Utilization of Blast Furnace Slag in Manufacturing of Paver Blocks

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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 and steel making process. Iron cannot be prepared in the blast furnace without the production of its co-product i.e. induction furnace slag. The use of induction 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.

I. INTRODUCTION

Now-a-days disposal of different waste produced from different Industries is a great problem. These materials pose environmental pollution in the nearby locality because many of them are non-biodegradable. The construction sector is exploring rapidly on a large scale and also involves new techniques for rapid and comfort works on the field. Concrete as a building material plays an important role in this sector. The consumption of natural resources as an ingredient of concrete, costs high it is on verge of extinct. These problems force us to recover the natural resources or to find replacement.

Concrete is a material which is composed of coarse aggregate, fine aggregate, cement, admixtures and water. Each material in concrete contributes in its strength and durability, so by partial or percentage replacing of material affects different properties of concrete. Using such waste material which harms the environment can be used for the development of low cost and eco-friendly structural materials. In this study an experimental investigation will be carried out by varying percentage of coarse aggregate, with used induction furnace slag to produce low cost and eco-friendly concrete.

Experimental program is planned to study the following objectives-

a) The purpose of this research is to explore the feasibility of utilizing the induction 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 induction furnace slag aggregates.
c) To study the effect on compressive strength of concrete with induction furnace slag.

II. SLAG

A. Manufacturing Process:

During production of iron, steel, iron scrap, steel 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. Slag is formed by the fusion of iron ore impurities after the fluxing agents (limestone and dolomite) and coke ashes are added to the mix. The melted slag is an insoluble and lower density mass which floats on the pig iron and is tapped through runners into a cooling place. Iron and steel slag refers to the type of metal manufacturing slag that is generated during the process of manufacturing iron and steel products. The term "slag" originally referred to slag produced by metal manufacturing processes, however it is now also used to describe slag that originates from molten waste material when trash and other substances are disposed. The final form of the slag is dependent on the method of cooling and can be produced in the following forms:

B. Types:

Different types of slag are produced according the different procedures used to cool the molten slag. We have used the induction furnace slag which is air cooled type slag

a) Granulated:

The molten slag is cooled rapidly by jets of pressurized water, resulting in a vitreous, granulated

b) Air-cooled:

The molten slag flows into a cooling yard, where it is cooled slowly by natural cooling and by spraying with water. This results in a crystalline, rock-like air-cooled slag.

c) Pelletised:

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 nitrification and less crystallization

d) Foamed:

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.

III. MATERIAL AND CONCRETE DESIGN MIX DETAILS

A. Material

a) Cement

Ordinary Portland cement (Birla 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.

Table 1: Properties of Cement

Sr. No.	Type of Test	Results
1	Fineness of Cement (%)	1.55 %
2	Standard Consistency (%)	31.00 %
3	Initial Setting Time (min)	275 min
4	Final Setting Time (min)	342 min
5	Specific gravity	3.15
6	7 Day's Compressive Strength	35.425 N/mm^2
7	28 Day's Compressive Strength	46.150 N/mm2

b) Coarse Aggregate

Table 2: Properties of Coarse Aggregate

Sr. No.	Properties	Value
1	Specific Gravity	3.05
2	Fineness Modulus	3.43
3	Water Absorption	0.5%

c) Fine Aggregate

Table 3: Properties of Fine Aggregate

Sr. No.	Properties	Value
1	Specific Gravity	2.83
2	Fineness Modulus	2.79
3	Water Absorption	0.45%

d) Induction Furnace Slag

Sourabh Metals, a machine part manufacturing industry is situated Gokul-Shirgaon, Kolhapur. When the induction 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 after which that molten iron going to be pour into moulds of machine parts 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 i.e. on dry places so as to cooled by air ; hence not so much expenditure is required for maintaining these sites and disposal of wastes.

Induction furnace slag is greyish-black in color. 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, induction furnace slag was procured from Sourabh Metals. The material was crushed and sieved and induction furnace slag passing through 10 mm sieve and retaining on 4.75mm is used for our experimental work.

Table 4: Properties of Slag

Sr. No.	Properties	Value
1	Specific Gravity	2.48
2	Fineness Modulus	1.34
3	Water Absorption	0.15 %

B. M20 Concrete Mix Design

a) Final Mix Proportion and Ratio

Table 5: Properties of Slag

Cement	Sand	Coarse Aggregate	Water	Chemical
350	1135.48	935.549	164.5	1% of Cement

Table 6: Properties of Slag

Cement	Sand	Coarse Aggregate	Water	Chemical
1	3.24	2.67	0.47	0.01

IV. RESULT ANALYSIS

Paver blocks having area 50500 mm^2 and casted with different % of replacement was tested under digital Compression Testing Machine after the curing period of 7 days & 28 days.

