows for its measurement. A certain amount of distortion can be regarded as the compressive load limit since certain materials shatter at their compressive strength limit while others undergo irreversible deformation. For structural designers, compressive strength is a crucial parameter. the strength and mass loss of a specimen brought on by acid, chloride, or sulfate attacks.

B. Concrete Durability

The ability of cement concrete to withstand weathering, chemical attack, or any other deterioration process is a clear definition of its durability. When exposed to the elements, durable concrete will maintain its original look and functionality. Prioritizing concrete's compressive strength over performance standards was one of the primary causes of the material's degradation in the past. When reinforced concrete constructions deteriorate, hostile substances from the environment are typically transported and then undergo physical and chemical reactions inside the structure. In terms of physicochemical degradation, concrete's permeability both boosts and decreases its durability performance. As a result, one of the most important factors in assessing concrete's longevity in harsh conditions is its permeability. The simplest way to assess the durability of concrete is to look at its resistance to chloride penetration, which is directly correlated with the low permeability that drives the deterioration process in concrete structures. As a result, this study used the quick chloride permeability test, acid attack test, and sulfate attack test procedures outlined in ASTM C 1202 (1997).

C. Slag from Ground Granulated Blast Furnace (GGBS)

Granulated Slag from Ground Blast Furnace One by-product of the iron-making process is blast furnace slag. The resulting molten slag floats on top of the molten iron at a temperature of around 15,000 to 16,000 degrees Celsius after iron ore, coke, and limestone are charged into the furnace. Glass granulate is created by quickly immersing the leftover molten slag—which mostly consists of granular siliceous and aluminous residues—in water after the molten portion has been removed. This glass granulate, known as GGBS, is dried and ground to the necessary size (Figure 2).

mostly silicon dioxide (SiO_2), aluminum oxide (Al_2O_3), and calcium oxide (CaO).

<u>Color:</u> Paler than regular Portland cement, with a hint of off-white.

<u>Activity:</u> It is a latent hydraulic substance, which means that while it interacts slowly with water on its own, it reacts more vigorously when calcium hydroxide—which is created during cement hydration—is present.

When used in concrete, it can partially substitute regular Portland cement, which is usually between 20 and 70 percent.

<u>Reduces permeability, increasing concrete's resistance to sulfate and chloride attack;</u>

* Lowers the heat of hydration, minimizing thermal cracking in big pours;
* Enhances workability and durability.

<u>Advantages for the environment</u>:

Uses an industrial by-product, boosting sustainability; Lowers CO_2 emissions by using less cement.

D. Definition and Types of Alcofine

High reactivity is attained using a granulation process in Alcofine, a specifically processed product based on glass slag. With a replacement level of up to 70% based on the concrete performance criteria, Alcofine offers reduced water demand for a given performance. Alcofine can also be used as a super workability aid to improve flow or as a high-grade water reducer to increase compressive strength.

E. Alcofine types include : Alcofine 1203 and Alcofine 1101.

Alcofine 1203. An innovative substance called Alcofine 1203 is utilized in place of fine silica or silica fume. Alcofine 1203 is helpful for giving strong strength, but it's also economical because it's a significant import substitute and environmentally beneficial (Figure 1).

Figure 1. Alccofine 1203

Figure 2. GGBS

Alcofine improves the long-term strength of fine aggregate concrete by increasing particle packing, which in turn raises concrete strength [1]. The use of fly ash and Alcofine has the effect of making high performance concrete more durable [2]. The pozzolanic action and micro filler effect of SF and GGBS increase the microstructure in the cement paste matrix, resulting in the creation of pores and interstitials [3].

