Experimental Study on Strength of Concrete Using GGBS and Alccofine as Partial Replacement of Cement

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Abstract — Concrete is the most widely used construction material in civil engineering industry because of its high structural strength and stability. Concrete is a mixture of cement, water, coarse aggregate and fine aggregate. Over the last few years the environment is greatly affected due to the amount of energy consumed and carbon dioxide emitted during the production of cement, due to this the interest of stimulation in development of alternative materials which would replace cement and improve the performance of concrete. This work focuses on the study of strength characteristics of M40 gras0zde concrete with partially replacing cement with Alccofine by 5%, 10%, 15% and 20% and GGBS by 30%. The cubes, cylinders and beams are tested for compression strength, flexural strength and split tensile strength test.

Keywords: Concrete, GGBS, Alccofine, Replacement of Cement

I. INTRODUCTION

The cement based material is one of the most important construction materials, which will also continue its importance in the future. The concrete is a versatile and widely utilised construction material that plays a vital role in various infrastructure projects.

It is a composite material which is made of cement, aggregates, water and sometimes additional additives or admixtures.

The strength, workability, durability, and other features of conventional concrete needed to be modified as technology advanced and the range of use of concrete and mortars increased. The price of the concrete is determined by the price of its constituents.

The efforts are made for improving the performance and durability by partially substituting cement with naturally occurring, industrial wastes or by-products that are less energy intensive such as alccofine and ggbs

Alccofine 1203 is a breakthrough material that can be used in place of micro silica or silica fumes. It is beneficial in terms of providing increased strength, but it is also cost effective. Because of this it is often used in low budget building and improves high compressive, tensile and flexural strength.

Ground granulated blast furnace slag (GGBS) is formed by quenching molten iron slag a by-product of iron and steel production, in water or a stream one can create granular product which is then dried and crushed into fine powder. Apart from that it produces less heat during the creation and curing of concrete due to its reduced heat of hydration. Therefore by using GGBS and Alccofine as mineral admixture in concrete it improves the concretes initial and final setting times, as well as its workability and compressive strength.

II. OBJECTIVES

1) To investigate the strength of concrete using mineral admixture GGBS and Alccofine
2) To find out the optimum content of replacement mix of usage in concrete

III. METHODOLOGY

A. Materials used
B. Cement (OPC 53)
C. GGBS
D. Alccofine 1203
E. Fine aggregate
F. Coarse aggregate
G. Water

1) Cement

A Cement is a binder material, a chemical substance that helps in sets, hardens and attaches to other materials to bind them together. Typically cement is used create a bond between sand and aggregates. Sand and aggregates are combined to create concrete. Aditya birla group cement (OPC 53) was utilized in this study the procurement of cement was from bidarhalli, Bangalore.

Sl. no	Characteristics	Results
1	Specific gravity	3.15
2	Fineness (m2 /kg)	276
3	Normal consistency (%)	38%
4	Setting Time (minutes) a. Initial setting time b. Cement final setting time	 50 140

Table. 1 Physical properties of cement

2) GGBS

GGBS is made by quenching molten iron slag (a by-product of iron and steel-making) from a blast furnace in water or steam resulting in a glassy, granular product that is subsequently dried and processed into fine powder.

GGBS is utilized to create durable concrete structures in combination with ordinary Portland cement or other pozzolanic materials. The quality of the GGBS should be as per IS 12089- 1987 and its quality should be checked. On a weight for weight basis basis, GGBS can be used as a straight replacement for cement. GGBS replacement levels range from 30% to 85%. In this study 30% GGBS as an constant replacement in cement is considered.

Fig. 1:

3) Alccofine 1203

Alccofine-1203 a material with minimal calcium silicate percentage that serves as an supplementary cementitious materials (SCM) to replace silica fumes when producing high strength and high performance concrete (HSC and HPC). It is an new generation, micro-fine material that has a partical size significantly smaller than that of conventional hydraulic materials such as cement, fly ash, ground granulated blast furnace slag (GGBS), silica fume etc which are being manufactured in India.

It reduces water usage for given workability of concrete, and reduces the heat of hydration, improving the concrete strength and durability at various ages, and 70% substitution can be done as per requirement. The alccofine is used as an partial substitution of cement with 5%, 10%, 15% and 20% changes.

Sl. no	Characteristics	Test Result
1	Specific gravity	2.86
2	Fineness (cm^2)	12000
3	Average partial size (Micron)	4 to 6
4	Bulk density (Kg/m^3)	685

Table 2: Physical properties of alccofine 1203

Fig. 2:

4) Fine Aggregate

In this study M sand or manufactured sand is used. It is an river sand replacement for concrete construction. Manufactured sand (M sand) is created by grinding rocks and stones into fine particles, the resulting crushed sand has a cubic shape and sharpened edges, there are then washed and graded for use in building.

