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An Experimental Investigation on Utilization of Waste Foundry Sand and Granulated Blast Furnace Slag as Partial Replacement to Sand in Fly Ash Bricks

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Abstract- ***The continuous technological development has led to enormous amount of waste, the accumulation of which is an environmental concern. The increased demand for River Sand has led to excessive mining and a need to find a sand substitute. The present work is one such attempt where Waste Foundry Sand (WFS) and Granulated Blast Furnace Slag (GBFS) are used as a substitute to Sand in the manufacture of Fly ash Bricks by replacing Sand with WFS and GBFS by 10%, 20%, 30%, 40%, 50% and 10%, 20%, 30%, 40%, 50%, 60% by weight respectively during their manufacture. The Fly ash bricks with only Natural sand (NS) as fine aggregate are designated as FB-1, those with sand replaced by WFS are designated as FB-2. The bricks with Sand replaced by GBFS are designated as FB-3. All the three types of bricks were manufactured with the same 8% Cement, 60% Fly ash and 32% fine aggregate. The Dry compressive strength for 40% replacement of sand with waste foundry sand and 50% replacement of sand with Granulated Blast Furnace Slag at 28 days of curing is 10.3% and 10.1% more than that of Fly ash bricks with no replacement of sand. The wet compressive strength for 40% replacement of sand with waste foundry sand and 50% replacement of sand with Granulated Blast Furnace Slag at 28 days of curing is 10.8% and 12.5% more than that of fly ash bricks with zero percent replacement of sand. The water absorption of Fly ash bricks decreased with increase in the percentage replacement of sand by waste foundry sand and increased with increase in the percentage replacement of sand by Granulated Blast Furnace Slag.***

Index terms- **Cement, Granulated Blast Furnace Slag, Waste Foundry Sand, Fly ash bricks.**

I. INTRODUCTION

In India around 960 tons of solid waste is being generated annually as byproduct from industrial, mining, agricultural and other processes. Out of these 960 million tons, around 360 million tons are organic, 290 million tons are inorganic and 4.5 tons are hazardous in nature. In order to safeguard the environment from the effects of these wastes several efforts are being made for recycling these industrial wastes and to utilize them in value added applications. In the production of iron and steel, fluxes (limestone and/or dolomite) are charged into blast furnace along with coke for fuel. The coke is combusted to produce carbon monoxide, which reduces the iron ore into a molten iron product. Fluxing agents separate impurities and Slag is produced during separation of molten steels. Blast furnace slag is a nonmetallic co-product primarily consists of silicates, alumino silicates, and calcium-alumina-silicates. The molten slag which absorbs much of the sulfur from the charge comprises about 20 percent by mass of iron production. [1] The foundry sand is obtained from the metal casting industries as a waste which has been used several times for molding purpose. If we are able to use these WFS and GBFS in the construction it would reduce the environmental impact of these wastes and also the cost of construction. In the present study an attempt has been made on use of WFS and GBFS as partial substitute to sand in the manufacture of fly ash bricks thus finding an alternative material to sand.

II. EXPERIMENTAL WORK

MATERIALS USED IN THE PRESENT WORK

1. Binder
- Cement (OPC 43 grade)
- Fly ash

2. Fine aggregates
- Sand
- Waste foundry sand
- Granulated Blast Furnace slag

3. Water

CEMENT

The cement is tested as per IS: 4031-1988 and the test results are tabulated. For this experimental study the cement used was Zuari OPC 43 grade.

Table.1. Physical Properties of Cement

Sl. No.	Property	Value Obtained	Requirements as per IS:8112-1989
1	Consistency (%)	32	No standard value.