Concrete containing 8% Alcofine (AL) and 16% Fly Ash (FA) has good compressive and flexural strengths [4]. Concrete cube and cylinder strength relationship utilizing Alcofine (3–18%) by cement weight. The compressive strength of cylinders and cubes has been determined. Higher strength is obtained with a 13% AL mix, and the cube strength is greater than the cylinder strength [5]. In order to assess the concrete's compressive and flexural strength, GGBS (0–40%) was partially substituted with cement. According to the investigation, a 20% substitution of GGBS results in increased strength. It has been determined that when the percentage of GGBS in concrete increases, its strength decreases [6]. AL (5–10%) is used in self-compacting concrete (SCC) to partially replace cement. The findings demonstrate the superiority of SCC with 10% AL over alternative combinations. It has been determined that adding AL to an SCC mixer improves its filling, passing, and segregation resistance [7]. To increase the compressive strength, it is crucial to replace some of the concrete with 20% FA and 20% GGBS [8]. In addition to improving the concrete's pore structure and electrical resistivity, GGBS also significantly decreased the total coulombs passed during RCPT. For specimens that had 30% and 50% GGBS replacement, the carbonation rate increased, but for GGBS blended cement concrete, the carbonation rate decreased with longer water curing [9]. Long-term strength is shown by the early strength attained by combining AL and FA. When compared to concrete prepared with AL and FA alone, it is determined that the ternary system (OPC+AL+FA) concrete gradually improves the concrete's compressive strength [10]. The ability of building components to carry their appropriate load in the event of a fire is known as fire resistance [11]. Alcofine-reinforced hybrid fibers meet durability requirements such fire resistance, acid attack resistance, water permeability, and water absorption [12]. It has been demonstrated that adding GGBS and Alcofine to SCC enhances its mechanical and rheological characteristics, resulting in concrete with high strength and performance [13]. Finding substitute materials is necessary because using GGBS and Alcofine in place of cement will not work well for making TBC [14]. According to the survey, Alcofine can be substituted with 0% to 20% cement to increase strength [15]. An efficient method of reducing the overall cost of the concrete mix used for construction projects is to combine Alcofine with fly ash and GGBS to achieve great performance in ready-mixed concrete [16]. Alcofine has the benefit of lowering the water/binder ratio in addition to its strength. The strength in flexure and compression is greatly increased by alcofine material [17]. After this range, strength starts to decrease when cement is partially replaced with GGBS up to 15% and metakaolin up to 10% [18]. In general, high-performance concrete (HPC) that has an aw/b ratio between 0.25 and 0.35 is more resilient than regular concrete. Due to the extremely difficult and superficial penetration of hazardous chemicals, the addition of supplemental cementing materials (SCMs) to high-performance concrete (HPC) greatly extends the concrete's lifetime. Physical or chemical processes like pozzolanic activity and nucleation effects cause Portland cement to hydrate more quickly [19]. In light of economic and environmental concerns, cement can be substituted with cementitious property materials GGBS and Alcofine, which resulted in a 40% reduction in CO2 emissions due to cement's high cost [20]. Making the concrete industry sustainable is crucial in the current climate in order to lessen its negative environmental effects. Choosing raw materials for building requires the usage of environmentally friendly resources. Because of its cementitious qualities, ultra-fine slag, a by-product of the steel industry, can be used in place of cement, which is a major source of pollution in the environment. High strength concrete of M70 grade is made using mineral combinations of GGBS and Alcofine.

II. REVIEW OF THE LITERATURE

The use of additional cementitious elements, such as fly ash, GGBS, silica fume, and Alcofine, to increase the strength and durability of concrete has been the subject of numerous studies. Below is a summary of the main conclusions drawn from earlier studies:

A. B.K. Shah and Suthar Sunil B. (2013)

The authors of the study noted a significant improvement in strength development throughout both the early and later curing stages of high-strength concrete that contained fly ash and Alcofine. The improvement was ascribed to the pozzolanic activity of fly ash, which generates more calcium silicate hydrate (C-S-H) gel, resulting in denser microstructures and decreased porosity, and the ultra-fine nature of Alcofine, which enhances particle packing.

B. B.K. Shah, P.J. Patel, and Suthar Sunil B. (2013)

This study examined the impacts of fly ash and alcofine in high-performance concrete and found that the mechanical qualities significantly improved. The authors stressed that while silica fume and GGBS's pozzolanic activity further densifies the microstructure and increases durability against sulfate and chloride penetration, Alcofine's micro-filler effect lowers the void content.

