Utilization of Blast Furnace Slag in Concrete

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Abstract -- To meet the global demand of concrete in the future, it is becoming a more challenging task to find suitable alternatives to natural aggregates for preparing concrete, hence the use of alternative sources for natural aggregates is becoming increasingly important. Slag is a co-product of the iron making process. Iron cannot be prepared in the blast furnace without the production of its co-product i.e. blast furnace slag. The use of blast furnace slag aggregates in concrete by replacing natural aggregates is a most promising concept because its impact strength is more than the natural aggregate. Steel slag aggregates are already being used as aggregates in asphalt paving road mixes due to their mechanical strength, stiffness, porosity, wear resistance and water absorption capacity.

Indexed Terms: Slag, BFS Concrete

I. INTRODUCTION

A detail investigation on steel slag concrete has been done by Jigar Patel (2008, at Cleveland state university), a detail has been submitted on GGBS as cementations constitute in concrete by ACI committee 223 in 2000. A study on GGBS chemical properties and its use with admixture has been conducted at Grace Construction product. A company name Beavers Valley's produces their own processed slag, they successfully used in road construction and at the same time proved that the road is more abrasion resistive.

Blast furnace slag is one of the major solid industrial wastes, and available in huge quantity about 10 million ton per year in India, which is non-biodegradable material. The cost almost negligible, only cost of crushing and transportation is considerable. A small amount of blast furnace is used in manufacturing of special type of cement. Concrete from such cement accomplishes good workability, high strength, and good durability, which are important factors for concrete performance. The original scope of this research was to investigate the properties of concrete with blast furnace slag aggregates. Hence this project has been carried out with these objectives.

Experimental program is planned to study the following objectives-

a) The purpose of this research is to explore the feasibility of utilizing the blast furnace slag as a replacement for natural aggregate in the concrete.
b) The original scope of this research is to investigate the properties of concrete with blast furnace slag aggregates.
c) To study the effect on compressive strength, and the flexural strength of concrete with blast furnace slag.

II. SLAG- MANUFACTURING AND TYPES

A. Origin:

In the production of iron, iron ore, iron scrap, and fluxes (limestone and/or dolomite) are charged into a blast furnace along with coke for fuel. The coke is combusted to produce carbon monoxide, which reduces the iron ore to a molten iron product. When the blast furnace is tapped to release the molten iron, it flows from the furnace with molten slag floating on its upper surface. These two materials are separated using a weir, the molten iron being channeled to a holding vessel and the molten slag to a point where it into be treated further. The final form of the blast furnace slag is dependent on the method of cooling and can be produced in the following forms:

a) Granulated;
b) Air-cooled;
c) Pelletised; and
d) Foamed.

Blast furnace slag is a nonmetallic co product produced in the process. It consists primarily of silicates, aluminosilicates, and calcium-aluminasilicates. The molten slag, which absorbs much of the sulfur from the charge, comprises about 20 percent by mass of iron production. The use of blast furnace slag aggregate in concrete has until recent years been confined mainly to the area adjacent to the steelworks. Over recent years blast furnace slag aggregate has begun to be used in concrete. Both blast furnace slag cement and air-cooled blast furnace slag aggregate have particular properties that can improve the performance of concrete. The use of these products can conserve our natural resources. Now and in the future, the specifies and producers of concrete must look to the use of materials such as blast furnace slag to conserve our natural resources while maintaining a source of engineering quality materials for the construction industry.

