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Mixing Concrete with GGBS and Alccofine

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***Abstract* - Concrete is an inevitable building material in construction industry. It is used to provide strength, durability and versatility in structures. Concrete is a mixture of cement, coarse aggregate, fine aggregate and water. Large scale production of cement consumes energy and produce number of unwanted products such as carbon-dioxide, which have negative impact on environment. By considering this negative impacts, construction industries are looking forward for innovative methods to improve the concrete properties without compromising sustainability .According to this theory, additives like fly ash, rice husk ash, ground granulated blast slag (GGBS), alccofine, etc. are tested to replace cement in concrete partially without weakening the material's strength. This paper mainly focuses on investigating the strength characteristics of M20 grade Concrete. Totally 36 specimens were casted, out of which cubes, beams and cylinders were 12 each with 4 different combinations of Cement(C), GGBS(G) and Alccofine (A) ($C_{100}G_0A_0$, $C_{60}G_{34}A_6$, $C_{60}G_{35}A_5$, $C_{60}G_{36}A_4$). The compressive strength, split tensile strength, and flexural strength tests were performed on the cast cubes, cylinders, and beams.**

Keywords: GGBS, Alccofine, Compressive strength, Splittensile strength, Flexural Strength.

I. INTRODUCTION

Concrete is an inevitable and commonly used material for construction purposes. Concrete has various physical properties like strength, durability and versatility during the construction of a structure. Large-scale cement production uses a lot of energy and produces a lot of unwanted byproducts, such CO_2, which harms the environment and depletes natural resources. Researchers and scientists advise using industrial byproducts as additional cementitious materials for concrete production, taking into account the detrimental effects of doing so. For this purpose, we are suggested to use chemical or mineral admixtures like GGBS, fly ash, rice husk, alccofine etc. are used in partially replacing in concrete without comprising on its strength.

As a by-product of iron manufacturing, ground granulated blast-furnace slag, or GGBS, is a cement-based substance primarily used in the making of concrete. Blast furnaces are supplied with a precisely regulated mixture of iron ore, coke, and limestone and run at a temperature of approximately 1,500°C.

Its primary physical characteristic is the gradual release of hydration heat, which limits the rise in temperature of large concrete structures and components during the cement setting and curing processes. GGBS-infused concrete keeps getting stronger over time. Alccofine is an innovative cement based tiny particle material used other than other hydraulic materials like cement, fly ash, GGBS, Silica fume, etc. being manufactured in India. Alccofine has special properties to increase the properties of concrete and enhance its strength. The admixture is prepared under controlled conditions with special type of equipments. Alccofine has the following benefits; it lowers permeability, increases the concrete's resistance to negative environmental effects, and refines the pore structures of the concrete to improve its durability parameters.

The goal is to create the mix percentage grade of concrete that incorporates Alccofine and GGBS by studying the qualities of materials like cement, Alccofine, and GGBS. The focus is on using these components to increase the strength and durability attributes of concrete.

If the desirable strength of concrete is determined by this type of concrete then it can be used for any concrete- based construction. Under NHAI constructions we can use it for all types of roads where concrete is base level, and other constructions like bridges, side barriers etc.

1.1 Objectives

- To determine the workability of concrete with varying percentage of replacement of cement with GGBS and Alccofine.
- To determine the optimum compressive, split tensile and flexural strength of concrete with various percentages of replacement.
- To determine the optimum percentage of replacement of cement with GGBS and Alccofine in conventional concrete.
- To determine the pros and cons of GGBS and Alccofine using test results.

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1.2 Methodology

- Material Collection.
- Preliminary tests.
- Mix design (M20,Proportion)
- Casting of test specimen with 40% of replacement of cement with GGBS and Alccofine, out of which, 34%, 35% and 36% were GGBS and 4%, 5% and, 6% were Alccofine.
- Curing for 28 days.
- Compressive, Split tensile and flexural strength test on specimens.
- Comparison and analysis of results.

II. EXPERIMENTAL PROCEDURE

2.1 Ground Granulated Blast Furnace Slag (GGBS)

GGBS stands for Ground Granulated Blast Furnace Slag. It is a byproduct of the steel production process, where molten blast furnace slag is quenched rapidly with water, resulting in a glassy, granular product GGBS is frequently utilized as an additional cementitious ingredient in concrete production. When added to concrete mixtures, GGBS enhances several properties such as durability, strength, and workability. It can partially replace Portland cement in concrete mixes, contributing to sustainability by reducing the carbon footprint associated with cement production. GGBS is widely used in construction projects worldwide as a sustainable alternative to traditional cementitious materials.

