Replacing Cement Partially by GGBS and Fine aggregate by the crushed waste glass in concrete mix

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Abstract - *This study consists of the activities performed in order to evaluate the performance of fresh and hardened concrete containing GGBS and waste glass as partial replacements for cement and fine aggregate respectively. An IS code proportioned control concrete mix design was achieved for testing the compressive and split tensile strength of concrete. Other concrete mixes with replacements of both cement and fine aggregate by 20%, 35% and 50% by weight with GGBS and waste glass respectively were also prepared. These mixes were tested in their fresh and hardened state and the results were compared with the control mix. The compressive and split tensile strength of concrete were found to be maximum at 20% and 35% replacements of GGBS and Waste glass respectively.*

Key Words *- GGBS, crushed waste glass, fine aggregate, partial replacement, concrete.*

1. INTRODUCTION

A major component of concrete is cement, which has its own environmental and social impacts and contributes heavily to those of concrete. Some of those effects are harmful while others are not. A shortage of conventional building materials such as sand is being created by rapid urbanization due to the limited availability of natural resources. The production of conventional building construction materials pollutes the environment. Increasing CO_2 amount discharged to the atmosphere due to human activity causes global warming and climate change has been a wide concern. Building construction materials that are energy efficient must be updated with local materials and technology at a reasonable price to meet the ever-increasing demand. Therefore, the construction industry is strongly recommended to use industrial wastes more effectively to reduce CO_2 emissions.

1.1 GGBS

Ground granulated blast furnace slag is a waste product obtained during the manufacture of iron in the blast furnaces. In order to manufacture GGBS, the floating materials above the iron is tapped off as molten material and quenched rapidly in large volumes of water. The quenching process optimizes the cementitious properties producing coarse sand-like granules. This dried granular slag is then ground to a fine powder. Silica, alumina, calcium oxide, and magnesia comprise 95% of slag, while manganese, iron, sulfur, and trace amounts of other elements make up 5% of slag [https://ukcsma.co.uk/]. The exact concentrations of elements vary slightly depending on where and how the slag is produced. Calcium silicate hydrate (CSH), the main component of cement strength is produced by the reaction of cement with water as well as calcium hydroxide $Ca(OH)_2$. With the addition of GGBS to the mixture, it also reacts with water to produce CSH from its available supply of calcium oxide and silica. A pozzolanic reaction also takes place which uses the excess SiO_2 from the slag source, $Ca(OH)_2$ produced by the hydration of the Portland cement and water to produce more of the desirable CSH making slag a beneficial mineral admixture to the durability of concrete(https://www.slideshare.net/sairamsanapala/sair). As with concrete, slag is soluble in water and alkaline. Steel production has led to severe environmental hazards related to waste disposal. It takes GGBS a very long time to harden on its own. Concrete requires GGBS to be activated by combining it with Portland cement, but a percentage of 20 to 80 percent is commonly used. The more GGBS there is, the more effort is put into concrete properties. .

1.2 GLASS

Whether plain, clear, or tinted, glass is one of the most versatile substances on Earth, being used in a variety of applications and forms. The use of waste glass in Construction companies is increasing because of the emphasis placed on sustainable construction. The raw materials used to make glass are silica, sodium potassium carbonate, lime, and lead that are ground, sieved, and mixed in specific proportions to produce glass. Efforts are being made to make use of both waste glass and GGBS in the concrete industry as partial replacements for cement and fine aggregate.

In this study, I have made an effort to replace cement with GGBS and fine aggregate with crushed waste glass to study the strength characteristics of concrete and compare it with that of conventional concrete.

2.0 OBJECTIVES OF THE STUDY

1. To use industrial waste GGBS for cement production which otherwise would have been a disposal problem.

2. To reduce cement consumption in concrete production.

3. To evaluate the effect of GGBS and crushed Waste glass on concrete strength and evaluate the possibility of using GGBS and glass in concrete without compromising the strength of concrete.

4. To evaluate GGBS as a partial substitute to OPC and Waste glass to fine aggregate.

5. To determine the maximum percentage of GGBS and crushed Waste glass which gives maximum strength when compared to the control concrete mix.