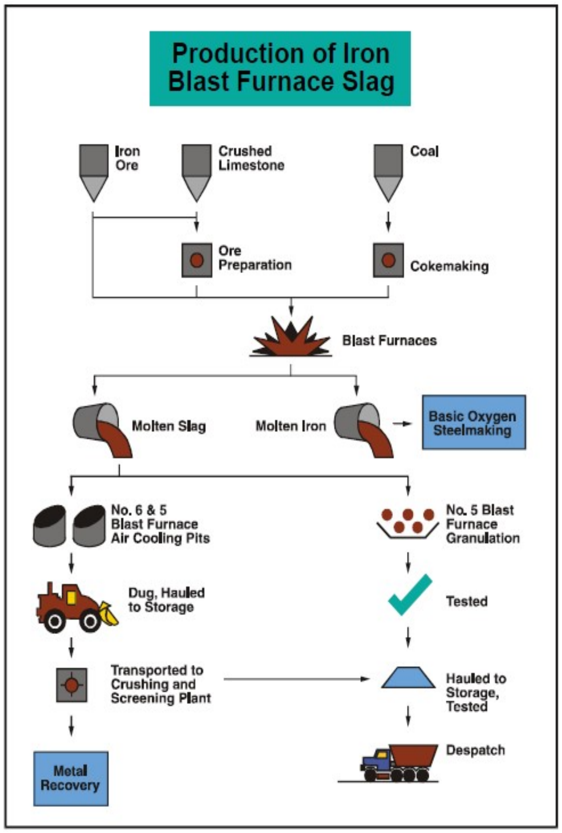

Fig. 1: Production of Iron Blast Furnace Salg

B. Types of Slag:

Different forms of slag product are produced depending on the method used to cool the molten slag. These products include air-cooled blast furnace slag (ACBFS), expanded or foamed slag, pelletized slag, and granulated blast furnace slag.

a) Air-Cooled Blast Furnace Slag

If the liquid slag is poured into beds and slowly cooled under ambient conditions, a crystalline structure is formed, and a hard, lump slag is produced, which can subsequently be crushed and screened.

b) Expanded or Foamed Blast Furnace Slag

If the molten slag is cooled and solidified by adding controlled quantities of water, air, or steam, the process of cooling and solidification can be accelerated, increasing the cellular nature of the slag and producing a lightweight expanded or foamed product. Foamed slag is distinguishable from air-cooled blast furnace slag by its relatively high porosity and low bulk density.

c) Pelletized Blast Furnace Slag

If the molten slag is cooled and solidified with water and air quenched in a spinning drum, pellets rather than a solid mass, can be produced. By controlling the process, the pellets can be made more crystalline, which is beneficial for aggregate use, or more vitrified (glassy), which is more desirable in cementations applications. More rapid quenching results in greater vitrification and less crystallization.

d) Granulated Blast Furnace Slag

If the molten slag is cooled and solidified by rapid water quenching to a glassy state, little or no crystallization occurs. This process results in the formation of sand size (or frit-like) fragments, usually with some friable clinker like material. The physical structure and gradation of granulated slag depend on the chemical composition of the slag, its temperature at the time of water quenching, and the method of production. When crushed or milled to very fine cement-sized particles, ground granulated blast furnace slag (GGBFS) has cementations properties, which make a suitable partial replacement for or additive to Portland cement.

III. MATERIAL AND CONCRETE DESIGN MIX DETAILS

A. Materials:

a) Cement:

Ordinary Portland cement (Ultratech 43 Grade) confirming to IS: 269-1976 was used throughout the investigation. Different tests were performed on the cement to ensure that it confirms to the requirements of the IS specifications. The physical properties of the cement were determined as per IS: 4031-1968 and are presented in following table.

Sr No	Properties	Value	Requirements of IS 8112-1989
1	Specific gravity	3.15	
2	Standard consistency	30%	
3	Initial setting time	103 min	Min.30 min
4	Final Setting Time	231 min	Max.600 min
5	Soundness	2.5	Less than 10
6	Fineness	8.5%	Less than 10 %
7	Compressive Strength In N/mm^2		
	7 days strength	39.67	Not less than 33 N/mm^2
	28 days strength	51.64	Not less than 44 N/mm^2

Table 1: Cement Properties

b) Coarse Aggregate:

Sr. No.	Properties	Value
1.	Specific gravity	3.1
2.	Fineness modoulus	3.44
3.	Water absorption	0.5%

Table 2: Properties of Coarse Aggregate

c) Fine Aggregate:

Sr. No.	Properties	Value
1.	Specific gravity	2.85
2.	Fineness modoulus	2.79
3.	Water absorption	2.5

Table 3: Properties of Fine Aggregate

d) Blast Furnace Slag:

Ghatge Patil Industry, a machine part manufacturing plant is situated Uchgaon, Kolhapur. When the blast furnace is tapped to release the molten iron, it flows from the furnace with molten slag floating on its upper surface. These two materials are separated using a weir, the molten iron being channelled to a holding vessel and the molten slag to a point where it is to be treated further and according to treatment the slag is classified. And it is dumped on the sides of artificial ponds which have now formed hillocks occupying a lot of space; hence considerable expenditure is involved in maintaining these sites and disposal of wastes.

