Experimental study on mechanical properties of concrete by partially replacing cement with GGBS and fine aggregate with copper slag

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Abstract

This paper is about the experimental study on mechanical properties of concrete by partially replacing cement with Ground Granulated Blast furnace Slag (GGBS) and fine aggregate with copper slag. In the current study an attempt has been made to minimize the cost of cement and sand in concrete mix of grade M30 by studying the mechanical behaviour of this concrete mix. This study is done by preparing concrete cubes and cylinders, thus measuring its compressive strength and split tensile strengths achieved after curing period of 7 & 28 days. Tests were conducted for various proportions of GGBS of 5%, 10%, 15%, 20% by replacing cement and 50% replacement of fine aggregate with copper slag at a time. Both compressive and split tensile strengths were found to be increased at 10% replacement of cement with GGBS and 50% replacement of sand with copper slag.

Key words: GGBS, Copper slag, compressive strength, split tensile strength, waste material.

1. Introduction

The utilization of industrial waste has encouraged the production of cement and concrete in construction field. New by-products and waste materials are being generated by various industries. Disposal of waste materials causes environmental and health problems. Therefore, recycling of waste materials is a great potential in concrete industry. For many years, by-products such as GGBS, silica fume and copper slag were considered as waste materials. Concrete prepared with such materials showed improvement in workability and durability compared to normal concrete.

1.1 GGBS

Ground Granulated Blast furnace Slag (GGBS) is a by-product from the blast furnaces used to make iron. These operate at a temperature of about 1500˚C and are fed with a controlled mixture of iron ore, coke and limestone. The iron ore is reduced to iron and the remaining materials from a slag that floats on top of the iron. This quenched granulated slag is then dried and ground to a fine powder.

Fig.1.1 Ground Granulated Blast furnace Slag (GGBS)

1.2 Uses of GGBS

- GGBS has been widely used for its superiority in concrete durability, extending the lifespan of buildings from fifty years to a hundred years
- Concrete made with GGBS cement sets more slowly than concrete made with ordinary Portland cement depending on the amount of GGBS in the cementatious material.
- This results in lower heat of hydration and lower temperature rises, and makes avoiding cold joints easier, but may also affect construction schedules where quick setting is required.

1.3 Copper slag

Copper slag is an industrial by-product material produced from the process of manufacturing copper. For every ton of copper production, about 2.2 tonnes of copper slag is generated. Although copper slag is widely used in the sand blasting industry and in the manufacturing of abrasive tools, the remainder is disposed of without any further reuse or reclamation. Dumping of such huge quantities of slag causes space problems.

Fig.1.3. Copper slag

Copper slag possesses mechanical and chemical characteristics that qualify the material to be used in concrete as a partial replacement for as a substitute for aggregates.

2. Tests Conducted

2.1 Tests on Cement:

Ordinary Portland cement of grade 53 is used for this experimental work. The following tests were conducted on cement and the results are tabulated below (as per IS 12269:1987)

S.NO.	TEST NAME	TEST RESULT
1.	Specific gravity	3.15
2.	Standard consistency	31%
3.	Initial setting time	40 min

2.2 Tests on Fine Aggregate:

Locally available river sand was used. The following tests conducted and the results are tabulated below (as per 383:1970)

S.NO.	TEST NAME	TEST RESULT
1.	Specific gravity	2.60
2.	Bulk density	1.690 kg/lit
3.	Fineness modulus	3.97

2.3 Tests on Coarse Aggregate:

Locally available stones from quarry was used. The following tests conducted and the results are tabulated below (as per 383:1970)

S.NO.	TEST NAME	TEST RESULT
1.	Specific gravity	2.83
2.	Bulk density	1.670 kg/lit
3.	Fineness modulus	8.64

2.4 Tests on Concrete:

The following workability tests were conducted on concrete and the results are tabulated below

S.NO.	TEST NAME	TEST RESULT
1.	Slump cone test	100 mm
2.	Compaction factor test	0.90
3.	Vee bee test	10 sec

2.5 Tests on Copper slag:

The following tests are conducted on copper slag and the results are tabulated below

