Flexural Strength of Concrete by Partial Replacement of Sand with Basic Oxygen Furnace Slag

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Research Article

Received date: 04/01/2018

Accepted date: 25/02/2018

Published date: 30/03/2018

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Keywords: Oxygen furnace, Slag, Natural aggregates

ABSTRACT

This research work evaluates the use of Basic oxygen furnace slag as a replacement for fine aggregates, in M-25 grade of concrete. The fine aggregates were partially replaced, by weight with Basic oxygen furnace slag. The prepared mixes were named as Mix-A, Mix-B, Mix-C and Mix-D. The mixes were prepared at 0%, 15%, 25% and 35% replacement levels respectively. All the mixes were fabricated at 0.46 water cement ratio. To study the behaviour and response of beam members, casted with above said composition, in flexure, the tests performed after 7 and 28 days on beam specimens and the composite mix prepared, were flexural strength test, density and slump test. IS standards were followed while conducting the above captioned tests. The obtained results were compared with those of controlled M-25 concrete mix.

The investigated results found, vary according to proportions of supplementary constituents added to the M-25 concrete mix. The substitution of Basic oxygen furnace slag enhances the Flexural strength of M-25 concrete mix up to certain percentage. After adding 15% Basic Oxygen furnace slag in the mix, there is an increase of 17.67% strength after 7 days, and 17.26% increase after 28 days. The Flexural strength increases as compared to control mix as the percentage of Basic Oxygen furnace slag is increased. At 25% addition of Basic Oxygen furnace slag in the mix, there is an increase of 28.37% strength after 7 days, and 23.31% increase after 28 days. A decline in Flexural strength as compared to control mix was observed when the percentage of Basic Oxygen furnace slag was increased to 35%. A decrease by 3.16% was observed after 7 days, and 16.42% decrease after 28 days. Slump and unit weight of thus manufactured concrete also increases with the addition of Basic oxygen furnace slag to it. Thus Basic oxygen furnace slag can be successfully used in concrete, to improve flexural strength, slump values and weight of concrete as wells.

INTRODUCTION

Production of residues from industries and construction sector has increased during last few years. Much of these wastes have been thrown to land fill, without considering its potential for reuse and re-cycling as well [1].

Basic Oxygen Furnace slag is formed during the conversion of hot metal from the blast furnace into steel in a basic oxygen furnace **(Figure 1)**. In this process the hot metal is treated by blowing oxygen to remove carbon and other elements that have a high affinity to oxygen. The slag **(Figure 2)** is generated by the addition of fluxes, such as lime stone or dolomite that combines with silicates and oxides to form liquid slag. Some amounts of scrap are also added in order to control the temperature of the exothermal reactions [2].

When the reaction process is complete, molten crude steel collects on the bottom of the furnace and the liquid slag floats on top of it **(Table 1)**. The crude steel and the slag are tapped into separate ladles/pots at temperatures typically above 1600°C. After tapping, the liquid slag in the pot can further be treated by injection of SiO_2 and oxygen in order to increase volume stability. The molten slag is then poured into pits or ground bays where it air-cools under controlled conditions forming crystalline slag [3]. In order to adjust the required technical properties for a specific use, different measures like weathering, crushing and sieving are performed on the crystalline slag **(Figures 3 and 4)**.

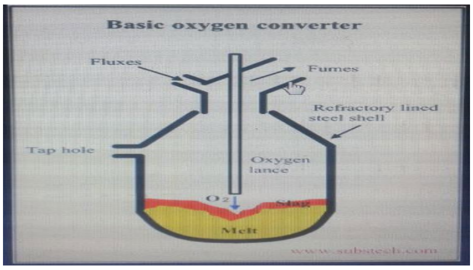

Figure 1. Basic oxygen furnace.

Figure 2. Basic oxygen furnace slag.