Table 7: ID Marks according to replacement

I.D. for Paver Blocks	Percentage of Coarse aggregate	Percentage of Induction Furnace Slag (IFS)
A	100	0
B	80	20
C	60	40
D	40	60

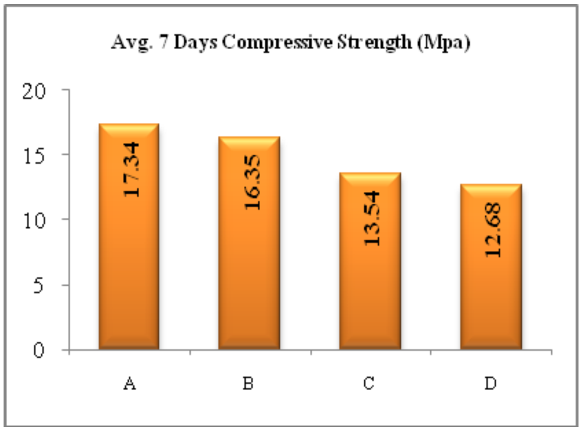
Table 8: 7 Days Compressive Strength

Block ID	Load (kN)	Comp. Strength (N/mm2)	Avg. 7 Days Compressive Strength (Mpa)
0 % Replacement			
A1	865.57	17.14	**17.34**
A2	886.78	17.56	
A3	873.65	17.3	
20 % Replacement			
B1	850.42	16.84	**16.35**
B2	830.22	16.44	
B3	797.9	15.8	
40 % Replacement			
C1	680.74	13.48	**13.54**
C2	699.93	13.86	
C3	671.65	13.3	
60 % Replacement			
D1	666.6	13.2	**12.68**
D2	626.2	12.4	
D3	628.725	12.45	

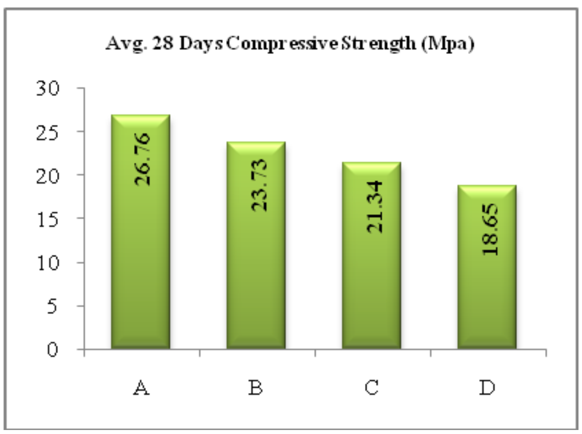
Table 9: 28 Days Compressive Strength

Block ID	Load (kN)	Comp. Strength (N/mm2)	Avg. 7 Days Compressive Strength (Mpa)
0 % Replacement			
A1	1334.21	26.42	**26.76**
A2	1356.43	26.86	
A3	1363.5	27	
20 % Replacement			
B1	1199.88	23.76	**23.73**

Block ID	Load (kN)	Comp. Strength (N/mm2)	Avg. 7 Days Compressive Strength (Mpa)
B2	1184.23	23.45	
B3	1210.49	23.97	
40 % Replacement			
C1	1053.43	20.86	**21.34**
C2	1093.83	21.66	
C3	1085.75	21.5	
60 % Replacement			
D1	957.48	18.96	**18.65**
D2	914.05	18.1	
D3	954.45	18.9	



Graph 1: 7 Days Compressive Strength



Graph 2: 28 Days Compressive Strength

V. DISCUSSION ON EXPERIMENTAL WORK

The effect of the % replacement of coarse aggregates by induction furnace slag on the compressive strength of paver blocks was determined by testing of the paver blocks in the compressive testing machine after curing period of 7 days & 28 days and the results are tabulated in table 2 & table 3

With reference to the tables and graphs (fig 1 to 2) it is interesting to note that for both 7 days & 28 days IFS Concrete with 20% replacement of Coarse Aggregate with Induction Furnace Slag give maximum Compressive Strength than that of other replacements. Then afterwards as we goes on increasing the % replacement of coarse aggregate by IFS compressive strength goes on decreasing.

VI. CONCLUSION

The main aim of this research was to study the behavior of concrete and changes in the properties of concrete with induction furnace slag aggregates by replacing the use of natural aggregates. Induction furnace slag is a byproduct 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 IFS 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 20% replacement by IFS 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. Thus, IFS as a replacement of aggregates performs well in concrete.

The results of the research program can be conclude that even though the compressive strength of 20% replacement is more amongst all the replacement but our design is for M20 grade concrete and the results obtained for 40% material replacement are also more than 20MPa and also 40% coarse aggregates are replaced by Induction Furnace Slag (IFS). So it can be finally concluded that 40% material replacement results are good and also the 40% utilization of Induction Furnace Slag (IFS) is done in concrete.

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