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Studies on Strength Characteristics of Concrete by Partial Replacement of Sand with Granulated BlastFurnace Slag

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Abstract: *The Iron and steel industries produce a huge quantity of Granulated blast furnace slag as a byproduct, which is a non–biodegradable waste material, from that only a small percentage of it is used by cement industries to manufacture cement. In the present investigation Granulated Blast Furnace Slag from local industries has been utilized to find its suitability as a fine aggregate in concrete making. Replacing all or some portion of natural sand with slag would lead to considerable environmental benefits. The experimental result showsthat the replacing of natural sand by 10%,20%, and 30%with Granulated Blast Furnace Slag causes negligible degradation in strength at 0.6 % and 0.7% of water cement ratio. But the compressive strength of Granulated Blast Furnace Slag concrete is found to be higher than that of conventional concrete at the age of 3,7,14, 28, 56 and 90 days at 0.4% and0.5% of water cement ratio.*

Keywords:*Compressive strength, Control mix, Granulated Blast Furnace slag (GBFS),Replacement of sand, water- cement ratio(w/c)*

I. Introduction

Due to scarcity of suitable river sand for use as fine aggregate in construction applications and recent construction boom has led to a drastic increase in price additionally various government agencies have put somerestrictions on sand quarrying to conserve this diminishing natural resources. This has prompted many engineers to look for other alternative materials that are cheaper while possessing similar characteristics. One such alternative is “blast furnace slag” which is a byproduct from steel industry. The use of slag in making concrete or mortar by partial/full replacement of river sand not only provides economy in cost of construction but also solves the problem of disposal of slag.The pozzolanic material used in the project was Granulated Blast Furnace Slag (GBFS).

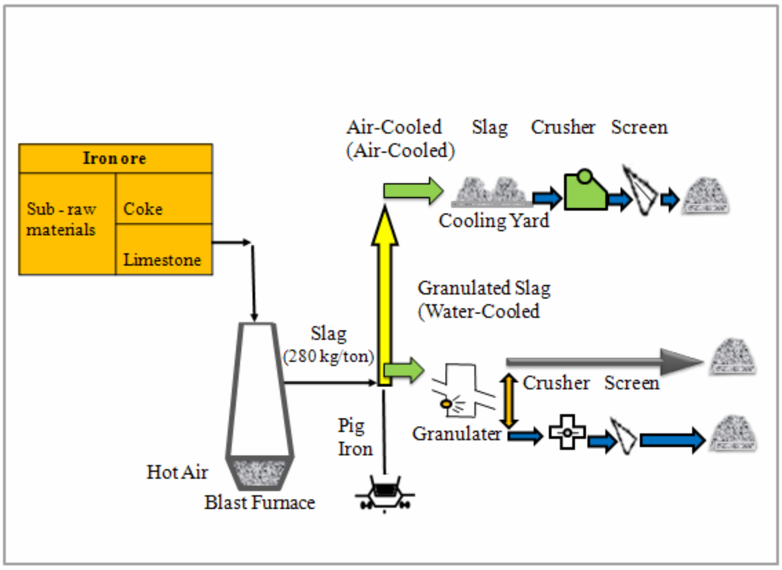

Figure 1: General Schematic view of blast furnace operation and slag productions.

Granulated Blast Furnace Slag is a by-product of the steel industry. It is defined as “the non-metallic by-product consisting essentially of calcium silicates and other bases that is developed in a molten condition simultaneously with iron in a blast furnace.” The iron ore, which is made up of iron oxides, silica, and alumina, comes together with the fluxing agents, molten slag and iron are produced. The molten slag then goes through a particular process depending on what type of slag it will become. GBFS is produced when molten slag is quenched rapidly using water jets, which produces a granular glassy aggregate. This glassy aggregate with little fines used as sand replacement in the present investigation.

Presently, use of slag in India is to the tune of 25 to 30 % by cement industry rest is mostly unused. GBFS has a positive effect on compressive strength of concrete after 28 days.The objective of thepresent study was tocompare compressive strength of conventional concreteand concrete in which fine aggregate (FA) replaced with 10%, 20%, and 30% of GBFS at different water cement ratios is 0.4, 0.5, 0.6, and 0.7.