3.0 EXPERIMENTAL PROGRAM

3.1 Materials Used:

3.1.1 Cement: Ordinary Portland cement of grade 53(Birla Super) has been used.

3.1.2 Fine aggregate: The material of size below (4.75mm) is termed fine aggregate. Natural sand is used as a fine aggregate. If natural sand is not available, it is replaced by crushed stone. In our study, fine aggregate extracted from the bed of the Cauvery River was used, confirming IS 383 1970 and comes under zone II.

3.1.3 Coarse aggregate: The material of a size greater than (4.75mm) is termed as coarse aggregate. Broken stone is used as a stone aggregate. Coarse aggregate used is a locally available crushed angular aggregate of sizes 20mm and 10mm.

3.1.4 Crushed waste glass: Glass is produced by melting a mixture of materials such as silica, soda ash, and Calcium Carbonate ($CaCO_3$) at high temperatures followed by cooling where solidification occurs without crystallization. The waste glass used in this work was brought from a local Glass vendor in Kumbalgodu, Bengaluru, India.

3.1.5 Ground Granulated Blast Furnace Slag: GGBS is an industrial by-product obtained from the blast furnaces used to make iron. GGBS used in this work was brought from a local GGBS store in Kumbalgodu, Bengaluru, Karnataka.

Chemical Composition of GGBS

Calcium Oxide 34 to 43%

Silicon Dioxide 27 to 38%

Aluminum Oxide 7 to 12%

Magnesium Oxide 7 to 15%

Iron 0.2 to 1.6%

4.0 METHODOLOGY

1. Material collection and study.

2. Mix design.

3. Curing of specimen: (Cube, Cylinder)

4. Casting of specimen: (Cube, Cylinder, Prism)
5. Testing of specimen: (Compression, Split tensile)

6. Result

7. Conclusion

4.1 CONCRETE MIX DESIGN– M30 Grade Concrete

4.2 MIX PROPORTION

The concrete mix design was proposed by using IS 10262 [10]. Concrete grade M-30 with a water to cement ratio of 0.45 was taken.

4.3 STIPULATIONS FOR PROPORTIONING M30

a) Type of cement: OPC 53 grade conforming to IS 12269

b) Maximum cement content: 450 Kg/m^3 (as per IS 456:2000)

c) Max. Nominal Size of aggregate: 20 mm

d) Grade designation: M30

e) Maximum W/C ratio: 0.55

f) Degree of supervision: Good

g) Exposure condition: Mild

h) Workability: 100 mm (slump)

i) Type of aggregate: Crushed angular aggregate

j) Minimum cement content: 340 Kg/m3

4.4 TEST DATA FOR MATERIALS

a) Specific Gravity of Coarse aggregate: 2.70 Fine aggregate: 2.70

b) Specific Gravity of cement: 3.15

c) Water Absorption of; Coarse aggregate: 0.13% Fine aggregate: NIL

d) Cement used: OPC 53 grade (Birla super)

e) Sieve Analysis of Coarse aggregate: Graded Fine aggregate: conforming to grading zone II

f) Free (surface) moisture of; Fine aggregate: Nil Coarse aggregate: Nil

4.5 TARGET STRENGTH FOR MIX PROPORTIONING

F'ck = Fck+ 1.65 S

where, F'ck =Target average compressive strength @ 28 days

Fck = Characteristic compressive strength @ 28 days

S-Standard deviation,

Standard deviation S= 5 N/mm^2

Target strength=40+ 1.65 x 5=48.25 N/mm^2

4.6 SELECTION OF WATER-CEMENT RATIO

From table-5 of 1S 456:2000,

Maximum W/C ratio – 0.55

4.7 SELECTION OF WATER CONTENT

From table -2, for 20 mm aggregate, Maximum Water content is 186 litre (for 25mm to 50mm slump).

So, we would take the estimated water content of 186 lt (Hence OK).