Figure 1: GGBS

2.2 Properties

GGBS is a byproduct from iron and steel manufacturing industries. The main advantages of using GGBS in concrete are that it improves strength, workability as well as durability of the structures. GGBS is typically lighter than Portland cement its colour ranges from off-white to various shades of grey. The chemical constituents in GGBS are silica (SiO_2), alumina (Al_2O_3), Calciumoxide (CaO), magnesia (MgO), sulphur (S) and other oxides such as iron oxides, titanium oxides and potassium oxides, When silica and calcium oxides combine with water, they create calcium silicate hydrate (C-S-H) gel, which gives concrete strength and durability.

Similar to this, alumina and calcium oxide combine to generate calcium aluminate hydrate, which adds durability and strength. Strength is increased by calcium oxides forming (CS-H) gel and calcium aluminate hydrates and the remaining ingredients are present in trace amounts with negligible effects in relation to the other ingredients.

Table 1: Constituents of GGBS

Ingredients	% Composition
SiO_2	25-40%
Al_2O_3	10-30%
CaO	35-40%
MgO	Up to 10%
S	2%
Other oxides	Various trace amounts

2.3 Alccofine

Alccofine is a additional common cementitious ingredient in concrete. It is produced by grinding GGBS into fine powder. Particle size is less than 10 microns. The main advantage of using Alccofine is that it improves workability, strength, durability and reduces permeability. Alccofine is generally divided into two types, Alccofine 1203 and Alccofine 1101. Alccofine 1203 is the material which contains low calcium silicates which are commonly used due to its fineness and particle size. Alccofine 1101 has high calcium silicates which are used in soil stabilization purpose. The colour of Alccofine ranges from off-white to various shades of grey. It can also be used as a water retarder. The chemical constituents in alccofine is calcium oxide (CaO), Silica (SiO_2), Alumina (Al_2O_3), magnesia (MgO), and other oxides such as titanium oxides and pottasium oxides.

Figure 2: Alccofine

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Table 2: Constituents of Alccofine

Ingredients	% Composition
CaO	30-35%
SiO_2	30-36%
Al_2O_3	18-20%
MgO	6-10%
Other oxides	Various trace amounts

III. MATERIAL COLLECTION

- Two bags of Ultratech PPC of 53 grade were collected at a rate of 600 Rs/bag from nearby shop.
- 50 kg of GGBS was obtained from Chennai's ASTRA Chemicals.
- 25kg of Alccofine was Obtained from ASTRA Chennai's ASTRA Chemicals.
- Around 300 kg coarse aggregate was collected from NHAI-Alappuzha.
- Around 200 kg fine aggregate was collected from NHAIAlappuzha.

IV. PRELIMINARY TEST RESULTS

The physical properties of cement, coarse aggregate and fine aggregate were tested and test results are given below:

Table 3: Results obtained for cement

Parameter	Results	Standard values
Specific gravity	2.9	3.15
Initial Setting time	63mins	Minimum 30mins
Final Setting time	600mins	Maximum 600mins
Consistency	33%	25-35%

Table 4: Results obtained for Coarse aggregate

Parameter	Results	Standard Values
Specific Gravity	2.75	2.5-3
Water absorption	0.40%	Not more than 2%

Table 5: Results obtained for Fine aggregate

Parameter	Results	Standard Values
Specific Gravity	2.61	2.5-3
Water absorption	1.98%	0.3-2.5%

V. MIX DESIGN

M20 grade concrete with water cement ratio 0.78 was prepared as per IS 10262:2019. The mix design details of M20 grade concrete is given below:

5.1 ($C_{100}G_0A_0$)

Weight of cement required = 19.766kg

Coarse aggregate weight required = 59.816kg

Fine aggregate weight required =29.701kg

Water required = 8.878 litres

From the above quantities the mix ratio obtained is 1:1.502:3.026:0.449 (cement: Coarse aggregate:fine aggregate:water) Replacement mix design was obtained from the above ratio and the mix design details of the three replacement mix design is shown below:

5.2 Replacement Mix 1 ($C_{60}G_{37}A_3$)

Cement weight required = 11.860kg

GGBS Weight required = 7.313kg

Alccofine Weight required = 0.593kg

Coarse aggregate Weight required =59.816kg

Fine aggregate weight required = 29.701kg

Water required = 8.878 litres

5.3 Replacement Mix 2 ($C_{60}G_{36}A_4$)

Cement weight required = 11.860kg

GGBS Weight required = 7.115kg

Alccofine Weight required = 0.790kg

Coarse aggregate weight required = 59.816kg

Fine aggregate weight required =29.701kg

Water required =8.878 litres

5.4 Replacement Mix 3 ($C_{60}G_{35}A_5$)

Cement weight required =11.860kg

GGBS Weighth required = 6.918kg

Alccofine Weight required = 0.988kg

Coarse aggregate weight required = 59.816kg

Fine aggregate weight required = 29.701kg

Water required = 8.878 litres

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VI. SPECIMEN PREPARATION

- First of all cement and fine aggregate should be mixed throughly until a uniform colour appeared.
- After mixing, the cement fine aggregate mixture is added to the coarse aggregate and was mixed well.
- A small pit is dugged in the middle of the mixture and water was added accordingly and the mixing was done from outside in.
- The concrete mixing was done until the required consistency has obtained.
- Iron moulds of 150*150*150 mm size cubes, 150mm diameter and 300mm height cylinders and 100*100*500mm size beam was taken.
- All the inner surface and base plates of moulds was cleaned and coated with oil for easy removal and smooth finish.
- Four layers of concrete mixture were filled in the mould by tamping 25 times using a tamping rod.

Figure 3: Specimen casting

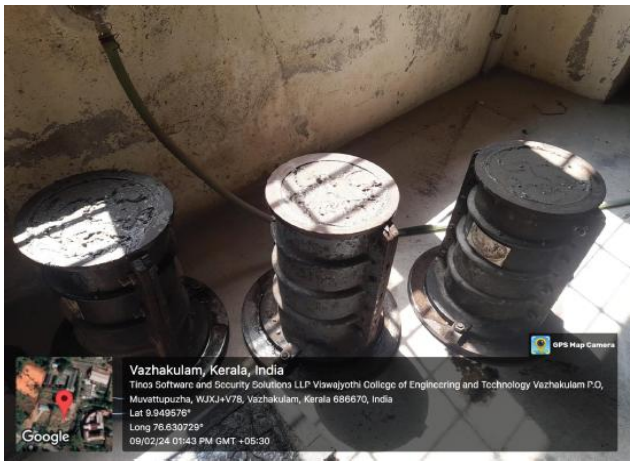

Figure 4: Casted specimen

6.1 Specimen testing

- After curing for 28 days the casted specimen, cubes of size 150*150*150mm, Cylinders of diameter 150mm, 300mm height and beams of size 100*100*500mm are tested in compressive testing machine to obtain compressive, split tensile and flexural strength.
- Average values of the above test results are evaluated to obtain the final results.

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Figure 6: Specimen testing

VII. RESULTS

7.1 Compressive Strength

Table 6: Results obtained for compressive strength

Concrete Ratio	Average Compressive strength (Mpa)
$C_{100}G_0A_0$	24.73
$C_{60}G_{37}A_3$	25.77
$C_{60}G_{36}A_4$	30.75
$C_{60}G_{35}A_5$	25.46

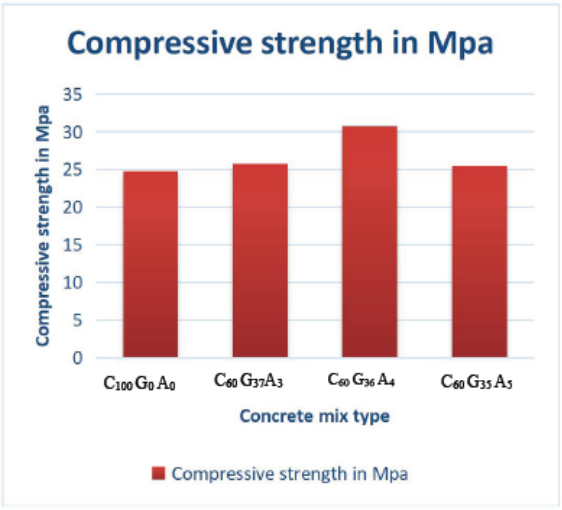

Figure 7: Graph of Compressive strength

Inference:

- Compressive strength of concrete increases with increase in replacement and maximum result obatined at second replacement which is 36% of GGBS and 4% of Alccofine.
- The maximum compressive strength obtained is 30.75Mpa.