Blast furnace slag is glassy black in colour. Its characteristics depend on the nature of iron ore used in the extraction of iron, which significantly differs from place to place.

For the purpose of present experimental work, blast furnace slag was procured from Ghatge Patil Industry. The material was crushed and sieved and blast furnace slag passing through 20 mm sieve and retaining on 4.75mm.

Sr. No.	Properties	Value
1.	Specific gravity	2.8
2.	Fineness modulus	6.17

Table 4: Properties of Fine Aggregate

B. M40 Grade Concrete Design Mix:

MIX A			
1	Cement content	=	340 Kg/m^3
2	Water cement ratio	=	0.50
3	Water content	=	170 Kg/m^3
4	Sand content [fa]	=	821.167Kg/m^3
5	Blast furnace slag [C-slag]	=	1210.142Kg/m^3
MIX B			
1	Cement content	=	360 Kg/m^3
2	Water cement ratio	=	0.45
3	Water content	=	132 Kg/m^3
4	Sand content [fa]	=	822.933Kg/m^3
5	Blast furnace slag [Cslag]	=	1212.743Kg/m^3

Table 5: Concrete Mix Design

Cement Kg/M^3	Sand Kg/M^3	Blast Furnace Slag Kg/M^3	Water Content Kg/M^3
MIX A			
340	821.167	1210.142	170
1	2.415	3.559	0.5
MIX B			
360	22.933	1212.743	162
1	2.285925	3.368731	0.45

Table 6: Final Mix Proportion

IV. RESULT ANALYSIS

Compressive strength of the concrete design mix was check by casting and testing of cubes (size 150 mm x 150 mm x 150 mm) after the curing period of 3 days, 7 days, 14 days, 28 days & 56 days. The obtained results are tabulated below (table no: 7 to 9)

Cube ID mark	Load in KN	Compressive strength in N/mm^2	Average Compressive strength in N/mm^2
MIX A			
AN	745	33.111	**33.111**
	740	32.889	
	750	33.333	
A100	565	25.111	**24.815**
	560	24.889	
	550	24.444	
A75	585	26.000	**25.852**
	580	25.778	
	580	25.778	
A50	655	29.111	**28.741**
	645	28.667	
	640	28.444	
MIX B			
BN	795	35.333	**35.185**
	790	35.111	
	790	35.111	
B100	545	24.222	**24.074**
	540	24.000	
	540	24.000	
B75	615	27.333	**27.556**
	625	27.778	
	620	27.556	
B50	700	31.111	**31.185**
	710	31.556	
	695	30.889	

Table 7: 7 Day's Compressive Strength

Cube ID mark	Load in KN	Compressive strength in N/mm^2	Average Compressive strength in N/mm^2
MIX A			
AN	1090	48.444	**48.741**
	1100	48.889	
	1100	48.889	
A100	895	39.778	**39.407**
	885	39.333	
	880	39.111	
A75	915	40.667	**40.815**
	920	40.889	
	920	40.889	
A50	1090	48.444	**48.148**
	1080	48.000	
	1080	48.000	
MIX B			
BN	1130	50.222	**50.519**
	1140	50.667	
	1140	50.667	
B100	935	41.556	**41.333**
	930	41.333	
	925	41.111	
B75	990	44.000	**44.444**
	1010	44.889	
	1000	44.444	
B50	1090	48.444	**48.741**
	1100	48.889	
	1100	48.889	

Table 8: 28 Day's Compressive Strength

Cube ID mark	Load in KN	Compressive strength in N/mm^2	Average Compressive strength in N/mm^2
MIX A			
AN	1100	48.889	**49.037**
	1100	48.889	
	1110	49.333	
A100	965	42.889	**43.111**
	975	43.333	
	970	43.111	
A75	955	42.444	**42.667**
	965	42.889	
	960	42.667	
A50	1120	49.778	**50.074**
	1130	50.222	
	1130	50.222	
MIX B			
BN	1220	54.222	**53.926**
	1210	53.778	
	1210	53.778	
B100	1030	45.778	**45.778**
	1020	45.333	
	1040	46.222	
B75	1080	48.000	**47.704**
	1070	47.556	
	1070	47.556	
B50	1250	55.556	**55.704**
	1260	56.000	
	1250	55.556	