C. Soni Deval, Vilin Parekh, and Suhasini Kulkarni (2013)

Their experimental study showed that concrete with 16% fly ash and 8% Alcofine had higher flexural and compressive strengths. Stronger interfacial transition zones (ITZ), greater hydration, and enhanced particle size distribution were attributed to this performance increase. These factors improve load transfer and lessen microcracking.

D. Ashok Kumar Gupta and Sourav (2014)

In concrete containing Alcofine, the authors investigated the connection between cube and cylinder strength. Cube specimens regularly outperformed cylinder specimens, and mixes containing 13% Alcofine produced the strongest results. This strength improvement was attributed to Alcofine's high reactivity and fineness, which promote packing density and quicken hydration.

E. Arun Kumar, P.N. Patil, and Patil Yogendra O. (2013)

According to the results of this investigation, compressive strength can be maximized by substituting 20% of OPC with GGBS in place of cement. The improvement was ascribed to GGBS's latent hydraulic activity, which forms more C-S-H gel when it combines with calcium hydroxide. However, it was discovered that adding more than 20% GGBS slowed early hydration, which decreased early strength.

F. A.C. Savji and M.S. Pawar (2013)

Their study on self-compacting concrete (SCC) showed that adding 10% Alcofine enhanced the concrete's ability to pass, fill, and resist segregation. These advantages result from the ultra-fine particles improving flow properties and lowering internal friction without sacrificing strength.

G. P. Kodanderram Rao, K. Venkateshwara Rao, and Swoop A.H.L. (2013)

According to this durability study, compressive strength and long-term resilience to harsh conditions were greatly increased by substituting 20% fly ash and 20% GGBS for cement. Together, these SCMs improved resistance to sulfate and acid assaults, decreased permeability, and optimized the pore structure.

III. RESOURCES AND TECHNIQUES

A. Material

* Alcofine 1203 (Properties Table)
* Cement (Grade 53 OPC)
* Micro-integrations
* Coarse aggregations
* Water
* Super plasticizer (Fosrock) (Comp last SP430 DIS)

1) Cement: The cement utilized is grade 53 regular Portland cement that was purchased from a single supplier. The standard code IS 12269-1987 is met by the cement used in the study.

2) Alcofine: Ambuja Cement Private Limited produces an ultra-fine slag known as Alco fine. The Alco fine utilized in the study has a specific gravity of 2.7. Alco fine has extremely fine particles, with an average size of 20–50 µm and a range of 1–75 µm. Table 1 displays all of Alco fine's physical characteristics in comparison to cement.

Table 1. Properties of OPC and Alccofine

Property	OPC	Alccofine
Bulk density (kg/cum)	1435	660
Surface area (m^2/kg)	350	1200
Specific gravity	3.18	2.70
Particle shape	Spherical	Irregular
Colour	Grey	Pale white

3) Micro-integrations: River sand is utilized in this study, and its physical characteristics are examined in accordance with IS 383: 2016. The physical characteristics of fine aggregates are presented in Table 2.
4) Coarse aggregations: Rough collection gathering Sand that is no larger than 20 mm is gathered from a nearby provider and satisfies IS 383: 2016 requirements, which outline the material's physical characteristics and are utilized in testing. The following physical characteristics of the coarse aggregate are listed in Table 2.

Table 2. Aggregate properties

Property	Fine Aggregate	Coarse aggregate
Size	4.75mm	20mm
Shape	-	Crushed Angular
Fineness Modulus	2.77	6.25
Zone	II	-
Specific Gravity	2.81	2.77
Bulk Density	1652	KG/m³

5) Water: In accordance with the mix design, water from the university laboratory is added to the concrete mix for casting and curing.
6) Extreme plasticizer: Fosrock is the superplasticizer employed in this investigation. Comp last DIS SP430. The amount of super plasticizer is changed based on the mixture, and the slump test is used to determine the final dosage.

B. Design of Mixes

In accordance with IS 10262:2019, the mix proportions for M20 grade concrete were created. In addition to regular Portland cement (53 grade), river sand, and crushed stone (maximum size 20 mm), Alcofine 1203 and ground granulated blast furnace slag (GGBS) were utilized to partially replace cement. To preserve performance, Fosrock Conplast SP430 DIS super plasticizer was applied.