M sand is free of contaminants such as clay, dust, and other organic materials making it suitable for construction purposes. It provides good compressive and flexural strength.

Sl. no	Characteristics	Results
1	Specific gravity (Sg)	2.65
2	Fineness modulus	2.76

Table 3: Physical properties of fine aggregate

5) Coarse aggregate

The coarse aggregates of sizes 20mm confirming to IS code are used in this project. These are gravel or crushed stone that occurs naturally and is used to make concrete. The shape of the aggregate is angular. The coarse aggregate was collected from the local sources.

Sl. no	Characteristics	Test result
1	Specific gravity	2.74
2	Aggregate impact value	26.37%
3	Aggregate crushing value	32.35%
4	Flakiness index	15
5	Elongation index	24%

Table. 4 Physical properties of coarse aggregate

6) Water

The portable water was used in this project to prepare the mix of concrete. Since water is a key component in the mixture of concrete it needs to be clean free from any acids, bases and other organic matters.

7) Superplasticizer

The superplasticizer which was used in this project is ADD bond SL 104+ this helps in reduction of w/c ratio and decrease the setting time of concrete, and to make concrete more workable. Based on the calculations the required amount of superplasticizer was added in the water during the preparation of concrete mix preparation.

Fig. 3:

8) Mix proportion

A concrete mix is generally made up of components in varying proportions such as cement, water, fine aggregate and coarse aggregate additional elements such as pozzolanic minerals and chemical admixtures can be included in the mix to give it desired qualities.

Mix proportions
Cement = 376 kg/m3
Water = 158 kg/m3
M sand = 683 kg/m3
Coarse aggregate = 1234 kg/m3
Chemical admixture = 3.76 kg/m3
Water-cement ratio = 0.42
Mix ratio = 1:1.8:3.28

Mix designation	Description of mixes
Mix – 1	Normal concrete of grade M40
Mix – 2	5% Alccofine + 30% GGBS
Mix – 3	10% Alccofine + 30% GGBS
Mix – 4	15% Alccofine + 30% GGBS

Mix – 5	20% Alccofine + 30% GGBS

Table. 7 Quantity of Alccofine and GGBS

Steps involved in preparing concrete mix

Concrete is a construction component that is generally made up of different elements such as cement, aggregates (sand or gravel), water and sometimes admixtures in the required proportions. After the concrete mix design is done, the next step is to prepare the concrete. Steps involved are

1) Batching
2) Mixing
3) Placing and Compacting
4) Curing

B. Tests carried on Hardened concrete

1) Compression strength testing

Cube size of 150 x 150 x 150 mm was used for compression strength test. It is done to test the capacity of concrete for withstanding loads before failure. The aggregates including GGBS and Alccofine are weighed accordance with the mix design and the concrete mix is prepared.

Concrete was placed into the cubes in 3 layers with each layer compacted with 35 blows with tamping rod, and the surface is leveled with trowel for uniform surface. After 24 hours the specimen was demolded and it was put for curing. The samples were kept for 7 and 28 days of curing respectively.

Compression strength test can be calculated by

$$F = P/A$$

Where, F = specimens compressive strength
p = maximum applied load in N
a = cross-sectional area in mm2

Fig. 4:

2) Flexural strength testing

In this test beam size 100 x 100 x 500 mm was used in flexural strength test of concrete. It helps in determining the rupture modulus. The specimen was prepared in accordance with the dimensions and mix design, upon 24 hours the specimen is demoulded and kept for curing in water. The test samples have been kept for 28 days curing.

Flexural strength test can be calculated by

$fb = 3pa / bd2$ if 'a' is between 110mm and 133mm for 100mm specimen

$fb = pL / bd2$ if 'a' is between 133mm for 100mm specimen

Where, a = the distance between the line of fracture and nearest support, measured on the central side of beam
b = width of the beam
d = depth of the beam
L = length of the beam
p = failure load

Fig. 5:

3) Split tensile strength test

For Split tensile strength test- cylinder of size 150mm x 300mm were used. The test for split tensile strength is done on hardened concrete to determine its tensile strength. The cylinder was prepared according to the required concrete mix design. The examination of specimen was done after 28 days of curing.

Split tensile strength can be calculated by

$$tsp = 2P / \Pi dL \ N/mm2$$

Where,
P = Failure load
d = Diameter of the cylinder
L = Length of the cylinder

Fig. 6:

4) SEM Analysis

SEM or scanning electron microscopy is a type of microscope which uses a focused beam of electrons to scan a surface sample to create a high resolution image. It helps to produce images that can show information on a surface composition and topogarhy.

