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Effect of blast furnace slag powder on compressive strength of concrete

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Abstract— The Ordinary Portland Cement (OPC) is one of the main ingredients used for the production of concrete. Unfortunately, production of cement involves emission of large amounts of carbon-dioxide gas into the atmosphere, a major contributor for green house effect and the global warming, hence it is inevitable either to search for another material or partially replace it by some other material. The search for any such material, which can be used as an alternative or as a supplementary for cement should lead to global sustainable development and lowest possible environmental impact. Concrete property can be maintained with advanced mineral admixtures such as blast furnace slag powder as partial replacement of cement 5 to 30%. Compressive strength of blast furnace slag concrete with different dosage of slag was studied as a partial replacement of cement. From the experimental investigations, it has been observed that, the optimum replacement of Ground Granulated Blast Furnace Slag Powder to cement without changing much the compressive strength is 15%.

Index Terms — Concrete, Blast Furnace Slag Powder, Compressive Strength, Optimum Replacement.

1 Introduction

BLast furnance slag is a solid waste discharged in large quantities by the iron and steel industry in India. The recycling of these slag's will become an important measure for the environmental protection. Iron and steel are basic materials that underpin modern civilization, and due to many years of research the slag that is generated as a by-product in iron and steel production is now in use as a material in its own right in various sectors. Slag enjoys stable quality and properties that are difficult to obtain from natural materials and in the 21st century is gaining increasing attention as an environmentally friendly material from the perspectives of resource saving, energy conservation and CO_2 reduction. The primary constituents of slag are lime (CaO) and silica (SiO_2). Portland cement also contains these constituents. The primary constituent of slag is soluble in water and exhibits an alkalinity like that of cement or concrete. And as it is removed at high temperatures of 1,200°C and greater, it contains no organic matter whatsoever. Ground Granulated Blast furnace slag (GGBS) is a by-product for manufacture of pig iron and obtained through rapid cooling by water or quenching molten slag. Here the molten slag is produced which is instantaneously tapped and quenched by water. This rapid quenching of molten slag facilitates formation of "Granulated slag". Ground Granulated Blast furnace Slag (GGBS) is processed from Granulated slag. If slag is properly processed then it develops hydraulic property and it can effectively be used as a pozzolanic material. However, if slag is slowly air cooled then it is hydraulically inert and such crystallized slag cannot be used as pozzolanic material. Though the use of GGBS in the form of Portland slag cement is not uncommon in India, experience of using GGBS as partial replacement of cement in concrete in India is scanty. GGBS essentially consists of silicates and alumina silicates of calcium and other bases that are developed in a molten condition simultaneously with iron in a blast furnace. The chemical composition of oxides in GGBS is similar to that of Portland cement but the proportion varies. This paper deals with the use of the blast furnace slag powder as a partial replacement of OPC and its effect on strength of cement concrete mix

2 Literature review

Throughout the long history of the iron and steel industries, ways have been sought to make effective use of these slag, but their traditional use as landfill material has been nearing its limit with the massive expansion of the steel industry since the mid-1970. The steel companies have since taken on as among their important management challenges the development of technology, the maintenance of production facilities and certification for ferrous slag products in the market in order to expand the applications of these slag, and the Japan Iron and Steel Federation (JISF) and Nippon Slag Association (NSA) have promoted the institution and widespread adoption of Japan Industrial Standards (JIS). As a result, 99% of slag is now useful material, employed by such national agencies as the Ministry of Land, Infrastructure and Transport and by local governments and other users, and it has gained both high acclaim and certification. The history of recycling ferrous slag is a long one. Production of Portland blast-furnace slag cement began in 1910, and the Japanese national standard for Portland blast-furnace slag cement (JES 29) was formulated in 1926.some of the study has been done in past which summarized as:

1. Sun, S.S., Zhu, G.L., Zhang concluded that the recycling of steel slag will inevitably become an important measure for the environment protection and therefore will be of great significance [1].
2. Mineral additives are available in large quantities that can be used to replace Portland cement in concrete[2]
3. .Few studies have been performed to determine, thermal properties, mechanical properties, transport mechanisms and the influence of mineral additions on the durability of blended concrete [3, 4, 5, 6].
4. Liu, Sun and Zhu found that when compound mineral admixtures with steel slag powder and blast-furnace slag powder are mixed into concrete, the performance of concrete can be improved further due to

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the synergistic effect and activation each other [7, 8].

