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Performance of Concrete with Partial Replacement of Cement and Fine Aggregate by GGBS and GBS

Rajith M[1], Amritha E K[2]
Department of Civil Engineering[1, 2], P.G Student[1], Assistant Professor[2], Universal Engineering College, Kerala, India
Email: mrajithragam@gmail.com[1] , ekamritha@gmail.com[2]

Abstract- We can reduce the pollution effect on the environment by increasing the usage of industrial by-products in our construction industry. This paper focus on investigating behavior of M30 concrete by partial replacement of cement and fine aggregate by Ground granulated blast furnace slag (GGBS) and Granulated blast furnace slag (GBS). Cubes, cylinders and beams are tested for compressive, split tensile and flexural strength after 28 days curing. Cubes are used to find the ultra-sonic pulse velocity. Replacement percentage of cement and fine aggregate by GGBS and GBS are 20, 25, 30 and 25, 50, 75 respectively. Water cement ratio used in this work is 0.45. It is found that by partial replacement of cement with GGBS and sand with GBS helped in improving the strength of concrete compared to normal mix concrete.

Index Terms- Ground granulated blast furnace slag (GGBS); Granulated blast furnace slag (GBS); Compressive strength; Split tensile strength; Flexural strength; Ultra sonic pulse velocity.

1. INTRODUCTION

Concrete is prepared by mixing various constituents like cement, aggregates, water, etc. which are economically available. Concrete is a composite material composed of granular materials like coarse aggregates embedded in a matrix and bound together with cement or binder which fills the space between the particles and glues them together. Over time, the cement forms a hard matrix which binds the rest of the ingredients together into a durable stone-like material with many uses. Concrete is used in large quantities almost everywhere mankind has a need for infrastructure. The amount of concrete used worldwide ton for ton is twice that of steel, wood, plastics and aluminum combined. Concrete usage in the modern world is exceeded only by that of naturally occurring water.

The cement industry is one of the three primary producers of carbon dioxide, a major greenhouse gas (the other two being the energy production and transportation industries). We can reduce the pollution effect on environment by increasing the usage of industrial by-products in our construction industry [6]. In India, natural river sand (fine aggregate) is traditionally used in mortars and concrete. However, growing environmental restrictions to the exploitation of sand from riverbeds have resulted in a search for alternative sand, particularly near the larger metropolitan areas [5]. This has brought in severe strains on the availability of sand forcing the construction industry to look for an alternative construction material. To overcome from this crisis, partial replacement of natural sand with industrial by-product is economic alternative. Usually used supplementary cementing materials are Ground Granulated Blast Furnace Slag (GGBS), Fly Ash (FA), Silica Fume (SF), Metakaolin (MK) [7].

This paper focus on investigating behavior of M30 concrete by partial replacement of cement and fine aggregate by Ground Granulated blast furnace slag (GGBS) and Granulated blast furnace slag (GBS).

GGBS is obtained by quenching molten iron slag (a by-product of iron and steel making) from a blast furnace in water or steam, to produce a glassy, granular product that is then dried and ground into a fine powder [4]. GBS is obtained by quenching the same slag to the size of fine aggregate. The granulated blast-furnace slag is sand-type slag manufactured by spraying high-pressure water jets on a blast-furnace molten slag. GGBS is a by-product from the blast-furnaces used to make iron. Blast-furnaces are fed with controlled mixture of iron-ore, coke and limestone and operated at a temperature of about 1,500°C. When iron-ore, coke and limestone melt in the blast-furnace, two products are produced-molten iron, and molten slag. The molten slag is lighter and floats on the top of the molten iron. GGBS is used to make durable concrete structures in combination with ordinary port land cement and/or other pozzolanic materials. GGBS has been widely used in Europe, and increasingly in the United States and in Asia (particularly in Japan and Singapore) for its superiority in concrete durability, extending the lifespan of buildings from fifty years to a hundred years [4].

2. EXPERIMENTAL PROGRAM

2.1. *Materials used*

Materials used in this work includes cement, M-sand, coarse aggregate, super plasticizer, GGBS and GBS. GGBS and GBS used are shown in Fig 1and Fig 2. Cement used was Portland pozzolana cement from Dalmia cements with specific gravity 3.1. M-sand is used as fine aggregate which comes under Zone II as per IS 383-1970. Specific gravity of M-sand was 2.5.

Fig 1. GGBS

Fig 2. GBS

Coarse aggregate used was crushed stone with maximum size 20mm. Super plasticizer used were CONPLAST SP430. GGBS was procured from local sources; specific gravity of GGBS was 2.5. GBS used was collected from local suppliers in Calicut confirming to Zone III as per IS 1383-1970. Specific gravity of GBS was 2.58.