II. Research Significance

The blast furnace slag obtained from steel plants is used as a replacement for natural sand in concrete mix. Optimal dosage range of this blast furnace slag is chosen based on concrete mix studies. The ultimate focus of this work is to ascertain the performance of concrete mix containing blast furnace slag and compare it with the plain concrete mix of ratio (1:1.6:3.1).

This is expected to provide:

1. To partially replace natural sand content in concrete as it directly influences economy in construction.
2. Environmental friendly disposal of waste steel slag.

III. Literature Review

Chetan Khajuria, Rafat Siddsique[1], 2014,Use of Iron Slag as Partial Replacement of Sand to Concrete.Iron slag is one of the industrial byproduct from the iron and steel making industries.In this paper investigation, the compressive strength of the iron slag concrete was studied. The results confirm that the use of iron slag overcome the pollution problems in the environment. The results shows that the iron slag added to the concrete had greater strength than the plain concrete.

M C Nataraja, P G Dileep Kumar, A S Manu and M C Sanjay[2], 2013, Use of Granulated Blast Furnace Slag as Fine Aggregate in Cement Mortar.In this investigation, cement mortar mix 1:3 and GBFS at 0, 25, 50, 75 and 100% replacement to natural sand for constant w/c ratio of 0.5 is considered. The work is extended to 100% replacements of natural sand with GBFS for w/c ratios of 0.4 and 0.6. The flow characteristics of the various mixes and their compressive strengths at various ages are studied. From this study it is observed that GBFS could be utilized partially as alternative construction material for natural sand in mortar applications. Reduction in workability expressed as flow can be compensated by adding suitable percentage of super plasticizer.

M.S.Rao and U.Bhandare[3], 2014.The paper highlights a case study of Granulated Blast Furnace Slag (GBFS/GBS) as a partial substitute of Crushed Stone Sand (CSS) in cement concrete. Laboratory Studies were conducted for different grades of concrete viz. M30 to M70 using blend of crushed stone sand and granulated slag sand in the ratio of 50:50 of total fine aggregate in concrete. From this study it is observed that GBS sand and CSS blend could be used as alternative construction material for natural sand in cement concrete applications.

IV. Materials and Methodology

4.1 Cement

Throughout the investigation Ordinary Portland Cement of 53 grade is used. The cement used has been tested for various properties as per IS:4031-1988 (part 4&5) and found to be conforming to specifications of IS: 8112-1989.The physical properties of cement are as show in table-2 below.

Table1: Physical Properties of Cement

S. No.	Properties	Test values
1.	Specific gravity	3.13
2.	Normal consistency	36%
3.	Initial setting time	90 (min)
4.	Final setting time	480 (min)
5.	Soundness(Le-chateliermethod)	1 (mm)
6.	Fineness	6.33%

4.2 Fine Aggregates (SAND & GBFS)
4.2.1 Sand

Naturally available sand is used as fine aggregate in the present work. The most common constituent of sand is silica, usually in the form of quartz, which is chemical inert and hard. The sand is free from clayey matter, silt and organic impurities etc. Hence used as a fine aggregate in concrete. The size of sand is that passing through 4.75 and retained on 150 micron IS sieve.Natural sand used confirms to grading zone-II as per IS:383(1970).

4.2.2 Granulated Blast Furnace Slag

Blast furnace slag is a non-metallic byproduct consisting essentially of calcium silicates and other bases. The exact concentrations of elements vary slightly depending on where and how the slag is produced. The size of slag is that passing through 4.75 and retained on 150 micron IS sieve is also used as sand up to 30% replacement of sand. The used slag contains both fines and sand sized particles.The blast furnace slag obtained from steel plants used in this study has chemical composition is given in below table 1

Table2: Chemical Composition of Slag

Composition	Percentage
CaO (%)	30-40
SiO_2 (%)	28-42
Al_2O_3 (%)	5-22
MgO(%)	5-15
S(%)	1-2
Fe_2O_3 (%)	0.3-1.7
Minor Components	5

The physical properties of Sand and GBFS such asspecific gravity, water absorption, etc., were determined as per IS: 2386(1963).