The sample was first collected and heated before testing is done, then the sample is places under the sem analysis machine where the sample is magnified and the readings are noted.

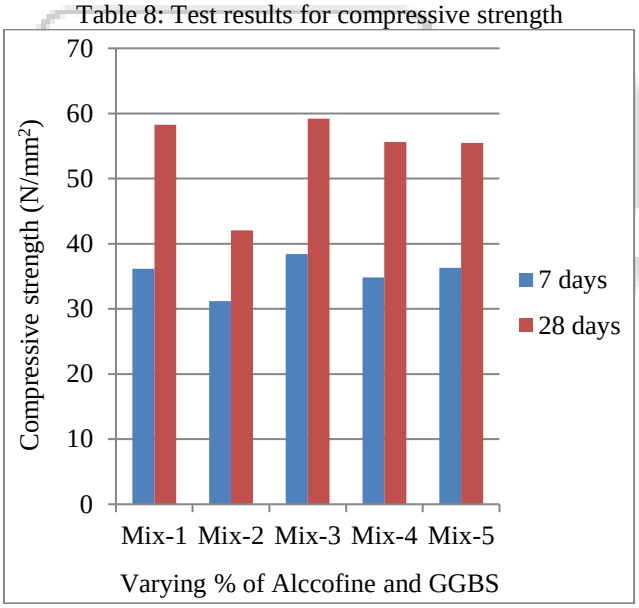
IV. RESULTS

A. Compressive Strength Test

The compression strength test results for 7 days and 28 days for the normal concrete mix and concrete with varying percentages of Alccofine and GGBS admixture are given below.

Mix Designation	Mix proportions	7 days (N /mm2)	28 days (N/mm2)
Mix - 1	Normal concrete of M40 grade	36.17	58.25
Mix - 2	5% Alccofine + 30% GGBS	31.18	46.06
Mix - 3	10% Alccofine + 30% GGBS	38.42	5.19
Mix - 4	15% Alccofine + 30% GGBS	34.84	55.6
Mix - 5	20% Alccofine + 30% GGBS	36.31	55.47

Table 8: Test results for compressive strength



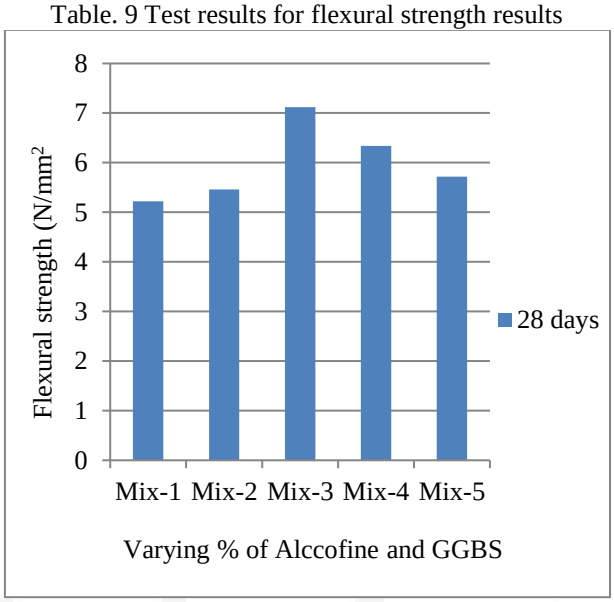
Graph 1:

From compressive strength results obtained for M40 grade of concrete, with varying percentages of Alccofine and GGBS kept constant from the table 4.2, it is observed that an increasing strength value of 38.42 N/mm2 for 7 days and 59.19 N/mm2 strength for 28 days respectively with 5% Alccofine and 30% GGBS replacement was obtained. With decrease in strength on 15% Alccofine and 30% GGBS with 34.84 N/mm2 and 55.6 N/m--m2 was observed.

B. Flexural Strength Test

Mix Designation	Description of varying mix proportions	28 days flexural strength (N/mm2)
Mix - 1	Normal concrete of M40 grade	5.22
Mix - 2	5% Alcccofine + 30% GGBS	5.46
Mix - 3	10% Alccofine + 30% GGBS	7.12
Mix - 4	15% Alccofine + 30% GGBS	6.34
Mix - 5	20% Alccofine + 30% GGBS	5.72