2.2. *Mix proportion*

M30 concrete was designed as per IS 10262-1982. W/C ratio used for mix design was 0.45 and 0.3% super plasticizer was used in the study. As per mix design cement content per m^3 was calculated as 377.78 kg. Mix proportion and quantity of material required are given in table 1.

Table 1. Mix Proportion of M30 concrete

Material	Mix proportion	By weight in (kg/m^3)
Cement	1	377.78
Fine aggregate	1.73	655
Coarse aggregate	3.3	1246
Water (liter)	0.45	170

3. SPECIMEN PREPARATION

Combined effect of GGBS and GBS on concrete was studied in this work. 16 mixes are prepared and their combinations are shown in table 2. Specimen were prepared as per IS 516-1959. For compressive strength test and ultra-sonic pulse velocity test cubes of dimension 150x150x150 mm were used. To find split tensile strength and modulus of elasticity cylinders of dimension 150x300mm were used. Beams of dimension 100x100x500mm were used to find the flexural strength of concrete. All the specimens are tested after 28 days curing.

Table 2. Mix combinations

Mix	Combination
M 1	0% GGBS and 0% GBS
M 2	20% GGBS and 0% GBS
M 3	25% GGBS and 0% GBS
M 4	30% GGBS and 0% GBS
M 5	0% GGBS and 25% GBS
M 6	20% GGBS and 25% GBS
M 7	25% GGBS and 25% GBS
M 8	30% GGBS and 25% GBS
M 9	0% GGBS and 50% GBS
M 10	20% GGBS and 50% GBS
M 11	25% GGBS and 50% GBS
M 12	30% GGBS and 50% GBS
M 13	0% GGBS and 75% GBS
M 14	20% GGBS and 75% GBS

M 15	25% GGBS and 75% GBS
M 16	30% GGBS and 75% GBS

4. RESULT AND DISCUSSION

4.1 *Compressive strength test*

Compressive strength test is done as per IS 516-1959. Cubes of size 150x150x150 mm were used. CTM of 5000kN capacity was used for testing the specimen. Compressive strength of the conventional concrete and GGBS-GBS concrete are shown in table 3.

Table 3. Compressive strength of specimens

Mix	Compressive strength (N/mm^2)
M 1	39.2
M 2	35.2
M 3	36.03
M 4	35.27
M 5	40.6
M 6	37.2
M 7	39.83
M 8	36.93
M 9	44.47
M 10	41.13
M 11	45.5
M 12	41.6
M 13	44
M 14	32.2
M 15	39.3
M 16	35.69

Graphical representation of variation in compressive strength for different mix is shown in Fig 3.

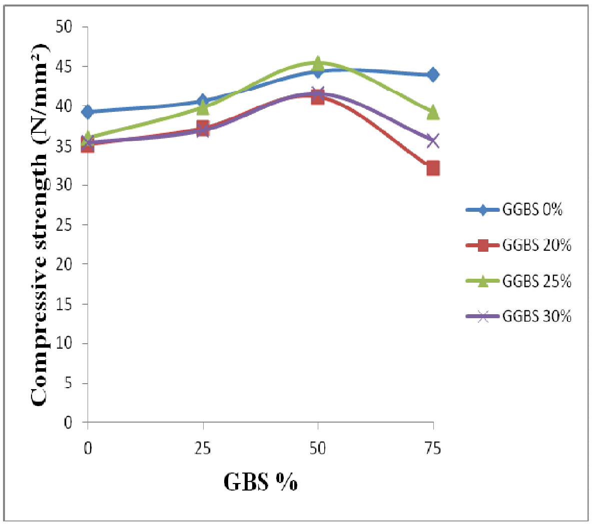

Fig 3. Graphical representation of compressive strength

4.2 *Split tensile strength test*

Cylinders of size 150x300mm were used for split tensile strength test. CTM of 5000kN capacity was used for testing. Split tensile strength of the specimens is shown in table 4.

Table 4. Split tensile strength of specimens

Mix	Split tensile strength (N/mm^2)
M 1	3.02
M 2	2.28
M 3	2.91
M 4	3.01
M 5	3.25
M 6	2.88
M 7	2.53
M 8	3.31
M 9	3.44
M 10	3.46
M 11	3.57
M 12	3.34
M 13	2.97
M 14	2.78
M 15	2.93
M 16	2.81

Split tensile strength variation in different mix is graphically represented as shown in Fig 4.