S.NO.	TEST NAME	TEST RESULT
1.	Specific gravity	3.2
2.	Bulk density	2083 kg/m^3

2.6 Tests on GGBS:

The following tests are conducted on Ground Granulated Blast furnace Slag (GGBS) and the results are tabulated below

S.NO.	TEST NAME	TEST RESULT
1.	Specific gravity	2.83

3. Mix Design (IS 10262:2009)

- Grade of concrete = M_{30}
- Type of cement = OPC 53 grade
- Maximum size of aggregate = 20mm
- Maximum cement content = 450 kg/m^3
- Adopted water-cement ratio = 0.40
- Target strength for mix proportioning (f_{ck1})= 38.25 N/mm^2

Proportions: for 1m^3 of mix

- Cement = 394 kg/m^3
- Water = 167.5 lit
- Fine aggregate = 716 kg/m^3
- Coarse aggregate = 1225 kg/m^3
- Ratio = 394: 716: 1225
- Mix proportion = **1: 1.82: 3.11**

4. Methodology

4.1 Compressive strength test

In order to determine the compressive strength of the concrete, cubes were made. The dimensions of the cube are 150mm x 150mm x 150mm. The prepared Concrete cubes are placed in compression testing machine and maximum load taken by cube is noted. 3 test samples are prepared for every change in percentage and the average value is taken.

Fig.4.1. Compression testing machine

4.2 Split tensile strength test

In order to determine the split tensile strength of the concrete, cylinders were made. The dimensions of the cylinder are 300mm in length and 150mm in diameter. The prepared Concrete cylinders are placed in split tensile testing machine and maximum load taken by cylinder is noted. 3 test samples are prepared for every change in percentage and the average value is taken.

Fig.4.1. Split tensile testing machine

5. Results and Discussion

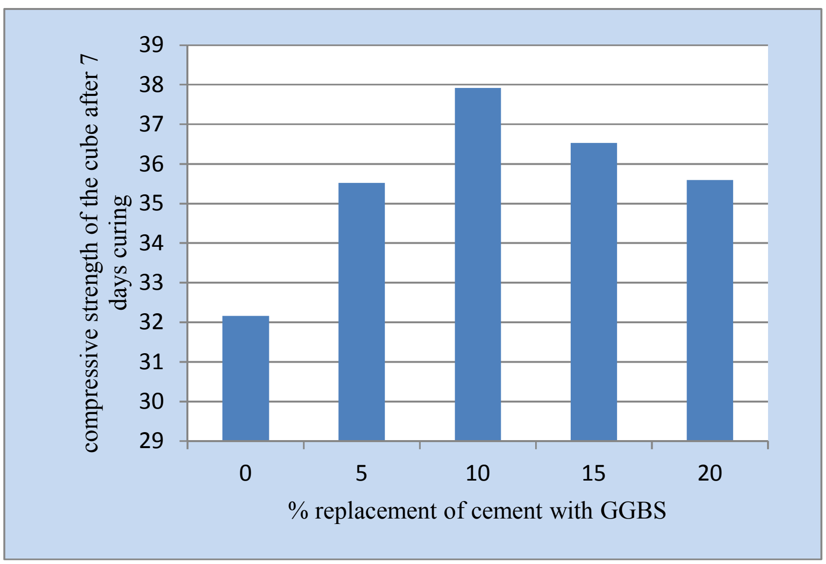
5.1 Compressive strength

5.1.1 After 7 days curing

The compression strength of the concrete cubes after 7days of curing for various compositions of GGBS and copper slag (CS) are tabulated below

Composition	Compressive strength of the cube after 7 days (in N/mm^2)			
	sample 1	sample 2	sample 3	Avg. value
0% CS + 0% GGBS	32.49	31.97	32.02	32.16
50% CS + 5% GGBS	35.63	35.12	35.82	35.52
50% CS + 10% GGBS	37.26	38.45	38.07	37.92
50% CS + 15% GGBS	36.53	36.75	36.33	36.53
50% CS + 20% GGBS	35.92	35.63	35.59	35.71