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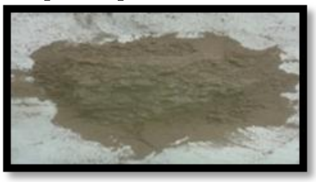
2	Setting Time(minutes) a. Initial b. Final	167 252		Minimum 300 Maximum 600
3	Fines retained in IS. 90 micron sieve (% by weight)	2.5		Not more than 10 percent.
4	Specific Gravity	3.15		No standard value.
5	Soundness (mm)	1.5		Not more than 10 mm.
6	Compressive Strength of cement (N/mm^2)	3 days	22.53	Minimum 43 N/mm^2 after 28 days of curing
		7 days	34.20	
		28 days	46.27	

FLY ASH

The fly ash was tested as per IS: 4031-1988. The Fly ash confirmed to the requirements of IS: 3812. The test results are tabulated. Class F fly ash procured from a local thermal power plant was used in the present work.



Fly ash

Table.2.Physical Properties of Fly ash

Sl No	Physical Property	Value Obtained
1	Particle size	< 90 Microns
2	Specific gravity	2.10
3	Color	Dark grey

SAND

The locally available river sand was used in the present work and was tested as per IS: 2386-1963 which confirmed to Zone II as per IS: 383-1970.The results of the tests on sand are tabulated.

Table.3. Physical Properties of Sand

Sl No	Property	Unit	Value Obtained
1	Bulking of sand	%	32
2	Loose bulk density of sand	kg/m^3	1748
3	Rodded bulk density of sand	kg/m^3	1872
4	Fineness modulus of sand	%	2.80
5	Specific gravity of sand	-	2.66
6	Zone		II

Table.4. Sieve analysis test results of Sand

Sieve size (mm)	Wt retained (kg)	% wt retained	Cumulative % wt retained (w)	% passing (100-w)
4.75	0.037	3.7	3.7	96.3
2.36	0.087	8.7	12.4	87.6
1.18	0.161	16.1	28.5	71.5
0.6	0.310	31.0	59.5	40.5
0.3	0.280	28.0	87.5	12.5
0.15	0.080	8.0	95.5	4.5
Pan	0.045	4.5	100	0

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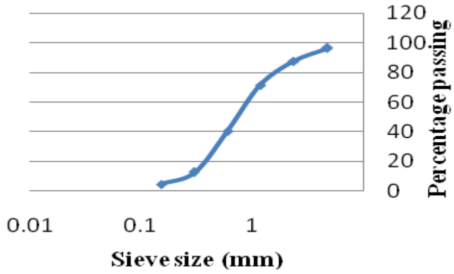

Fig.1. Grain size distribution curve for Sand

WASTE FOUNDRY SAND

The waste foundry sand procured from Naetek Ferro castings PVT Ltd, Machenalli, Shimoga district was used in the present work. The WFS was tested as per IS: 2386-1963 which confirmed to Zone IV as per IS:383-1970. Physical properties of waste foundry sand are as tabulated.

Waste Foundry Sand

Table.5. Physical Properties of WFS

Sl No	Property	Unit	Value Obtained
1	Bulking of WFS	%	70
2	Loose bulk density of WFS	kg/m³	1447
3	Rodded bulk density of WFS	kg/m³	1589
4	Fineness modulus of WFS	%	1.494
5	Specific gravity of WFS	-	2.41
6	Zone		IV

Table.6.Sieve analysis test results of WFS

Sieve size (mm)	Wt retained (kg)	% wt retained	Cumulative % wt retained (w)	% Passing (100-w)
4.75	0.001	0.1	0.1	99.9
2.36	0.007	0.7	0.8	99.2
1.18	0.015	1.5	2.3	97.7
0.6	0.087	8.7	11	89
0.3	0.392	39.2	50.2	49.8
0.15	0.348	34.2	85	15
Pan	0.150	15.0	100	0

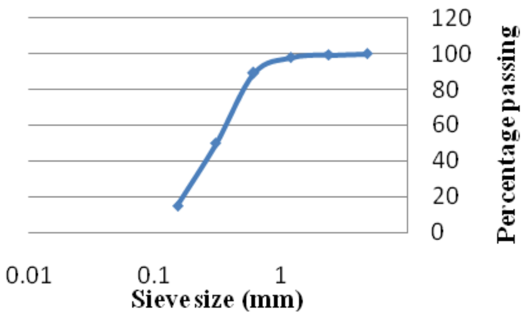

Fig.2. Grain size distribution curve for WFS

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GRANULATED BLAST FURNACE SLAG

GBFS from a local Iron and Steel plant was supplied by M/S Aavishk Buildtech, Bangalore. GBFS was tested as per IS: 2386-1963 which confirmed to Zone I as per IS: 383-1970.The results are tabulated.