5. Li, Yao ,Wang, Lin The high performance concrete can be produced using mineral admixture with steel slag powder and blast furnace slag so the recycling of steel slag can bring enormous benefits and environmental benefit to whole society.[9]

6. Ground granulated blast furnace slag is commonly used in combination with Portland cement in concrete for many applications[10,11]

7. The heat of hydration is dependent on the Portland cement used and the activity of the GGBF slag. Roy and Idorn (1982) found a correlation of heat of hydration to strength potential of various blends of GGBF slag and Portland cement.[12]

8. The early age strength development of mixtures containing GGBS is highly dependent on temperature. under standard curing conditions ,GGBS mortars gain strength more slowly than Portland cement mortars[13]

9. Partial replacement of Portland cement with GGBF slag is found to improve the sulfate resistance of concrete. High resistance to sulfate attack has been demonstrated when the GGBF slag proportion exceeds 50 percent of the total Cementitious material where Type II cements were used (Hog- an and Meusel 1981) [14]

10. GGBF slag's has no negative effect on the corrosion of steel (Fulton 1974; Lea 1971; Hogan and Meusel 1981). It has been found that a slight reduction in the pH of pore solution does not have a negative impact on the passivity of reinforcing steel, and that use of GGBF slag in good quality concrete, reduces concrete permeability, thus reducing the penetration of chlorides and carbon dioxide which promote corrosion of steel.[15]

11. The use of GGBFS as a partial Portland cement replacement takes advantage of the energy invested in the slag making process and its corresponding benefits with respect to the enhanced Cementitious properties of the slag. Grinding slag for cement replacement requires only about 25 percent of the energy needed to manufacture Portland cement.[16]

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3 Research Significance

The research reported in this study, blast furnace slag powder obtained from steel plant Bhilai is used as a cement replacement material in concrete mix. Optimal dosage range of this blast furnace slag powder is chosen based on concrete mix studies .The ultimate focus of this work is to ascertain the performance of concrete mix containing blast furnace powder and compare it with the plain concrete mix of ratio(1:1.67:3.2). This is expected to provide:-

1. To partially replace cement content in concrete as it directly influences economy in construction.
2. Environmental friendly disposal of waste steel slag.
3. To boost the use of industrial waste

4 Material Characteristics

The blast furnace slag powder obtained from Bhilai steel plant used in this study has the chemical composition given in table no 1

Table 1

Constituent	Percent
Sio2	34.4
Al2O3	21.5
Fe2O3	0.2
Cao	33.2
MgO	9.5
P2O5	0.54
SO3	0.66
PASSING 90 MICRON	80%
SPECIFIC GRAVITY	3.15

4.1 Ordinary Portland cement (43 grade)

The physical properties are shown below in table 2

Table2 Properties of Ordinary Portland cement:

Specific gravity	3.1
Initial setting time (min)	90 min
Final setting time (min)	360 min

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4.2 Fine aggregate

The sand used in this study conforms to Zone-II

Table 3 Properties of fine aggregate:

Properties	Results Obtained
Specific Gravity	2.43
Water absorption	1%
Fineness Modulus	2.40

4.3 Coarse aggregate

The coarse aggregate used in this study have the maximum size of 20mm.

Table 4 Properties of coarse aggregate

Specific gravity	2.853
Water absorption	0.6%
Fineness modulus	7.02

5 RESEARCH METHODOLOGY

Cement concrete mix: The cement concrete mix was prepared as per the procedure given in the relevant IS 10262:2009 .For optimal dosage selection of blast furnace slag powder in the concrete mix, modified cubes (% ranging from 5 % to30 % Table 5) are prepared and compared with plain cement concrete cubes. (1:1.67:3.2) .Fig (1) Depicts the compressive strengths of modified blast furnace slag powder cement concrete cubes and plain concrete cube cured under saturated conditions for 28 days. From fig (1) it can be noticed that, at 28 days the blast furnace modified pastes show compressive strength very close to that of the plain paste, even at 20 % replacement levels.
Cement used: OPC 43 grade

- . W/ c Ratio: 0.5%
- Cement: Fine Aggregate: coarse aggregate proportion used: 1: 1.67:3.2