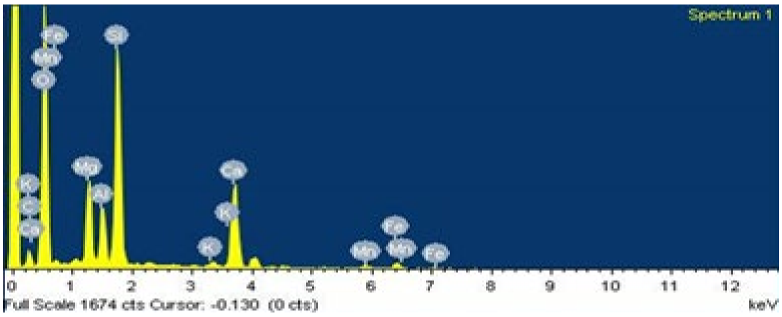

Figure 3. EDS graph of basic oxygen furnace slag.

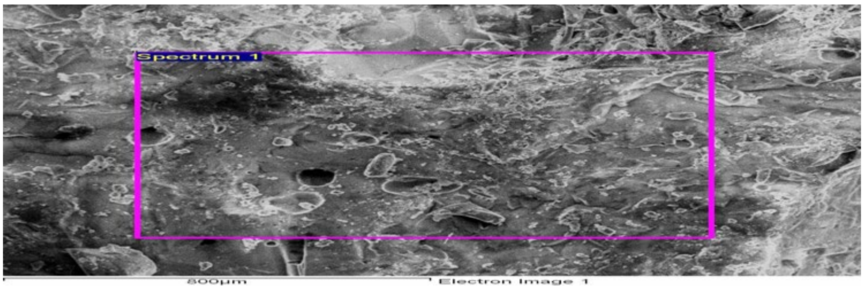

Figure 4. Electron image of basic oxygen furnace slag.

Element	Weight%	Atomic%
C	8.85	15.87
O	44.29	59.63

Mg	0.44	0.39
Al	8.57	6.84
Si	6.15	4.72
Ca	0.79	0.42
Ti	0.64	0.29
Cr	4.24	1.76
Mn	6.10	2.39
Fe	19.92	7.68

Table 1. Composition of basic oxygen furnace slag.

MATERIALS AND METHODS

The selection of aggregate material is important as aggregates control concrete properties and make up 60% - 75% of the total concrete volume. Hence careful attention should be given in the selection and proportioning of aggregates [4].

Materials

The materials were used in the test program; Ordinary Portland Cement, Natural coarse aggregate, Basic oxygen furnace slag, Sand and Water. Material properties are as under [5]:

Cement

Ordinary Portland cement of 43 grades was used throughout the investigation. The cement was available in the local market Ambala City and kept in dry location [6]. The tests were conducted to determine the properties of cement **(Table 2)**.

Table 2. Physical properties of ordinary portland cement.

S.No	Property	Results
1	Fineness	3%
2	Soundness	1 mm
3	Setting time	Initial = 95 min, Final = 165 min
4	Specific gravity	3.15
5	Compressive strength	After 7 days = 33.2 MPa
		After 28 days = 44.32 MPa

Water

Tap water, potable without any salts or chemicals was used in the study. The water source was the concrete laboratory in Ram Devi Jindal College.

Natural aggregates

In this study, both coarse and fine aggregates were used to prepare a controlled as well as Basic oxygen furnace slag added concrete **(Tables 3-5)**. The various physical properties of coarse aggregates and fine aggregates were investigated using IS: 383-1970 **(Table 6 and Figures 5 and 6).**

Table 3. Sieve analysis of natural coarse aggregate with max. size of 20 mm 3 kg sample (IS: 383-1970).