7.2 Split tensile strength

Table 7: Results obtained for Split tensile strength

Concrete Ratio	Average Split tensile strength (Mpa)
$C_{100}G_0A_0$	2.36
$C_{60}G_{37}A_3$	1.94
$C_{60}G_{36}A_4$	2.48
$C_{60}G_{35}A_5$	1.96

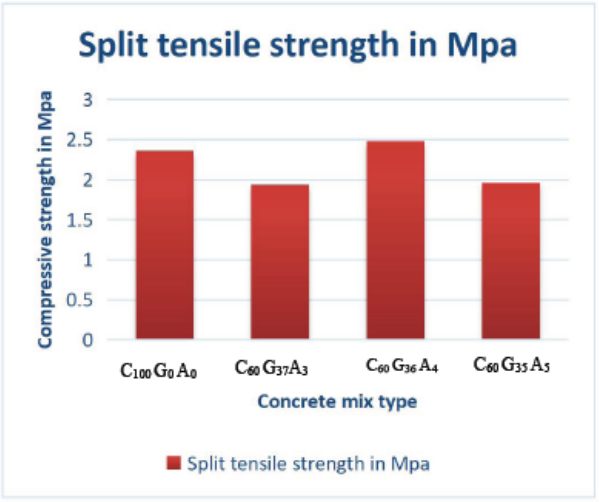

Figure 8: Graph of Split tensile strength

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Inference:

- Split tensile strength of concrete increases with increase in replacement and the maximum replacement obtained is at second replacement which is 36% of GGBS and 4% of Alccofine.
- The maximum compressive strength obtained is 2.48Mpa.

7.3 Flexural Strength

Table 8: Results obtained for Flexural Strength

Concrete Ratio	Average flexural strength (Mpa)
$C_{100}G_0A_0$	4.4
$C_{60}G_{37}A_3$	5.7
$C_{60}G_{36}A_4$	6.92
$C_{60}G_{35}A_5$	5.58

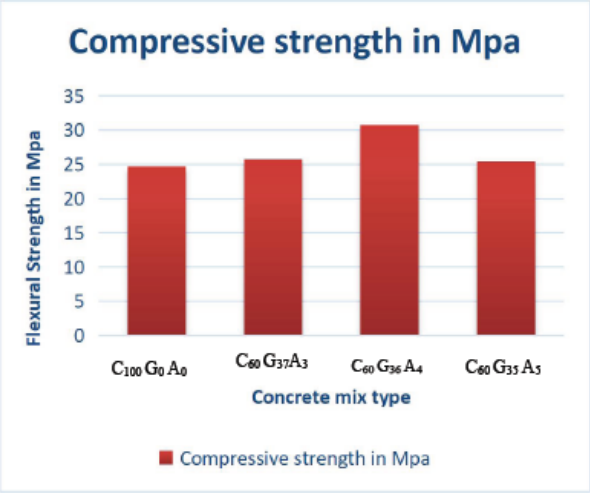

Figure 9: Graph of Flexural Strength

Inference:

- Flexural strength of concrete increases with increase in replacement and the maximum replacement obtained is at second replacement which is 36% of GGBS and 4% of Alccofine.
- The maximum flexural strength obtained is 6.92Mpa.

VIII. CONCLUSION

- By partially replacing cement with GGBS and Alccofine in concrete the usage of cement can be minimised.
- Maximum Compressive strength obtained is 30.75Mpa.
- Maximum Split tensile strength obtained is 2.48Mpa.
- Maximum flexural strength obtained is 6.92 Mpa.
- These strengths are obtained for the partial replacement ratio- $C_{60}G_{36}A_4$.
- Therefore, this is the optimum percentage of replacement to obtain concrete of maximum strength.
- Usage of Alccofine and GGBS improves durability parameters of concrete, reduces permeability and enhance resistance of concrete against harmful environmental impacts.

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