Granulated Blast Furnace Slag

Table.7. Physical Properties of GBFS

Sl No.	Property	Unit	Value Obtained
1	Bulking of GBFS	%	32
2	Loose bulk density of GBFS	kg/m³	1048
3	Rodded bulk density of GBFS	kg/m³	1215
4	Fineness modulus of GBFS	%	3.16
5	Specific gravity of GBFS	-	2.25
8	Zone		I

Table.8.Sieve analysis test results of GBFS

Sieve size (mm)	Wt retained (kg)	%wt retained	Cumulative % wt retained (w)	% Passing (100-w)
4.75	0.004	0.4	0.4	99.6
2.36	0.044	4.4	4.8	95.3
1.18	0.388	38.8	43.5	56.5
0.6	0.363	36.3	79.8	20.2
0.3	0.125	12.5	92.3	7.7
0.15	0.033	3.3	95.6	4.4
Pan	0.044	4.4	100.0	0

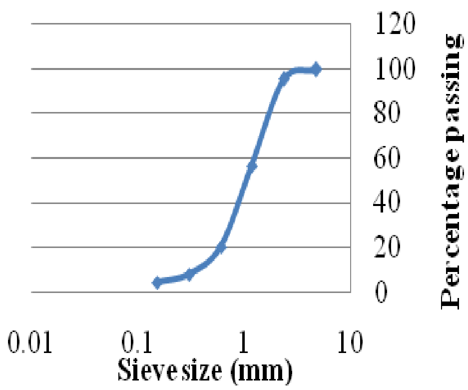

Fig. 3. Grain Size Distribution curve for GBFS

MIX PROPORTION FOR FLY ASH BRICKS

For fixing up the mix proportion IS- 12894: 2002, Guidelines for manufacturing quality fly ash bricks was used. The fly ash, cement and sand were mixed properly with addition of required amount of water and then pressed by hydraulic pressing machine to obtain FB-1.The sand was then replaced partially with waste foundry sand and then with granulated blast furnace slag by various percentages to obtain FB-2 and FB-3.

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Table.9. Mix Proportion for FB-1

Sample Code	Cement (%)	Fly Ash (%)	Natural Sand (%)
NS(100)	8	60	32

Table.10. Mix Proportion for FB-2

Sample Code	Cement (%)	Fly Ash (%)	Natural Sand (%)	WFS (%)
			32%	
FS (10)	8	60	28.8	3.2
FS (20)	8	60	25.6	6.4
FS (30)	8	60	22.4	9.6
FS (40)	8	60	19.2	12.8
FS (50)	8	60	16	16

Table.11. Mix Proportion for FB-3

Sample Code	Cement (%)	Fly Ash (%)	Natural Sand (%)	GBFS (%)
			32%	
GBFS (10)	8	60	28.8	3.2
GBFS (20)	8	60	25.6	6.4
GBFS (30)	8	60	22.4	9.6
GBFS (40)	8	60	19.2	12.8
GBFS (50)	8	60	16	16
GBFS (60)	8	60	12.8	19.2

III. PREPARATION OF TEST SPECIMENS

The bricks were manufactured according to the guidelines provided by NTPC in order to confirm to the IS requirements.

STORAGE OF RAW MATERIALS All raw materials were stored in covered sheds and suitably protected from the rain.
BATCHING Weigh batching of all raw materials was used for the production of bricks.
MIXING OF RAW MATERIALS Mixing of raw materials was done in pan mixer of capacity 500 Kg. The raw materials were mixed in pan mixer for about 3 to 5 minutes to obtain a homogenous mix.