Table 9: 56 Day's Compressive Strength

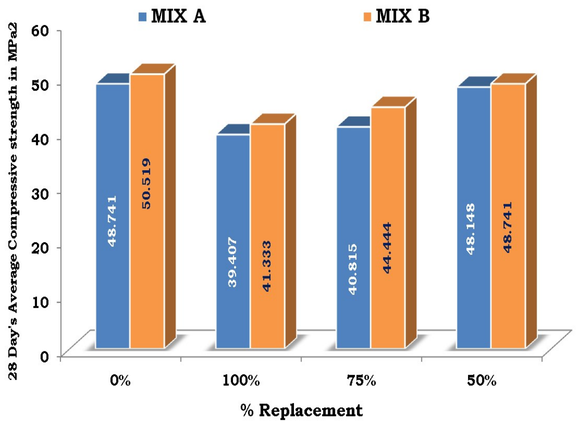

Fig. 2: 28 Day's Compressive Strength Graph

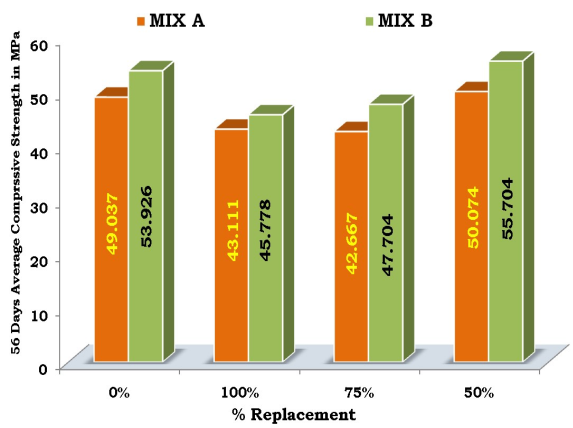

Fig. 3: 56 Day's Compressive Strength Graph

V. DISCUSSIONS ON EXPERIMENTAL WORK

The effect of the % replacement of aggregates by blast furnace slag on the compressive strength of concrete was determined by testing of the cube samples in the compressive testing machine after curing period of 7 days, 28 days, and 56 days and the results are tabulated in table 7 to table 9