4.8 CALCULATION OF CEMENT CONTENT

Cement content-186/0.55-338.18 kg/m^3-340 kg/m^3 [because W/C ratio-0.55]

From table-5 of IS 456:2000,

Minimum cement content for mild exposure condition – 300 kg/m^3

Therefore, 340 kg/m^3 > 300 kg/m^3, hence OK.

4.9 PROPORTION OF VOLUME OF COARSE AND FINE AGGREGATE CONTENT

From table -3,

The volume of coarse aggregate corresponding to 20 mm size of coarse aggregate & fine aggregate (Zone II) for W/C ratio of 0.50 = 0.62

In the present case, the W/C ratio is lower by 0.55.

Therefore, the volume of coarse aggregate is required to be increased to decrease the fine aggregate content.

As the W/C ratio is lower by 0.05, the proportion of the volume of coarse aggregate is increased by 0.01 (at the rate of +0.01 for every +0.05 change in the W/C ratio).

Therefore, Volume of coarse aggregate = 0.62 +0.1 = 0.63

Volume of fine aggregate=1.0-0.63 = 0.37

4.10 MIX CALCULATIONS

The mix calculations per unit volume of concrete shall be as follows:

a) Volume of concrete = 1 m^3

b) Volume of cement = mass of cement /specific gravity of cement x (1/1000) = 340/3.15 x (1/1000) = 0.108 m^3

c) Volume of water = mass of water /specific gravity of water x (1/1000) = 186/1.0 x (1/1000) =0.186 m^3

d) Volume of All in Aggregate = [a-(b+c)] = [1-(0.108 +0.186] = 0.706 m^3

e) Mass of Coarse Aggregate = e x volume of CA x sp. Gr. Of CA x 1000 = 0.706 x 0.63 x 2.70 x 1000 = 1200.90 kg ≈ 1201 kg

f) Mass of Fine Aggregate = e x volume of FA x sp. Gr. Of FA x 1000 = 0.706 x 0.37x 2.7 x 1000 = 705.294 kg ≈ 706 kg

From Step 9 of mix design:

Equation 1; V = [W+(C/ Sc) +1/px (fa/Sfa)) x (1/1000)

Equation 2; V = [W+(C/Sc) + 1 (1-P) x (ca/sca)) x (1/1000)

Substituting the values in the above two equations;

V = [W+(C/Sc) + 1/px (fa/Sfa)] x (1/1000 ……… (1)

= 0.98 [172+(430/3.15) +1/0.365 x (fa/2.61)) x (1/1000) 31

FA = 640 ~ 650 kg V = [W+(C/Sc)+1/(1-P) x (ca/sca)] x (1/1000) ……… (2)

= 0.98 [172+(430/3.15) + 1/(1-0.365) x (Ca/2.65)) x (1/1000)

CA = 1130.09 ~ 1130 kg

4.11 MIX PROPORTIONS

a) Coarse Aggregate = 1201 Kg//m^3

b) Water = 186 lts

c) Cement = 340 Kg/m^3

d) Fine Aggregate – 706 Kg//m^3

e) W/C Ratio = 0.55

Hence, Mix proportion: 1:2.07:3.53

5.0 TESTS ON FRESH CONCRETE

In accordance with IS CODE 456-2000, a workability test was conducted. An accurate filling of the form is determined by the workability of a fresh concrete mix. Workability depends on water content, aggregate (shape and size distribution), Cementitious content, and age (level of hydration and may be changed by adding chemical admixtures, like Superplasticizer).

1) Slump cone test: When left unsupported, Fresh concrete flows to the sides and sinks in height. This vertical settlement is known as a slump.

 The workability (ease of mixing, transporting, placing, and compaction) of concrete depends on the wetness of concrete (consistency) i.e., water content as well as proportions of fine aggregate to coarse aggregate and aggregate to cement ratio.
 The slump test is only an approximate measure of consistency defining ranges of consistency for most practical works. This test is performed by filling fresh concrete in the mould and measuring the settlement i.e., slump.
The results obtained showed the concrete had a slump of 100mm, hence the concrete has good workability.