Graph for compressive strength of the cube after 7 days of curing



Graph 5.1.1 compressive strength of the cube after 7 days of curing

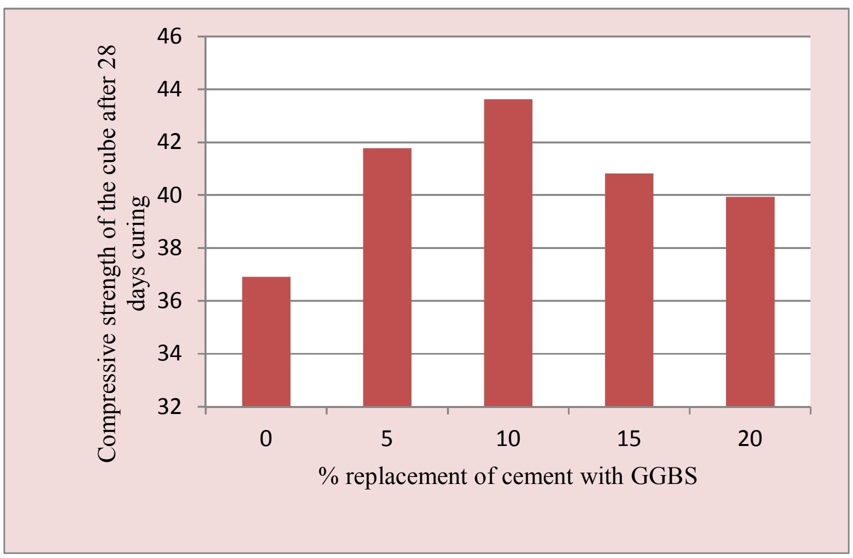
From the above graph, maximum compressive strength of the cube is achieved at 10% replacement of cement with GGBS and 50 % replacement of fine aggregate with copper slag and the value is 37.92 Mpa.

5.1.2 After 28 days curing

The compression strength of the concrete cubes after 28 days of curing for various compositions of GGBS and copper slag (CS) are tabulated below

Composition	Compressive strength of the cube after 28 days (in N/mm^2)			
	sample 1	Sample 2	Sample 3	Avg. value
0% CS + 0% GGBS	36.92	37.09	36.73	36.91
50% CS + 5% GGBS	41.80	41.69	41.87	41.78
50% CS + 10% GGBS	43.56	43.29	44.02	43.62
50% CS + 15% GGBS	40.46	40.97	41.01	40.81
50% CS + 20% GGBS	40.01	39.88	39.93	39.94

Graph for compressive strength of the cube after 28 days of curing



Graph 5.1.2 compressive strength of the cube after 28 days of curing

From the above graph, maximum compressive strength of the cube is achieved at 10% replacement of cement with GGBS and 50 % replacement of fine aggregate with copper slag and the value is 43.62 Mpa.

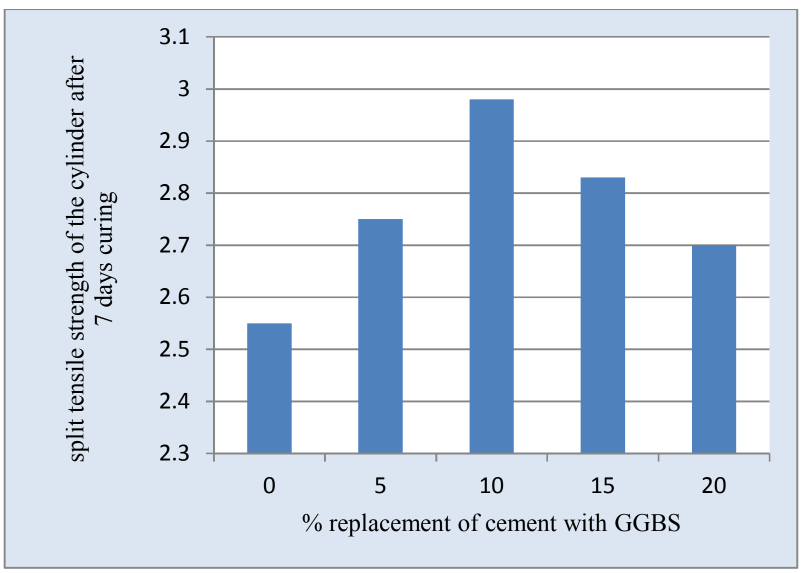
5.2 Split tensile strength

5.2.1 After 7 days curing

The split tensile strength of the concrete cylinders after 7 days of curing for various compositions of GGBS and copper slag (CS) are tabulated below