Pan Mixer

1) HANDLING AND PRESSING OF THE MIX

Properly mixed raw materials were transferred through to the press feed hopper through a belt conveyor. The mix was then fed to hydraulic rotary press, where the moulds are automatically filled in. Set of two moulds each is located 120° apart at the rotary table. Bricks were produced at a pressure of 150kg/cm² with size of 235mm×110mm×75mm. The pressed bricks were taken manually and laid on metal pallets in layers. Brick laden pallets were transported on hydraulic trolley from press area to stack yard. Finished bricks were then air dried for 1-2 days.

Hydraulic Pressing Machine

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5) **CURING** The bricks were air dried for 1-2 days. There after air dried bricks were water cured for 28 days. Curing was carried out by sprinkling water manually.

IV. METHODOLOGY OF TESTS ON FLY BRICKS

1) **COMPRESSION TEST (IS: 3495 (Part 1) - 1992)**

Three brick samples of size 235 mm×110mm×75 mm from all the mixes were tested for compressive strength both in the wet and dry state by keeping them between two plates and subjecting them to compressive load. The average of the three readings is taken as the compressive strength of the fly ash brick of the corresponding mix. The wet compressive strength was determined by immersing the bricks in water for 24 hours and then subjecting them to UTM.

Compression test

2) **WATER ABSORPTION TEST (IS: 3495 (Part 2)-1992)**

Three specimens from all the mixes were tested for water absorption by immersing them in water for 24 hours. The difference in weight expressed as percentage of the dry weight is the water absorption of the Fly ash brick.

Water Absorption test

V. RESULTS AND DISCUSSIONS

COMPRESSION TEST

The fly ash bricks were tested for compressive strength by subjecting all the mixes to UTM. The average of the three samples was taken as the compressive strength of the corresponding type of brick.

Table.12. Compression test results for FB-1

Sample Code	Dry Compressive Strength (N/mm²)				Wet Compressive Strength (N/mm²)
	3 days	7 days	14 days	28 days	28 days
NS (100)	3.22	3.545	4.706	6.89	5.73

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Table.13. Compression test results for FB-2

Sample Code	Dry Compressive Strength (N/mm^2)				Wet Compressive Strength (N/mm^2)
	3 days	7 days	14 days	28 days	28 days
FS (10)	3.61	3.93	5.15	7.09	5.86
FS (20)	4.12	4.32	5.35	7.22	5.93
FS (30)	4.577	4.706	5.86	7.47	6.20
FS (40)	5.157	5.35	6.51	7.60	6.35
FS (50)	4.89	5.15	6.06	7.49	6.28

Table.14. Compression test results for FB-3

Sample Code	Dry Compressive Strength (N/mm^2)				Wet Compressive Strength (N/mm^2)
	3 days	7 days	14 days	28 days	28 days
GBFS (10)	3.46	3.68	4.90	6.90	5.78
GBFS (20)	4.02	4.12	5.25	7.02	5.83
GBFS (30)	4.50	4.60	5.78	7.37	6.00
GBFS (40)	5.00	5.15	6.31	7.50	6.23
GBFS (50)	5.15	5.34	6.58	7.59	6.45
GBFS (60)	4.78	5.21	6.43	7.53	6.31

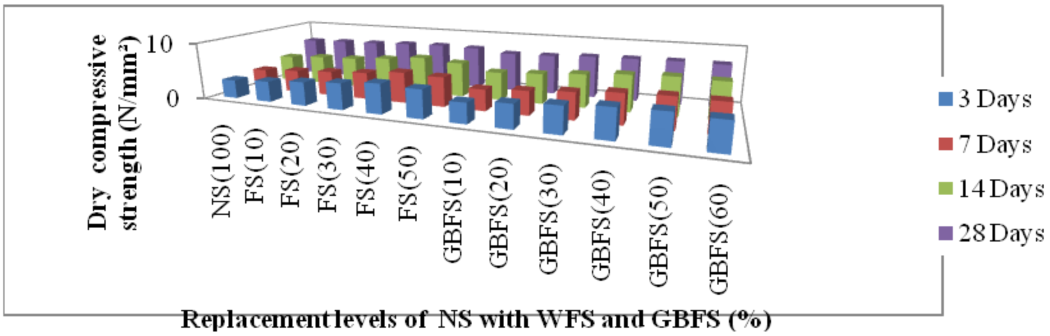

Fig.4.Variation of Dry Compressive Strength for all the replacement levels of Sand at various curing periods