Table. 9 Test results for flexural strength results



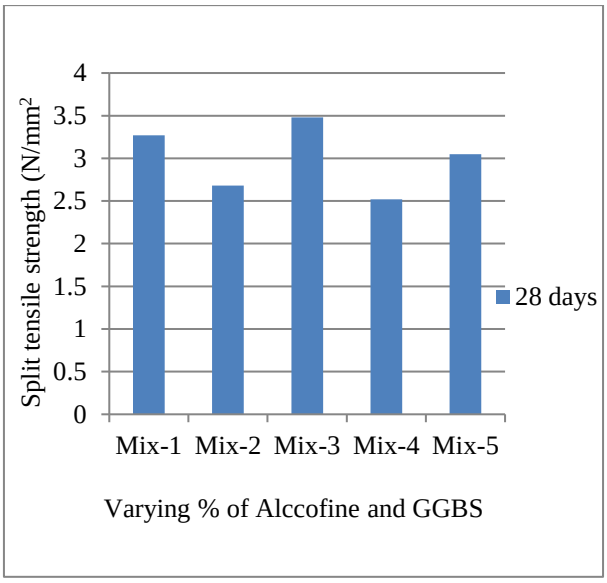
Graph 2:

Flexural strength results were obtained for 28 days with varying percentages of Alccofine and GGBS kept constant, from the table 4.4 it is seen that there is an increase in strength for the mix-3 with 10% Alccofine and 30% GGBS with 7.12 N/mm2 when compared with mix-1 of normal M40 grade concrete of 5.12 N/mm2. There was reduction on the strength with 15% Alccofine and 30% GGBS of mix-4.

C. Split Tensile Test

Mix Designation	Description of varying mix proportions	28 days split tensile strength (N /mm^2)
Mix-1	Normal concrete of M40 grade	3.27
Mix-2	5% Alcccofine + 30% GGBS	2.68
Mix-3	10% Alccofine + 30% GGBS	3.48
Mix-4	15% Alccofine + 30% GGBS	2.52
Mix-5	20% Alccofine + 30% GGBS	3.05

Table 10: Test results for Split tensile strength



Graph 3:

From the split tensile test results obtained for M40 grade of concrete with varying percentages of Alccofine and GGBS kept constant from the above table it is sfound that the strength increased by 3.48 N/mm2 for 10% Alccofine and 30% GGBS mix proportion when compared to conventional concrete of M40 grade with 3.27 N/mm2. There was a decrease in strength of 2.52 N/mm2 for 15% Alccofine and 30% GGBS mix.

D. SEM Analysis

SEM Analysis was carried out for 28 days test sample

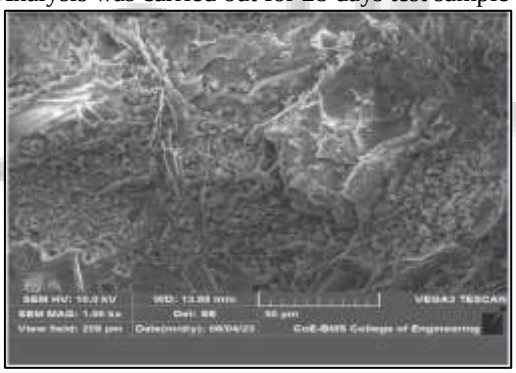


Fig. 7

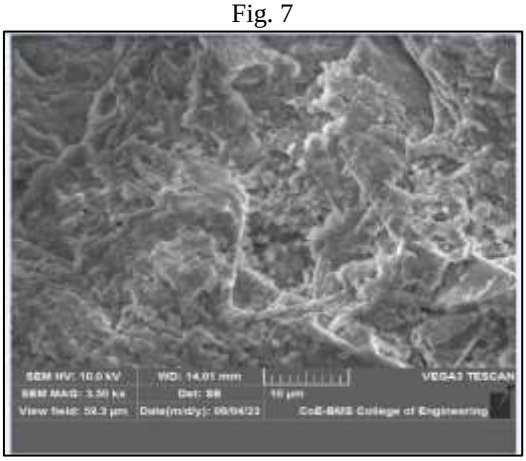


Fig. 8

V. CONCLUSIONS

The following conclusions from the study can be made on replacement of cement using Alccofine and GGBS admixtures for the test.

- The normal concrete of M40 grade shows compression strength of 58.25 N/mm2 and 36.17 N/mm2 for 7 days and 28 days, and 28 days strength of 26 KN/mm2 for flexural and 3.27 N/mm2 for split tensile strength test.
- The cement is replaced by Alccofine in incremental percentages of 5%, 10%, 15% and 20% and GGBS 30% is kept constant during the mix proportions.
- The maximum strength is achieved for compression, flexural and split tensile at mix-3 having 10% Alccofine and 30% GGBS mix proportion.
- The durability of concrete increases as Alccofine and GGBS percentage is increasing up to an optimum point, after this the strength of the concrete decreases.
- Reduction of strength is observed at mix-4 having 15% Alccofine and 30% GGBS mix proportion.
- The use of these supplementary materials in concrete helps in eco-friendly and sustainable concrete.ncrete decreases.

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