Sieve size	Material retained (gm)	Percentage retained	Cumulative %age passing	Cumulative %age retained
80 mm	0	0.00	100	0.00
40 mm	0	0.00	100	0.00
20 mm	68.5	2.28	97.72	2.28
10 mm	2776.5	92.55	5.17	94.83
4.75 mm	113.5	3.78	1.38	98.62
2.36 mm	0	0.00	0.00	100
1.18 mm	0	0.00	0.00	100
600 μ	0	0.00	0.00	100
300 μ	0	0.00	0.00	100

150 µ	0	0.00	0.00	100
Pan	0	0.00	-	-
Sum	3000		Sum	695.73
FM				**6.95**

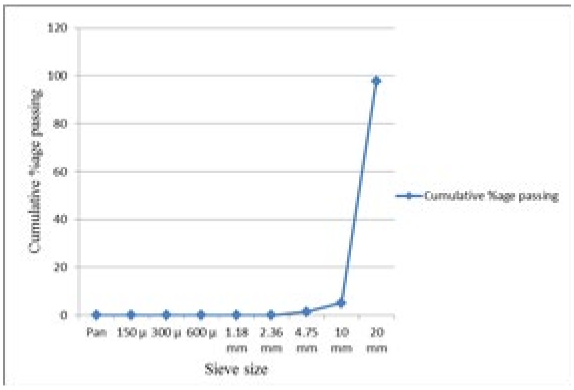

Figure 5. Graph of sieve size versus cumulative percentage passing of coarse aggregate.

Table 4. Physical properties of natural coarse aggregates.

Characteristics	Value
Colour	Grey
Shape	Angular
Maximum size	20 mm
Specific Gravity	2.64
Total water absorption	1.01%
Fineness Modulus	6.96

Table 5. Sieve analysis of natural fine aggregates (1 kg) as per IS 383-1970.

Sieve Size	Material retained (in gm)	Retained%age	Cumulative %age passing	Cumulative %age retained
4.75 mm	14.5	1.45	98.55	1.45
2.36 mm	37	3.70	94.85	5.15
1.18 mm	246.5	24.65	70.20	29.80
600 µ	205.5	20.55	49.65	50.35
300 µ	287.5	28.75	20.90	79.10
150 µ	177	17.70	3.20	96.80
Pan	32	3.20	-	-
Sum	1000		Sum	262.65
FM				**2.62**

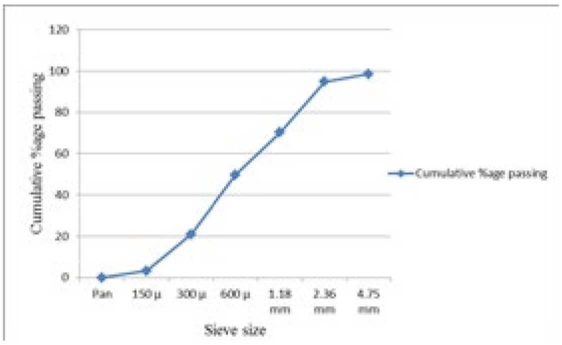

Figure 6. Graph of sieve size versus cumulative percentage passing of fine aggregate.

Table 6. Physical properties of natural fine aggregate.

Characteristics	Value
Water absorption	2.04
Fineness modulus	2.63
Bulk density	2.60
Specific Gravity	2.57

Basic oxygen furnace slag

The Basic oxygen furnace slag and was collected from Bassi steel ltd and JTL Infrastructure ltd **(Tables 7-9 and Figure 7)**.

Table 7. Sieve analysis of basic oxygen furnace slag.

Sieve Size	Material retained in gms	Retained %age	Cumulative %age passing	Cumulative %age retained
4.75 mm	22	2.2	97.8	2.2
2.36 mm	51	5.1	92.7	7.3
1.18 mm	165	16.5	76.2	23.80
600 µ	247	24.7	51.5	48.50
300 µ	279	27.9	23.6	76.40
150 µ	137	13.7	9.9	90.10
Pan	93	9.3	-	-
Sum	1000	-	Sum	248.3
FM				2.48