From the above bar chart it can be observed that the dry compressive strength of FB-1 at 3 days, 7 days and 14 days of curing is 46.7%, 51.4% and 68.3% as that of the dry compressive strength at 28 days. The dry compressive strength of FB-2 at all curing periods has been increased with the increase in the replacement of Sand with WFS up to 40%. The maximum dry compressive strength is observed for 40% replacement of sand with WFS at 28 days and is 10.3% more than that of the dry compressive strength observed for no replacement of sand and at 50% replacement level the dry compressive strength is reduced and is 98.5% as that for 40% replacement. The dry compressive strength of FB-3 has been compressive strength of FB-3 observed at 28 days is slightly less and is 99.2% as that for 50% replacement. The dry compressive strength of FB-3 at 28 days for 50% replacement of sand with GBFS is 10.1% more than that for FB-1 for no replacement of sand.

From the below chart (Fig 5) it can be observed that the wet compressive strength observed for zero replacement of sand at 28 days of curing is 83% of the dry compressive strength at the same curing period. The wet compressive strength of FB-2 at 28 days of curing has been increased with the increase in the replacement of sand by WFS up to 40% replacement. For 50% replacement of sand the wet compressive strength of FB-2 is slightly lower and is 98.8% as that for 40% replacement. The wet compressive strength of FB-2 for

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40% replacement of sand is 10.8% more than that of FB-1. At 28 days of curing the wet compressive strength of FB-3 has been increased with increase in the percentage replacement of sand by GBFS. For 50% replacement the wet compressive strength of FB-3 observed at 28 days is maximum and is 12.5% more than that of FB-1 for no replacement of sand.

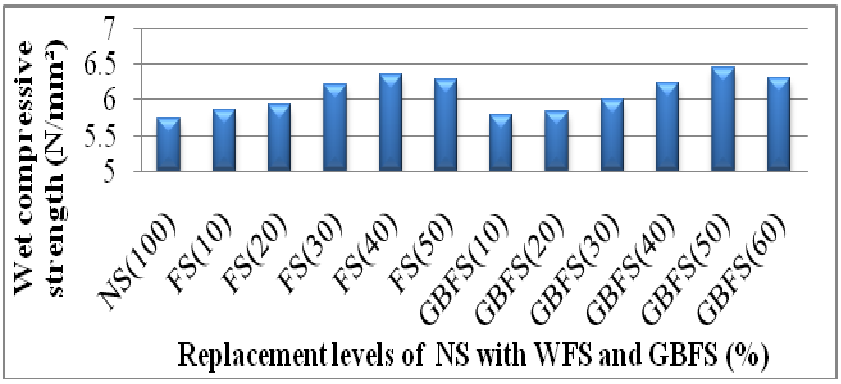

Fig.5.Variation of Wet Compressive Strength for all the replacement levels of Sand at 28 days of curing

WATER ABSORPTION TEST

The water absorption test was conducted for all the types of bricks for each mix at 14 days and 28 days of curing and the results are tabulated. The bricks were immersed in water for 24 hours. They were then removed from water and wiped properly after which they were subjected to UTM. The wet compressive strength was then obtained for all the bricks.