Table5 mix specification for 1 m^3 concrete

Particulars	Plain concrete Mix	5 % slag	10% slag	15% slag	20% slag	25 % slag	30 % slag
Cement in kg/ m^3	380	361	342	323	304	285	266
Sand in kg/ m^3	635	635	635	635	635	635	635
Coarse Aggregate in kg/ m^3	1216	1216	1216	1216	1216	1216	1216
Blast furnace slag Powder in kg/ m^3	0	19	38	57	76	95	114
Water in kg/ m^3	190	190	190	190	190	190	190

6 TEST RESULTS

Compressive strength test was conducted to evaluate the strength development of Cement concrete mix, containing various % of blast furnace slag powder at the age of 7, 14, 28 days respectively. Cubes were made of standard size (150mmx150mmx150mm)

Table 6: Compressive Strength test results in N/mm²

MIX DESCRIPTION	PLAIN	5 BFSP	10BFSP	15 BFSP	20 BFSP	25 BFSP	30 BFSP
% REPLACEMENT LEVEL WITH BLAST FURNACE SLAG POWDER	0 %	5 %	10%	15 %	20 %	25 %	30 %
7 DAYS	**21.03**	**20.74**	**20.44**	**19.85**	**18.07**	**16.88**	**15.40**
14 DAYS	**23.70**	**22.81**	**22.66**	**22.36**	**19.55**	**18.51**	**16.74**
28 DAYS	**26.9**	**25.00**	**24.59**	**24.29**	**20.88**	**20.74**	**18.81**

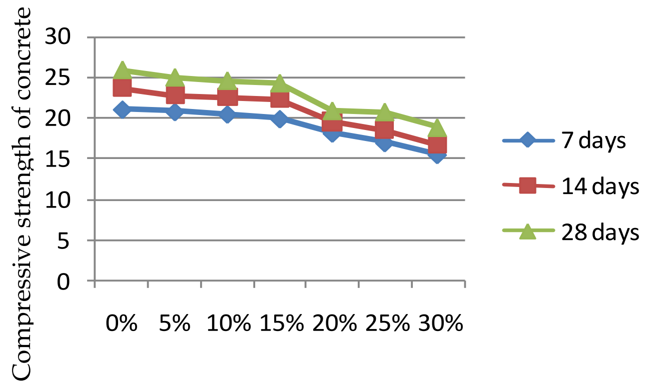

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Figure2 Percentage of blast furnace slag

7 Discussion & Conclusion

This study was carried out to obtain the results, tests conducted on blast furnace slag powder modified cement concrete mix, in order to ascertain the influence of blast furnace slag powder on the characteristics strength of concrete

The variation of compressive strength of concrete mix with different proportion of blast furnace slag powder as partial replacement of cement is shown in fig.1 and fig2 It was observed that 7 days, 14 days and 28 days compressive strength on 30% replacement of cement reduces about 30% that is from 21.03 N/mm² to 15.40N/mm², 23.70 N/mm²to 16.74 N/mm².and 26.9 N/mm²to18.81 N/mm² respectively. From study it can be concluded that as the % of BFSP increase, the strength tends to decrease.

The results obtained from compressive strength tests conducted on concrete containing OPC and various percentage of blast furnace slag powder is comparable to that of concrete mix without slag powder. On replacement of OPC with 15% blast furnace slag powder the depreciation in 28day compressive strength is being near about 5 %

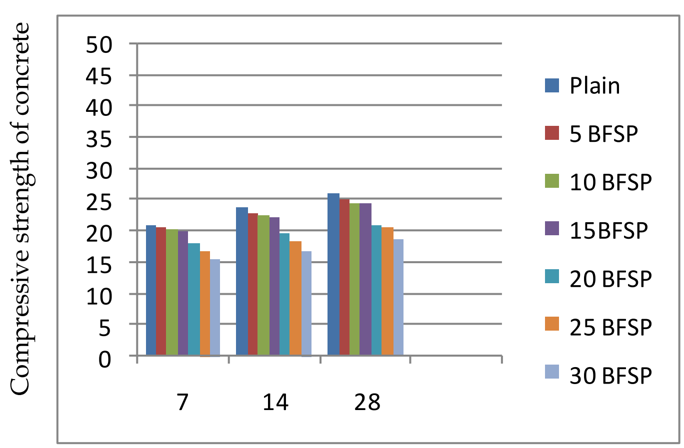

Figure 1 Variation of 7,14and 28 days Compressive strength of concrete with % replacement of cement by blast furnace slag powder

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