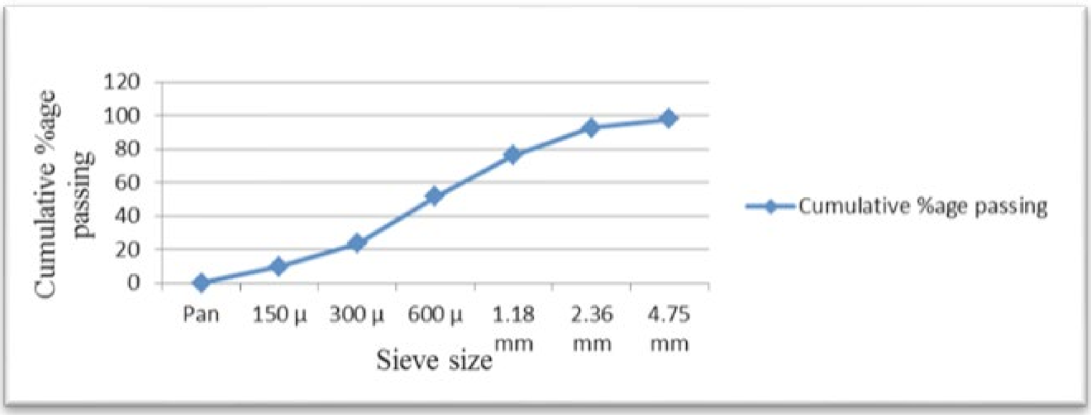

Figure 7. Graph of sieve size versus cumulative percentage passing of basic oxygen furnace slag.

Table 8. Physical properties of Basic oxygen furnace slag.

Characteristics	Value
Water absorption	0.40
Fineness modulus	2.48
Specific Gravity	2.69

Mix proportions

Table 9. Mix-proportions of different mixes

Material Description	Material source	Mix-A kg/m^3	Mix-B kg/m^3	Mix-C kg/m^3	Mix-Dkg/m^3
Cement (OPC) 43 Grade	Ambala City	418	418	418	418
Natural Fine sand	Pathankot sand (Zone II)	660	561	495	429
Natural coarse Aggregate	Handesra stone crusher	1105	1105	1105	1105
Basic Oxygen furnace slag	Derabassi, Bassi steel ltd	Nil	99	165	231
Water cement ratio	-	0.46	0.46	0.46	0.46
Free Water	RDJ lab water	192	192	192	192
Ratios(Cement: Sand: BOF-Slag: Coarse aggregate)	-	1:1.27:0:2.64	1:1.34:0.21:2.64	1:1.18:0.39:2.64	1:1.02:0.55:2.64

RESULTS AND DISCUSSION

Slump

The slump increases with the increase in the percentage of Basic oxygen furnace slag in the concrete and reaches a maximum of 72 mm at 35% replacement of sand with basic oxygen furnace slag [7-9], when compared with control mix of concrete **(Table 10 and Figures 8 and 9)**.

Table 10. Slump values obtained.

Mix	% age Replacement of fine Aggregate	Slump(mm)
Control mix(Mix A)	0%	58
M_{25}BOF-Slag(Mix B)	15%	63
M_{25}BOF-Slag(Mix C)	25%	68
M_{25}BOF-Slag(Mix D)	35%	72

Figure 8. Slump test.

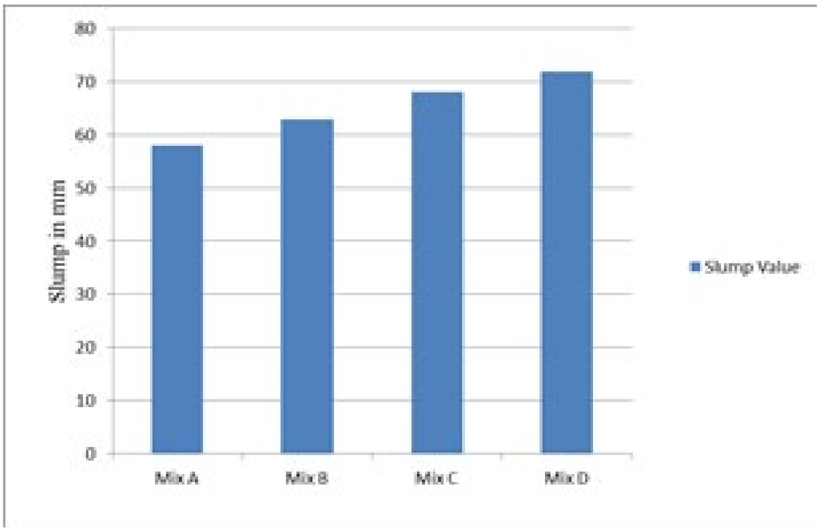

Figure 9. Slump versus material graph at various %age levels.