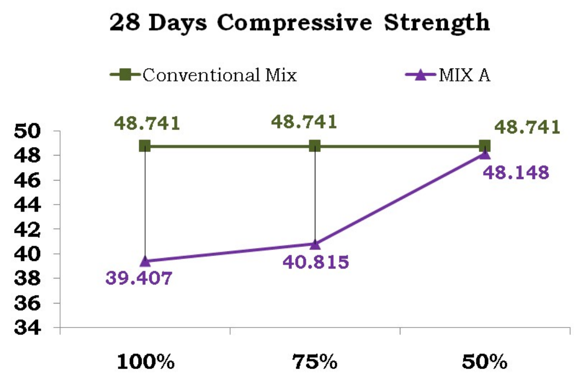

Fig. 4: 28 Day's Compressive Strength –Mix A

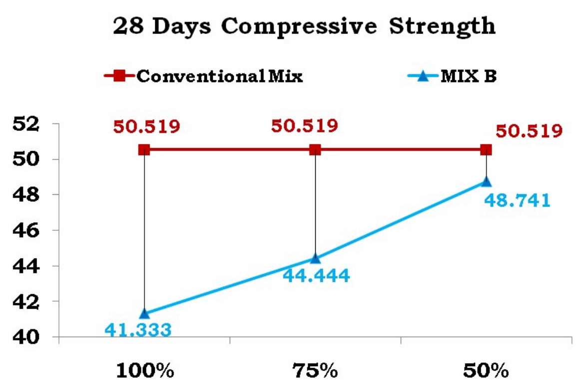

Fig. 5: 28 Day's Compressive Strength –Mix B

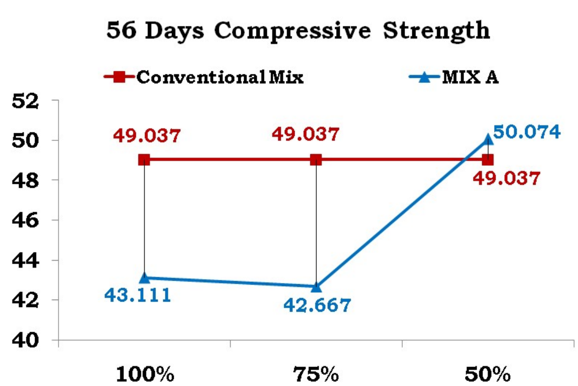

Fig. 6: 56 Day's Compressive Strength –Mix A

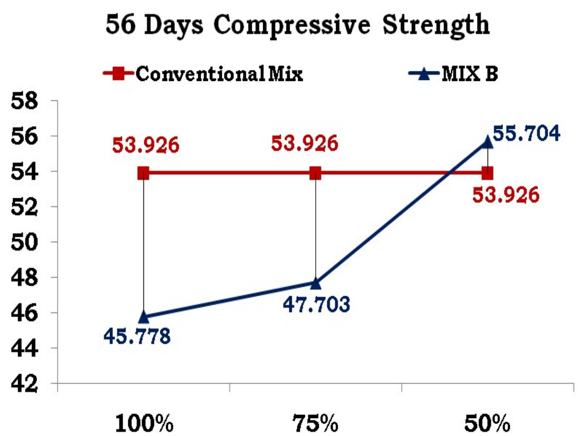

Fig. 7: 56 Day's Compressive Strength –Mix B

With reference to the tables and graphs (fig 4 to 7) it is interesting to note that for both Mixes(i.e Mix A and Mix B) BFS Concrete with 50 % replacement of Course Aggregate with Blast Furnace Slag give maximum Compressive Strength than that of other replacements.

A. MIX A:

7 Days Compressive Strength of 50 % replacement by BFS is 28.741 MPa which is lower than that of Conventional Mix (0 %), ie, 33.111 MPa.

On the other hand, such strengths of 50% replacement by BFS aggregate concrete and Conventional Mix (0 %) at the age of 28 days are 48.148 Mpa and 48.741 MPa, respectively. The 28 days compressive strength of 50% replacement by BFS Concrete is nearly equal to the 28 days compressive strength of Conventional Mix (0 %) (Figure 2)

The compressive strength of 50% replacement by BFS aggregate concrete is higher than that of the Conventional Mix (0 %) at the age of 56 days with the values being 50.074 MPa and 49.037 MPa respectively (Figure 3)

B. MIX B:

7 Days Compressive Strength of 50 % replacement by BFS is 31.185 MPa which is lower than that of Conventional Mix (0 %), ie, 35.185 MPa.

On the other hand, such strengths of 50% replacement by BFS aggregate concrete and Conventional Mix (0 %) at the age of 28 days are 48.741 Mpa and 50.519 MPa, respectively. The 28 days compressive strength of 50% replacement by BFS Concrete is nearly equal to the 28 days compressive strength of Conventional Mix (0 %) (Figure 2)

The compressive strength of 50% replacement by BFS aggregate concrete is higher than that of the Conventional Mix (0 %) at the age of 56 days with the values being 55.704 MPa and 53.926 MPa respectively (Figure 3)

VI. CONCLUSION

The main aim of this research was to study the behaviour of concrete and changes in the properties of concrete with blast furnace slag aggregates by replacing the use of natural aggregates. Blast furnace slag is a by-product and using it as aggregates in concrete will might prove an economical and environmentally friendly solution. The demand for aggregates is increasing rapidly and so as the demand of concrete. Thus, it is becoming more important to find suitable alternatives for aggregates in the future.
The BFS contains higher percentage of CaO that reacts with silica after 28 days and produces extra gel in the concrete. This extra quantity of gel increases the gel/space ratio and reduces the porosity of concrete, resulting in its higher compressive strength.

The compressive strength of 50% replacement by BFS aggregate concrete is marginally lower than that of the stone aggregate concrete at the age of 7 days while, no significant difference is observed at the age of 28 days. Compressive strength at the age of 56 days is higher for 50% replacement by BFS concrete. Thus, BFS aggregate concrete performs better in long term conditions.

The results of the research program can be conclude that as age of concrete increases, the rate of increase of strength of BFS concrete is higher than the rate of increase of strength of Conventional Mix (0 %).

But the rate of increase of strength is different in both Mixes (i.e. Mix A and Mix B).

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