Table.15. Water Absorption test results for FB-1

Sample Code	Dry Weight (kg)		Wet Weight (kg)		Water Absorption (%)	
	14 days	28 days	14 days	28 days	14 days	28 days
NS(100)	3.118	3.121	3.555	3.536	14.01	13.29

Table.16. Water Absorption test results for FB-2

Sample Code	Dry Weight (kg)		Wet Weight (kg)		Water Absorption (%)	
	14 days	28 days	14 days	28 days	14 days	28 days
FS (10)	3.095	3.100	3.521	3.51	13.76	13.22
FS (20)	3.083	3.095	3.502	3.501	13.59	13.11
FS (30)	3.028	3.035	3.428	3.428	13.21	12.94
FS (40)	3.011	3.015	3.406	3.400	13.11	12.7
FS (50)	2.980	2.985	3.369	3.360	13.05	12.56

Table.17. Water Absorption test results for FB-3

Sample Code	Dry Weight (kg)		Wet Weight (kg)		Water Absorption (%)	
	14 days	28 days	14 days	28 days	14 days	28 days
GBFS (10)	3.083	3.085	3.522	3.513	14.23	13.87
GBFS (20)	3.051	3.058	3.507	3.493	14.94	14.22
GBFS (30)	3.011	3.013	3.476	3.461	15.44	14.86
GBFS (40)	2.995	3.00	3.474	3.459	15.99	15.3
GBFS (50)	2.971	2.973	3.466	3.451	16.66	16.07
GBFS (60)	2.959	2.968	3.461	3.449	16.96	16.20

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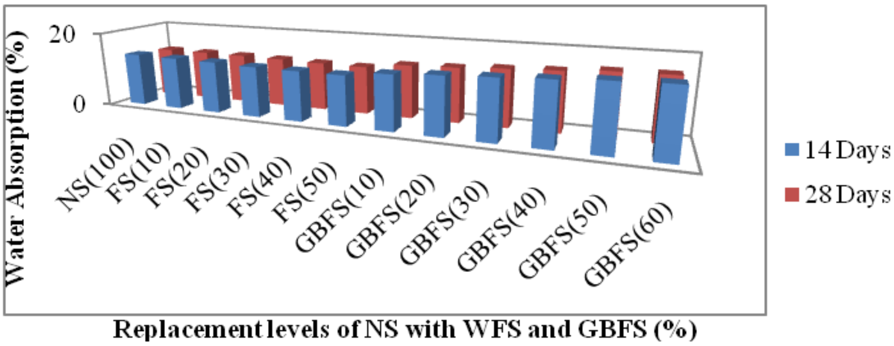

Fig.6. Variation of Water Absorption for all the replacement levels of Sand at various curing periods

From the above chart it can be observed that the water absorption of FB-1 has been decreased from 14.01% at 14 days to 13.29% at 28 days of curing. Water absorption of FB-1 observed at 28 days is 94.8% as that at 14 days of curing. At both 14 days and 28 days of curing the water absorption for FB-2 has been decreased with increase in the replacement of sand with WFS. For 50% replacement of sand with WFS the water absorption of FB-2 observed is the least and is 93.1% and 94.5% as that of FB-1 at 14 and 28 days respectively. The water absorption of FB-3 has been increased with increase in the replacement of sand by GBFS at both 14 days and 28 days of curing. The water absorption of FB-3 for 60% replacement of sand is 21% and 21.8% more than that of FB-1 at 14 and 28 days of curing respectively.

V. CONCLUSION

Based on the above study the following conclusions are drawn.

- WFS and GBFS fulfill the requirements of fine aggregates; hence can be used as a Sand substitute in Fly ash bricks.
- The Dry Compressive Strength of Fly ash bricks increase with increase in the replacement level of Sand by WFS as well as by GBFS up to replacement level of 40% and 50% respectively as compared to conventional Fly ash brick.
- The Wet Compressive Strength of Fly ash bricks increase with increase in the replacement level of Sand by WFS as well as by GBFS up to 40% and 50% respectively as compared to conventional Fly ash brick.
- The Water absorption of Fly ash bricks decrease with increase in the percentage replacement of Sand by WFS and increase with the increase in the percentage replacement of Sand by GBFS.

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