C. The process of Mixing and Casting

1) All dry components were weighed and well mixed, including cement, Alcofine, GGBS, fine aggregate, and coarse aggregate.
2) The superplasticizer was first dissolved in the leftover water after about 80% of the mixing water had been added.
3) Until a consistent consistency was reached, the concrete was mixed.
4) The slump angle test was used to evaluate the performance.
5) A table vibrator was used to condense it after it had been poured into a mold.
6) The samples were taken out and kept in water curing tanks at 27 ± 2 °C until the test age after a 24-hour period.

IV. PROCEDURES

Physical characteristics of natural coarse aggregate, fine aggregate, and alcofine are assessed. After being manually gathered and cleaned, recycled aggregates are processed using a mortar-free friction testing machine, and their physical characteristics are computed. The design of the M40 concrete mix is based on IS: 10262-2019. Table 6 lists the elements needed to make 1 m3 of M40 concrete.

The following four varieties of binary mixed concrete samples have recycled aggregates added to them: 25% flyash and 25% RCA, 25% flyash and 50% RCA, 25% flyash and 75% RCA, 25% flyash and 100% RCA, and additionally, 5%, 10%, and 15% Alcofine. Concrete's workability (slump) is quantified. Prisms, cubes, and cylinders are cast. Mechanical characteristics are assessed after seven and twenty-eight days of water cure. Concrete cubes were submerged in a 3% NaOH solution to measure alkaline attack. After 28 days of curing, tests are conducted to determine the concrete's resistance to alkaline assault.

Experimental Plan for M20 Mix Design

Mix Design	Details	Tests Conducted
M20	100% OPC	SEM, XRD, EDAX
M20	5% Alcofine	Compressive Strength, Split Tensile Strength, Flexural Strength, SEM
M20	10% Alcofine	Compressive Strength, Split Tensile Strength, Flexural Strength, SEM
M20	15% Alcofine	Compressive Strength, Split Tensile Strength, Flexural Strength, SEM
M20	20% Alcofine	Compressive Strength, Split Tensile Strength, Flexural Strength, SEM

V. CASTING

Concrete made of concrete, concrete made with 10% Alcofine (C90A10G0) in place of cement, concrete made with 10% Alcofine and 30% GGBS (C60A10G30) in place of cement, concrete made with 0% Alcofine and 30% GGBS (C70A0G30), concrete made with 10% Alcofine and 60% GGBS (C30A10G60), concrete made with 15% Alcofine (C85A15G0), concrete made with 0% Alcofine and 60% GGBS (C40A0G60), concrete made with 15% Alcofine and 30% GGBS (C55A15G30), and concrete made of concrete were the nine main mixtures of M20 grade concrete. In place of cement, 60% GGBS (C25A15G60) and 15% Alcofine are combined.

VI. STRENGTH UNDER COMPRESSION

In accordance with IS 516-1959, the test was carried out to determine the concrete's compressive strength after seven days. A compression testing machine (CTM) with a 2000 kN capacity was used to test the cubes. The highest compressive strength was recorded when GGBS and Alcofine were switched.

Compressive strength set up for cube

VII. RESULTS AND DISCUSSION

A. *Strength of Compression*

The above table shows the results of this test, which validates IS 516-1959 to determine the compressive strength of concrete after 28 days. CTM was used to test the cubes. According to Civil Engineering Journal Volume 5, No. 6, June 2019 1281, the compressive strength increases to 38.01 N/mm2 after 28 days. The C60A10G30 blend exhibits the highest compressive strength. Alcofine's excellent pozzolanic nature and void-filling capabilities greatly increase the compressive strength of concrete.