Table3: Physical Properties of Fine Aggregates

S. No.	Properties	Fine Aggregates	
		Natural sand(NS)	GBFS
1.	Specific gravity	2.67	2.07
2.	Water absorption	0.82(%)	9.642(%)
3.	Bulking of sand	30(%)	18.46(%)
4.	Fineness modulus	2.48	2.37
5.	Moisture content	-	20.58(%)

4.3 Coarse Aggregate

The coarse aggregate is free from clayey matter, silt and organic impurities etc. Coarse aggregate is tested for specific gravity, in accordance with IS: 2386-1963. The maximum size of 20 mm is used as a coarse aggregate in concrete. For most of building constructions, the coarse aggregate consists of gravel or crushed stone up to 20mm size. However, in massive structures, such as dams, the coarse aggregate may include natural stones or rock.

Table4: Physical Properties of Coarse Aggregate

S. No.	Properties	Test values
1.	Specific gravity	2.66
2.	Water absorption	0.423(%)
3.	Fineness modulus	3.91

V. Experimental Study

For the w/c Ratio 0.4, 0.5, 0.6, and 0.7, the various quantities of the aggregate are shown in table 5 and water quantities in table6. Where Cement: Fine Aggregate(FA): Coarse Aggregate(CA) proportion used is 1:1.59:3.1.

Table 5: Quantities of Aggregate

S. No.	Particulars	Plain concrete Mix	10% of GBFS	20% of GBFS	30% of GBFS
1.	Cement in kg/m^3	372	372	372	372
2.	GBFS in kg/m^3	0	59.23	118.46	177.69
3.	Sand in kg/m^3	592.3	533.07	473.84	414.61
4.	Coarse Aggregate in kg/m^3	1161.25	1161.25	1161.25	1161.25

Table 6: Quantities of Water

S. No.	Particular	Water Cement ratio(w/c)			
		0.4	0.5	0.6	0.7
1.	Water in lt/m^3	149	186	223.2	260.4

NOTE: All thus quantities are calculated for 1m^3 of concrete.

VI. Results & Discussion

6.1 Compressive Strength

Compression test is the most common test conducted on hardened concrete, partly because it is easy test to perform and partly because most of desirable characteristic properties of concrete are qualitatively related to its compressive strength. Compression test is carried out on specimens of cubical shape. The standard size of specimen is 150mm×150mm×150mm.

Table 7: Compressive Strength

Sample	Compressive Strength (N/mm^2)					
	3 Days	7 Days	14 Days	28 Days	56 Days	90 Days
0 % GBFS & w/c=0.4	28.36	33.29	37.35	37.56	51.77	55.77
0 % GBFS & w/c=0.5	27.78	32.44	36.45	36.67	50.22	52.88
0 % GBFS & w/c=0.6	20.45	30.5	34.78	35	48.88	49.33
0 % GBFS & w/c=0.7	19	25.11	26.98	27.22	32	33.33
10 % GBFS & w/c=0.4	29.86	30.23	43.15	43.79	57.33	60
10 % GBFS & w/c=0.5	23.11	29.78	42.5	43	56.44	58.22
10 % GBFS & w/c=0.6	19.33	25.65	38	39.11	53.33	53.77
10 % GBFS & w/c=0.7	17.5	22.45	28	28.89	30.66	35.55
20 % GBFS & w/c=0.4	35.37	33.23	46.22	47.62	53.77	54.44
20 % GBFS & w/c=0.5	24	30.22	43.11	45.33	52	54.22
20 % GBFS & w/c=0.6	20	28	39.11	41.77	51.11	51.55
20 % GBFS & w/c=0.7	18.66	23.11	29.33	30.22	27.55	37.66
30 % GBFS & w/c=0.4	18.68	19.12	26.56	30	42.27	48.93
30 % GBFS & w/c=0.5	17.78	18.66	24.22	28.66	35.55	39.33
30 % GBFS & w/c=0.6	17.33	18.66	25.77	26.22	34.22	35.55
30 % GBFS & w/c=0.7	16.88	18.66	20	22.22	28.44	28.98