2) Compaction factor test:

This test is performed to determine the workability of fresh concrete by compacting factor test as per IS: 1199 – 1959. Tests of this kind are primarily designed for laboratory use but are also useful for concrete that is compacted by vibration, as it is more precise and sensitive than slump tests and particularly useful for low workability concrete. The method applies to plain and air-entrained concrete, made with lightweight, normal weight, or heavy aggregates with a nominal maximum size of 38 mm or less but not to aerated concrete or no-fines concrete.

The results showed the concrete had a slump of 100mm, hence the concrete has good workability.

6.0 TESTS ON HARDENED CONCRETE

6.1 COMPRESSIVE STRENGTH RESULTS:

This test determines the hardness of cube specimens of concrete. The strength of a concrete specimen depends upon cement, aggregates, bond, w/c ratio, curing temperature & age, and size of the specimen. The major factor controlling the strength is the concrete mix design. Cubes of size 15cm x 15cm x15 cm are tested. Each specimen is given sufficient time for hardening (approx. 24 h) and then it is cured for 7, 14 & 28 days.

The type of concrete, age of concrete, the density of concrete and compressive strengths of the experiment are tabulated in the table given below. The compressive strength of concrete replaced with GGBS and glass has been seen to be significantly higher than that of plain concrete up to 20% replacement by GGBS and 35% replacement by the waste glass as per the results obtained in the table below:

S no.	Type of mould	Compressive strength (MPa) at 7 Days	Compressive strength (MPa) at 28 days
1	Plane cement concrete	15.378	32
2	Concrete with 20% GGBS	23.334	29.778
3	Concrete with 35% GGBS	22.444	25.550
4	Concrete with 50% GGBS	8.889	21.112
5	Concrete with 20% Glass	28.889	26.444
6	Concrete with 35% Glass	26.223	31.770
7	Concrete with 50% Glass	23.112	30.444
8	Concrete with 50% of GGBS and 30% Glass	20.444	28.000

6.2 SPLIT TENSILE TEST RESULTS:

This test consists of applying a diametric compressive load along the entire length till failure. This loading induces tensile stresses on the plane containing the applied load and compressive stresses in the area around the applied load. To avoid local compressive strength, plywood strips are used between the specimen and the plate. Tensile failure occurs instead of compressive failure since the areas under the load application are in a triaxial compression state, therefore allowing them to resist higher compressive stresses than what would have been indicated by a uniaxial compressive strength (ASTM Standard C496, 2002).

The type of concrete, age of concrete and split tensile strengths of the experiment are tabulated in the table Given below. The split tensile strength of concrete replaced with GGBS and glass has been seen to be significantly higher than that of plain concrete up to 20% replacement by GGBS and 35% replacement by waste glass as per the results obtained in table below:

S no.	Type of mould	Split tensile strength (MPa) at 7 days	Split tensile strength (MPa) at 28 days
1	Plane cement concrete	2.112	2.193
2	Concrete with 20% GGBS	2.512	3.042
3	Concrete with 35% GGBS	2.334	2.829
4	Concrete with 50% GGBS	1.810	2.688
5	Concrete with 20% Glass	2.157	3.254
6	Concrete with 35% Glass	2.263	2.829
7	Concrete with 50% Glass	2.122	2.829
8	Concrete with 50% of GGBS and 30% Glass	1.860	2.829

7.0 CONCLUSIONS

Based on limited study carried out on performance of GGBS and waste glass concrete in comparison with normal concrete of design strength of M30, following conclusions can be drawn:

A. At 28 days, concrete with 35% Glass has a compressive strength and split tensile strength of 31.77 N/mm^2 and 2.829 N/mm^2 respectively, which is approximately equal to the strength of normal concrete at 28 days.

B. At 28 days, among all the replacements of GGBS, 20% GGBS replacement yields highest compressive strength of 29.778 N/mm^2 and highest split tensile strength of 3.042 N/mm^2.

C. PCC shows a compressive strength of 15.378 N/mm^2 at the end of 7 days which almost doubles after 28 days (32.00 N/mm^2).

D. The optimum replacement percentage for GGBS has been found to be 20% by weight of cement content while as for glass replacement, the optimum replacement percentage has been found to be 35% by weight of fine aggregate.

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