Variation of Compressive Strength for Different Mix Proportions :

Sr.No.	Mix	Average Compressive Strength N/mm²		
		7 Days	14 Days	28 Days
1	NSCC	21.9	30.2	36.6
2	PM1	26.2	34.2	40.2
3	PM2	29.6	38.9	42.9
4	PM3	27.7	33.9	39.8
5	PM4	25.2	31.6	38.2

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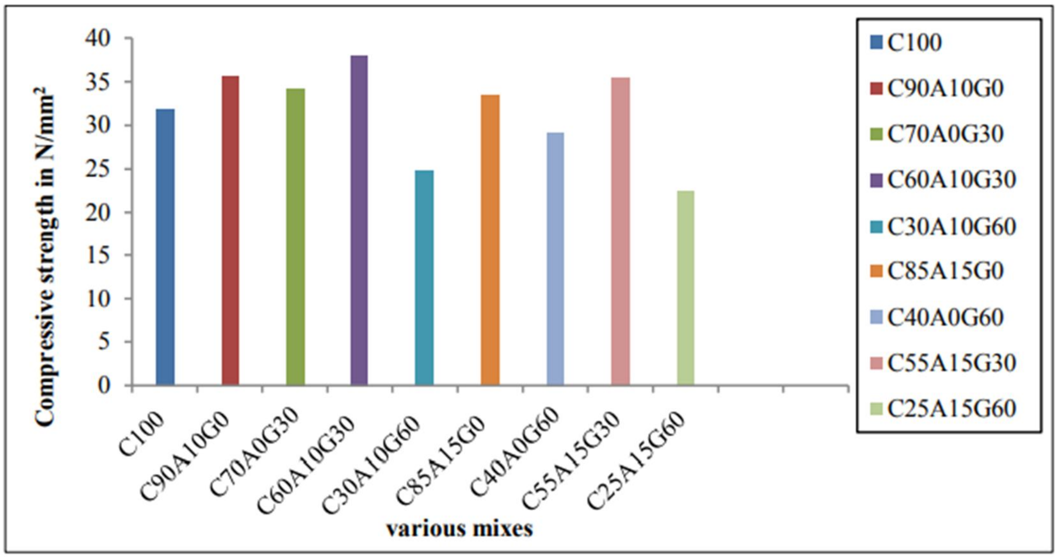
Compressive strength for various mixes at 28 days

Mix	Compressive Strength (N/mm²)
C100	34
C90A10G0	33
C70A0G30	35
C60A10G30	36
C30A10G60	30
C85A15G0	33
C40A0G60	28
C55A15G30	34
C25A15G60	22



Compressive strength for various mixes at 28 days

VIII. CONCLUSION

In this study, the effect of AL and GGBS as supplementary cementations materials and the durability of concrete were investigated. The following conclusions are drawn based on the experimental investigation.

• A total of nine different combinations were investigated for strength and durability testing.

• All different combinations using Alcofine and GGBS as partial replacements for cement.

•The maximum compressive strength of concrete using AL10% and GGBS 30% out of the nine different combinations is 38.08 N/mm2. C60A10G30 is 28.76% higher than the control mix.

The present research investigated the combined use of Alcofine and Ground Granulated Blast Furnace Slag (GGBS) as partial replacements for Ordinary Portland Cement (OPC) in M20 grade concrete. A total of nine mix proportions were designed and tested to evaluate both mechanical properties—specifically compressive strength—and durability parameters, including resistance to acid attack, sulfate attack, and chloride penetration.

Among the tested combinations, the mix containing 10% Alcofine and 30% GGBS (C60A10G30) exhibited the highest compressive strength, achieving 38.08 N/mm² at 28 days, which is approximately 28.76% higher than the control mix (C100). This improvement is attributed to the ultra-fine particle size and high pozzolanic reactivity of Alcofine, which enhances early-age hydration, and the latent hydraulic activity of GGBS, which contributes to long-term strength development and pore structure refinement.

In terms of durability, the inclusion of these supplementary cementitious materials significantly improved the concrete's resistance to aggressive chemical environments. The combined action of Alcofine and GGBS reduced permeability, limited the ingress of deleterious ions, and enhanced resistance to sulfate and acid attacks.

Overall, the results demonstrate that partial replacement of cement with Alcofine and GGBS not only leads to superior strength and durability performance but also offers substantial environmental benefits by reducing cement consumption and associated CO emissions. These characteristics make Alcofine and GGBS highly promising materials for the production of sustainable, high-performance concrete suitable for modern construction needs.

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