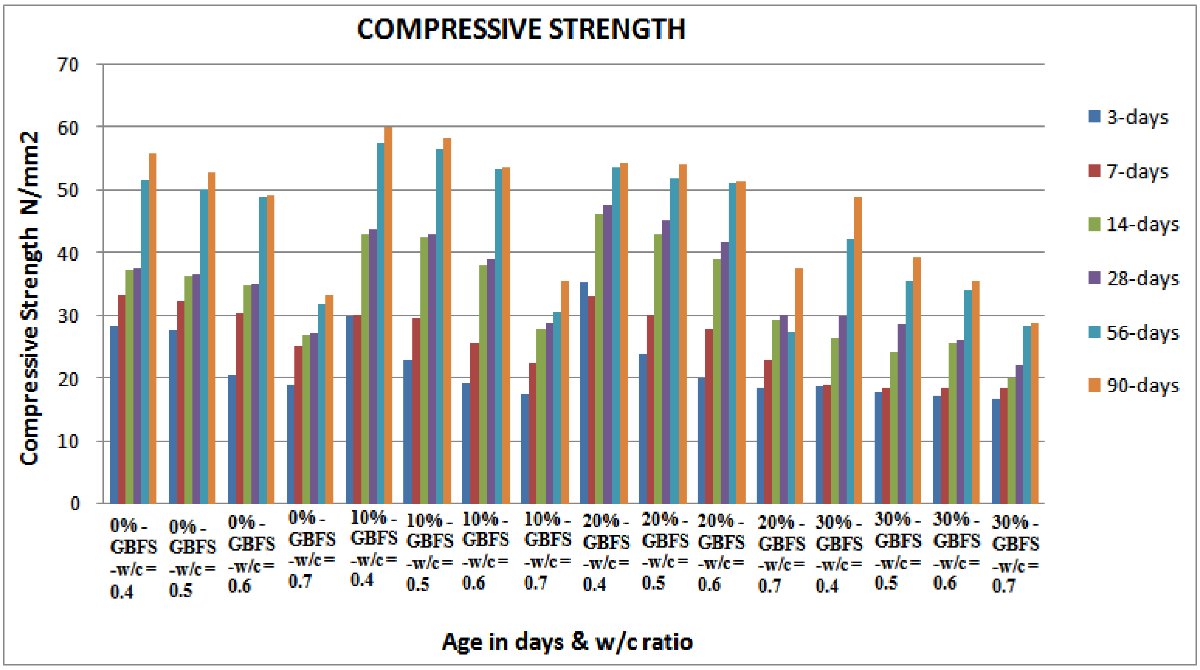

Table8: Percentage of Increase in Compressive Strength at W/C Ratio 0.4

Days	Without Replacement	10% Replacement	% of increase/ decrease	20% Replacement	% of increase/ decrease	30% Replacement	% of increase/ decrease
3	28.36	29.86	5.29	35.37	24.71	18.68	-34.13
7	33.29	30.23	-9.19	33.23	-0.23	19.12	-42.56
14	37.35	43.15	15.53	46.22	23.74	26.56	-28.83
28	**37.56**	**43.79**	**16.58**	**47.62**	**26.78**	**30**	**-20.12**
56	51.77	57.33	10.74	53.77	3.86	42.27	-18.35
90	55.77	60	7.58	54.44	-2.28	48.93	-12.26

Table 9: Percentage of Increase in Compressive Strength at W/C Ratio 0.5

Days	Without Replacement	10% Replacement	% of increase/ decrease	20% Replacement	% of increase/ decrease	30% Replacement	% 0f increase/ decrease
3	27.78	23.11	-16.81	24	-13.60	17.78	-35.99
7	32.44	29.78	-8.19	30.22	-6.84	18.66	-42.47
14	36.45	42.5	16.59	43.11	18.27	24.22	-33.55
28	**36.67**	**43**	**17.26**	**45.33**	**23.61**	**28.66**	**-21.84**
56	50.22	56.44	12.38	52	3.54	35.55	-29.21
90	52.88	58.22	10.09	54.22	2.53	39.33	-25.62