Composition	Split tensile strength of the cylinder after 7 days (in N/mm^2)			
	sample 1	sample 2	sample 3	Avg. value
0% CS + 0% GGBS	2.61	2.50	2.55	2.55
50% CS + 5% GGBS	2.75	2.7	2.8	2.75
50% CS + 10% GGBS	3.00	2.88	3.06	2.98
50% CS + 15% GGBS	2.91	2.75	2.83	2.83
50% CS + 20% GGBS	2.73	2.70	2.67	2.70

Graph for split tensile strength of the cylinder after 7 days of curing



Graph 5.2.1 split tensile strength of the cylinder after 7 days of curing

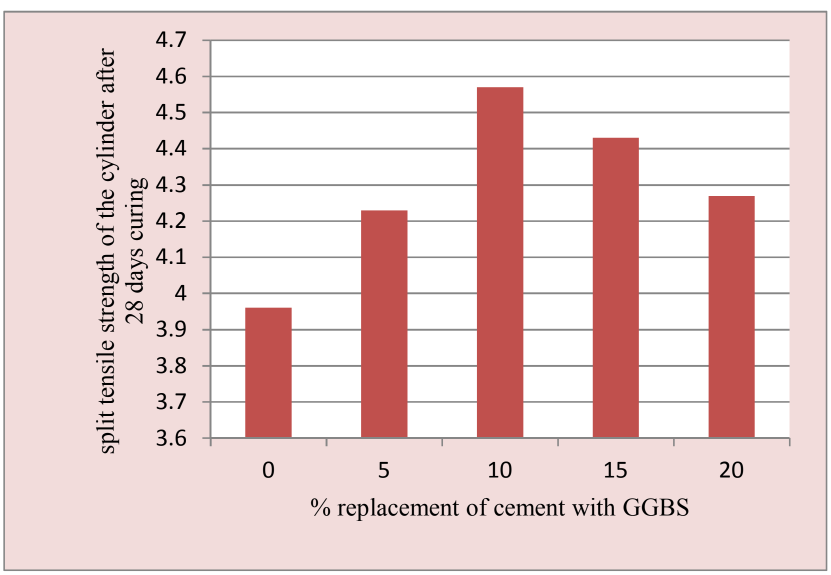
From the above graph, maximum split tensile strength of the cylinder is achieved at 10% replacement of cement with GGBS and 50 % replacement of fine aggregate with copper slag and the value is 2.98 Mpa.

5.2.2 After 28 days curing

The split tensile strength of the concrete cylinders after 28 days of curing for various compositions of GGBS and copper slag (CS) are tabulated below

Composition	Split tensile strength of the cylinder after 28 days (in N/mm^2)			
	sample 1	sample 2	sample 3	Avg. value
0% CS + 0% GGBS	4.03	3.98	3.87	3.96
50% CS + 5% GGBS	4.23	4.29	4.18	4.23
50% CS + 10% GGBS	4.62	4.58	4.51	4.57
50% CS + 15% GGBS	4.49	4.37	4.43	4.43
50% CS + 20% GGBS	4.21	4.29	4.31	4.27

Graph for split tensile strength of the cylinder after 28 days of curing



Graph 5.2.2 split tensile strength of the cylinder after 28 days of curing

From the above graph, maximum split tensile strength of the cylinder is achieved at 10% replacement of cement with GGBS and 50 % replacement of fine aggregate with copper slag and the value is 4.57 Mpa.

6. CONCLUSIONS

- From the above results it is observed that maximum compressive strength obtained at 10% replacement of cement with GGBS and 50% replacement of fine aggregate with copper slag and further increase in % of GGBS leads decrease in compressive strength.
- It is also observed that maximum tensile strength obtained at 10% replacement of cement with GGBS and 50% replacement of fine aggregate with copper slag and further increase in % of GGBS leads decrease in tensile strength.
- The workability of concrete was observed to be increased with increase in copper slag and GGBS in concrete.
- The replacement of cement by GGBS and sand by CS increases the strength compared to normal concrete, as well as decreases use of cement and sand which is environmentally sustainable.

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