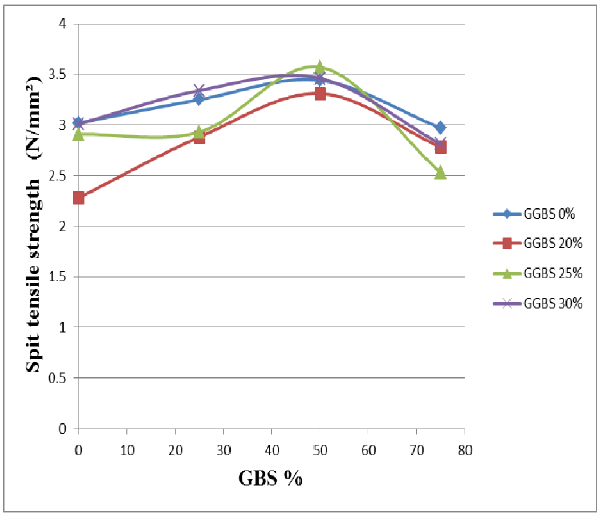

Fig 4. Graphical representation of split tensile strength

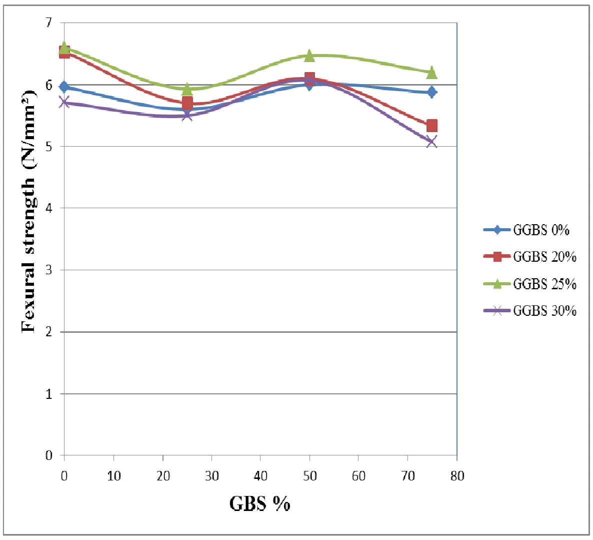

Fig 5. Graphical representation of flexural strength

4.3. *Flexural strength test*

Test is done as per IS 516-1959, beam specimen of size 100x100x500mm are used to find the flexural strength of concrete. Flexural strength testing machine of 100kN capacity was used for testing specimens. Loading is done on the machine manually. Results are shown in table 5.

Table 5. Flexural strength of specimen

Mix	Flexural strength (N/mm^2)
M 1	5.96
M 2	6.53
M 3	6.6
M 4	5.71
M 5	5.6
M 6	5.7
M 7	5.93
M 8	5.5
M 9	6
M 10	6.1
M 11	6.47
M 12	6.07
M 13	5.87
M 14	5.33
M 15	6.2
M 16	5.07

Variation in flexural strength of concrete is graphically represented as in Fig 5.

4.4 *Ultra sonic pulse velocity test*

Test is done as per IS 13311-1:1992. Cubes of size 150x150x150mm were used to find UPV of concrete. Transducer of natural frequency kHz was used in this test. UPV of the specimens are shown in table 6.

Table 6. Ultra sonic pulse velocity

Mix	Ultra sonic pulse velocity (m/s)	Quality of concrete
M 1	4.46	Good
M 2	4.74	Excellent
M 3	4.62	Excellent
M 4	4.52	Excellent
M 5	4.5	Excellent
M 6	4.75	Excellent
M 7	4.63	Excellent
M 8	4.6	Excellent
M 9	4.75	Excellent
M 10	4.85	Excellent
M 11	4.92	Excellent
M 12	4.68	Excellent
M 13	4.52	Excellent
M 14	4.66	Excellent
M 15	4.85	Excellent
M 16	4.64	Excellent

5. CONCLUSIONS

Behavior of concrete by partial replacement of cement and fine aggregate by GGBS and GBS were studied. From the results obtained the following conclusions can be made,

- Compressive strength increases by increasing percentage of GBS up to 50% and GGBS up to 25% in concrete.
- Split tensile strength and flexural strength of the concrete are also increased up to 50% replacement of fine aggregate by GBS and up to 25% replacement of cement by GGBS.
- UPV of all specimens containing GGBS and GBS are greater than compared to control mix and all have excellent quality as per IS 13311-1:1992
- Compressive strength, split tensile strength and flexural strength were increased up to 16.07%, 17.88% and 9.56% respectively

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