Table 10: Percentage of Increase in Compressive Strength at W/C Ratio 0.6

Days	Without Replacement	10% Replacement	% of increase/ decrease	20% Replacement	% of increase/ decrease	30% Replacement	% of increase/ decrease
3	20.45	19.33	-5.47	20	-2.20	17.33	-15.25
7	30.5	25.65	-15.90	28	-8.19	18.66	-38.81
14	34.78	38	9.26	39.11	12.44	25.77	-25.90
28	**35**	**39.11**	**11.74**	**41.77**	**19.34**	**26.22**	**-25.08**
56	48.48	53.33	10.00	51.11	5.42	34.22	-29.41
90	49.33	53.77	9.00	51.55	4.50	35.55	-27.93

Table 11: Percentage of Increase in Compressive Strength at W/C Ratio 0.7

Days	Without Replacement	10% Replacement	% of increase/ decrease	20% Replacement	% of increase/ decrease	30% Replacement	% of increase/ decrease
3	19	17.5	-7.89	18.66	-1.78	16.88	-11.15
7	25.11	22.45	-10.59	23.11	-7.96	18.66	-25.68
14	26.98	28	3.78	29.33	8.71	20	-25.87
28	27.22	28.89	**6.13**	30.22	**11.02**	22.22	-18.36
56	32	30.66	-4.18	27.55	-13.90	28.44	-11.12
90	33.33	35.55	6.66	37.66	12.99	28.98	-13.05

VII. Concluding Remarks

Based on limited experimental investigations conducted following concluding remarks may be made.

1. The results show that at water cement ratio of 0.4 there is **26.78%** increase in 28 days compressive strength of concrete when 20% slag is used and **16.58%** increase when 10% slag is used.
2. At water cement ratio of 0.5 there is **23.61%** increase in 28 days compressive strength of concrete when 20% slag is used and **17.26%** increase when 10% slag is used.
3. At water cement ratio of 0.6 there is **19.34%** increase in 28 days compressive strength of concrete when 20% slag is used and **11.74%** increase when 10% slag is used.
4. At water cement ratio of 0.7 there is **11.02%** increase in 28 days compressive strength of concrete when 20% slag is used and **6.13%** increase when 10% slag is used.-
5. Hence we can conclude that with the increase in the water cement ratio the workability is increased but the strength of the concrete decreases.
6. The strength of 3^{rd} day and 7^{th} day for slag replacement is less compared to normal concrete mix. The real gain of strength is noticed after 7 days as it gives even more strength than normal concrete mix.
7. By using the slag as an ingredient of concrete we can reduce environmental pollution and also preserve the natural resources.

References

[1]. Chetan Khajuria, RafatSiddsique, 2014 Use Of Iron Slag As Partial Replacement Of Sand To Concrete, Volume 3, Issue 6, June 2014.

[2]. M C Nataraja, P G Dileep Kumar, A S Manu and M C Sanjay Use Of Granulated Blast Furnace Slag As Fine Aggregate In Cement Mortar,Vol.2, No.2, May 2013.

[3]. M.S. Rao and U. Bhandare, Application of Blast Furnace Slag Sand in Cement Concrete–A Case Study, ISSN 2278-3652 Volume 5, Number 4 (2014), pp. 453-458.

[4]. IS: 12269-2013: Specification for 53-grade Ordinary Portland Cement, Bureau of Indian Standards, New Delhi.

[5]. IS: 4031-1988: Methods of physical tests for hydraulic cement, Bureau of Indian Standards, New Delhi.

[6]. IS: 516-1959, Method of Tests for Strength of Concrete, Bureau of Indian Standard (Eleven reprint), New Delhi, 1985.

[7]. IS: 383-1970: Specification for Coarse and Fine Aggregates from Natural Sources for Concrete, Bureau of Indian Standards, New Delhi, 1993.

[8]. IS: 5512-1983: Specification for Flow Table for use in Tests of Hydraulic Cements and Pozzolanic Materials, Bureau of Indian Standards, New Delhi.

[9]. IS: 2386-1963: Method of Tests for Aggregate for Concrete, Bureau of Indian Standards, New Delhi, 1982.