Density of Mixes

The average weight of control mix is 8.15 kg [10]. As the percentage of Basic oxygen furnace slag increases subsequently the average weight of all the fabricated mixes increase and reaches a maximum of 8.858 kg in Mix-D **(Table 11)**.

Table 11. Densities of various mix proportions.

Particulars	Age of cubes (days)	%age Replacement of fine Aggregate	Average Weight (kg)	Volume of Cubes (m^3)	Mass Density of Concrete(Kg/m^3)
Control mix (Mix A)	28	0%	7.84	0.003375	2323
M_{25}BOF-Slag (Mix B)	28	15%	8.21	0.003375	2432.6
M_{25}BOF-Slag (Mix C)	28	25%	8.428	0.003375	2497.2
M_{25}BOF-Slag (Mix D)	28	35%	8.858	0.003375	2624.59

The variation in densities of different mixes is shown graphically in **Figure 10.**

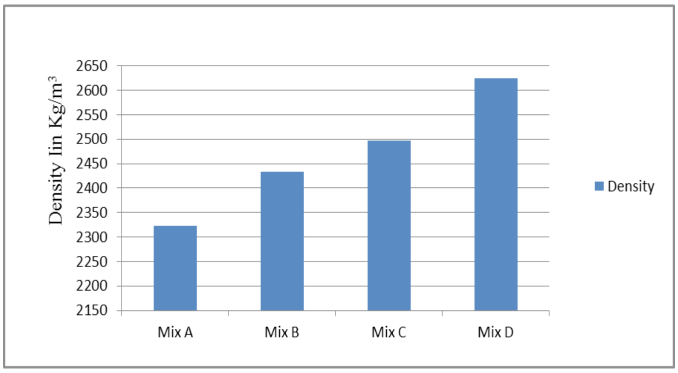

Figure 10. Density versus material graph at various %age levels.

Flexural Strength

This test was performed on the Beam samples at the age of 7 and 28 days. **Figure 11** shows the test results of controlled and treated specimens at 7 and 28 days with 15% replacement of fine aggregate with Basic Oxygen furnace [11-13]. The 7 days and

28 days results are presented in **Table 12.**

Table 12. Flexural strength test results for the beam samples (700 x 150 mm x 150 mm).

MIX	Basic Oxygen Furnace Slag			
	Flexural strength (kg/cm^2)		Average flexural strength (kg/cm^2)	
	7 Days	28 Days	7 Days	28 Days
A	58.30	70.23	54.94	65.57
	56.37	65.54		
	50.15	60.96		
B	64.42	77.78	64.65	76.89
	68.60	76.25		
	60.95	76.66		
C	70.13	80.42	70.53	80.86
	70.54	80.83		
	70.94	81.34		
D	54.23	57.28	53.20	54.80
	54.12	56.27		
	51.27	50.86		

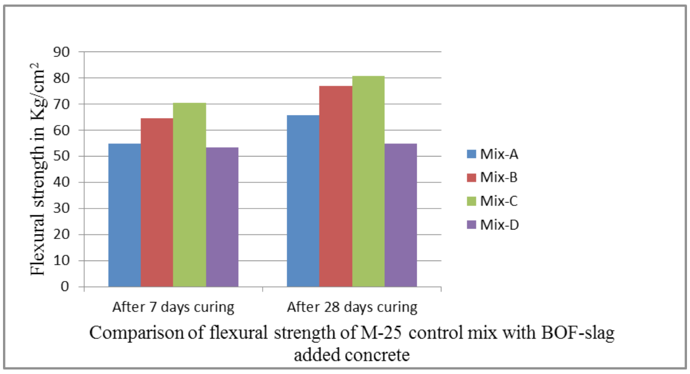

Figure 11. Comparison of flexural strength of M-25 control mix with basic oxygen furnace slag added concrete.

Flexural Strength In %Age After Adding Basic Oxygen Furnace Slag

The Flexural strength decrease as compared to control mix (Mix-A) as the percentage of Basic Oxygen furnace slag is increased [14,15]. After adding 35% Basic Oxygen furnace slag in the mix, a decrease in flexural strength by 3.16% was observed after 7 days **(Figure 12)** and 16.42% decrease after 28 days **(Figure 13)**. The %age of flexural strength decreases at 35% replacement level [16].

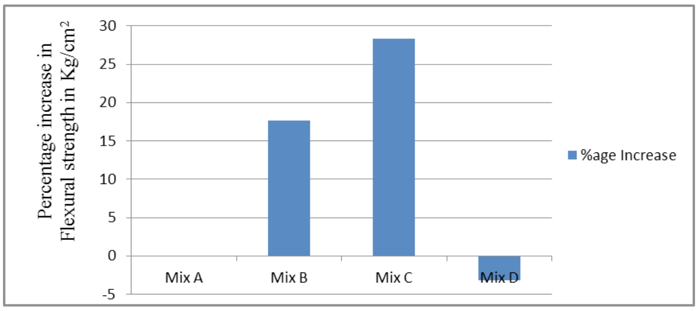

Figure 12. Percentage increase in 7 days flexural strength of basic oxygen furnace slag added concrete at various percentage levels.

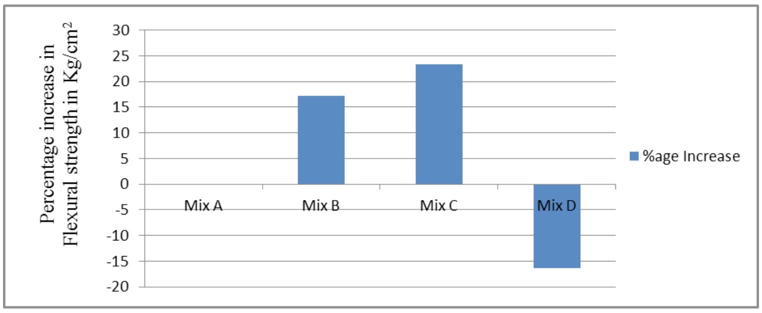

Figure 13. Percentage increase in 28 days flexural strength basic oxygen furnace slag added concrete at various percentage levels.

CONCLUSION

Workablity

From the Slump test results, the concrete produced with Basic Oxygen furnace slag gives higher values of slump i.e., 72 mm at 35% replacement level than controlled M-25 grade concrete, prepared with 0% replacement of sand.

Density

From the obtained values of density, Basic Oxygen furnace slag based concrete gives greater density than controlled M-25 grade of concrete and gives a maximum value 2497.2 kg/m^3 at 35% replacement.

Flexural Strength

- At 15% and 25% replacement by weight of fine aggregate with Basic Oxygen furnace slag, a remarkable achievement in flexural strength was observed.
- When the percentage of replacement, is increased to 35%, the flexural strength decreases abruptly.
- The 7 days flexural strength increased by 17.67%, 28.37%, in case of Basic Oxygen furnace slag based concrete at 15%, 25% replacement levels respectively and decreases by 3.16% and 6.18% at 35% replacement level.
- The 28 days flexural strength increased by 17.26%, 23.31% in case of Basic Oxygen furnace slag based concrete at 15%, 25% replacement levels respectively and decreases by 16.42% and 20.13% at 35% replacement level.
- Hence it could be recommended that Basic Oxygen furnace slag could be effectively utilized as fine aggregates in all concrete applications, upto certain replacement levels of fine aggregate as discussed in the results to improve the strength of concrete in Flexure.

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