

Experimental Investigation on Iron Waste Based High Performance Concrete

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Abstract - A mixture of cement, fine aggregate and coarse aggregate is known as concrete. It plays an important role in infrastructure development like buildings, bridges and industrial structures etc. Long term performance of buildings without deterioration helps economics of nation. High performance concrete (HPC) is a concrete which shows special performance than conventional concrete. This leads to usage of admixtures to improve concrete performance. On the other side cost of concrete ingredients plays vital role, this leading to usage of alternative materials which is economic in its production. This requirement made the investigators to find new replacement for concrete ingredients which should improve long term performance and stability of structures. This research focuses on strength and durability characteristics of M60 concrete with partial replacement of sand with ROBO Sand (crusher dust) and cement with Ground Granulated Blast furnace Slag (GGBFS), it is a byproduct in manufacture of iron in steel industry, usage of these replacement materials are more eco friendly. To study the strength and durability characteristics the following properties should be studied such as Compressive strength, Chloride penetration (RCPT test), Permeability (Sorptivity test), Stress strain, Acid resistance. As a part of study strength characteristics were studied by testing compressive strength of cubes. It is found that different percentage of replacement of cement with GGBFS and sand with ROBO Sand helped in improving the strength of the concrete more over equal to normal mix concrete.

Keywords: HPC, GGBFS and RCPT.

I. INTRODUCTION

1.1 General

High performance concrete (HPC) has been defined as concrete that possesses high workability, high strength and high durability. ACI (American Concrete Institute) has defined HPC as a concrete in which certain characteristics are developed for a particular application and environment. Under the ACI definition durability is optional and this has led to a

number of HPC structures, which should theoretically have very long services lives, exhibiting durability associated distress early in their lives. ACI also defines a high-strength concrete as concrete that has a specified compressive strength for design of 41MPa or above. High Performance Concrete (HPC) is a concrete made with appropriate materials combined according to a selected mix design; properly mixed, transported, placed, consolidated and cured. So, that the resulting concrete will give an excellent performance in structure in which it is placed and environment exposed with the loads to which it will be subject for its design life. Mix proportions for high-performance concrete (HPC) are influenced by many factors, including specified performance properties, locally available materials, local experience, personal preferences and cost. With today's technology, there are many products available for use in concrete to enhance its properties. The primary application for HPC have been structures requiring long service lives such as oil drilling platform, long span bridges and parking structures. HPC still requires good construction practice and good curing to deliver high performance. High-performance concretes are also more sensitive to changes in constituent material properties than conventional concretes. This means that a greater degree of quality control is required for the successful production of high-performance concrete.

1.1.1 Benefits of HPC

- i. Performance Benefits: Ease of placement and consolidation without affecting strength, long term mechanical properties, early high strength, toughness, volume stability and longer life in severe environments.
- ii. Cost and other benefits: Less material, fewer beams, reduced maintenance, extended life cycle and aesthetics.

1.1.2 Advantages of GGBFS

- i. GGBS is used to make durable concrete structures in combination with ordinary Portland cement and/or other pozzolanic materials.
- ii. Concrete made with GGBS cement sets more slowly than concrete made with ordinary Portland cement, depending on the amount of GGBS in the cementitious material, but

also continues to gain strength over a longer period in production conditions. This results in lower heat of hydration and lower temperature rises and makes avoiding cold joints easier, but may also affect construction schedules where quick setting is required.

- iii. Use of GGBS significantly reduces the risk of damages caused by alkali-silica reaction (ASR), provides higher resistance to chloride ingress-reducing the risk of reinforcement corrosion and provides higher resistance to attacks by sulfate and other chemicals.
- iv. Concrete containing GGBS cement has a higher ultimate strength than concrete made with Portland cement.
- v. Reduced permeability.
- vi. Dirt does not adhere to GGBS concrete as easily as concrete made with Portland cement, reducing maintenance costs. GGBS cement prevents the occurrence of efflorescence, the staining of concrete surfaces by calcium carbonate deposits.

1.1.3 Objectives

- i. To assess the effect of GGBFS on strength and durability characteristics of high performance concrete.
- ii. To assess the effect of ROBO Sand on strength and durability characteristics of high performance concrete.
- iii. To assess the effect of combination of GGBFS and ROBO Sand on strength and durability characteristics of high performance concrete.
- iv. To find out the optimum mix combination.

II. MATERIALS AND METHODS

2.1 Materials

In this research various materials are used. The details of materials are discussed as follows

2.1.1 Cement

The cement used was pozzolana Portland cement. Specific gravity of cement used is 3.15. The Portland Pozzolana Cement is a kind of Blended Cement which is produced by either inter grinding of OPC clinker along with gypsum and pozzolanic materials in certain proportions or grinding the OPC clinker, gypsum and Pozzolanic materials separately and thoroughly blending them in certain proportions. Pozzolana is a natural or artificial material containing silica in a reactive form. It may be further discussed as siliceous or siliceous and aluminous material which in itself possesses little, or no cementitious properties but will in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperature to form compounds possessing cementitious properties.

2.1.2 Ground granulated blast-furnace slag (GGBFS)

Ground Granulated Blast Furnace Slag (GGBFS) is a recyclable material created when the molten slag from melted iron ore is quenched rapidly and then ground into a powder. This material has cementitious properties and has been used as a replacement for cement for over 100 years. 100 Class (ASTM C 989) A Grade GGBFS was supplied from salem. Activity index of GGBFS was 75% and 96% for ages of 7 and 28 days, respectively. Concrete made with GGBS cement sets more slowly than concrete made with ordinary Portland cement, depending on the amount of GGBS in the cementitious material, but also continues to gain strength over a longer period in production conditions. This results in lower heat of hydration and lower temperature rises, and makes avoiding cold joints easier, but may also affect construction schedules where quick setting is required. Use of GGBS significantly reduces the risk of damages caused by alkali-silica reaction (ASR), provides higher resistance to chloride ingress - reducing the risk of reinforcement corrosion and provides higher resistance to attacks by sulphate and other chemicals. Investigations were carried out with 40%, 50%, 60%. It is obtained by quenching molten iron slag (a by-product of iron and steel-making) from a blast furnace in water or steam, to produce a glassy, granular product that is then dried and ground into a fine powder. The chemical composition of a slag varies considerably depending on the composition of the raw materials in the iron production process. Silicate and aluminate impurities from the ore and coke are combined in the blast furnace with a flux which lowers the viscosity of the slag. In the case of pig iron production the flux consists mostly of a mixture of limestone and forsterite or in some cases dolomite. In the blast furnace the slag floats on top of the iron and is decanted for separation. Slow cooling of slag melts results in an unreactive crystalline material consisting of an assemblage of Ca-Al-Mg silicates. To obtain a good slag reactivity or hydraulicity, the slag melt needs to be rapidly cooled or quenched below 800 °C in order to prevent the crystallization of merwinite and melilite. To cool and fragment the slag a granulation process can be applied in which molten slag is subjected to jet streams of water or air under pressure. Alternatively, in the pelletization process the liquid slag is partially cooled with water and subsequently projected into the air by a rotating drum. In order to obtain a suitable reactivity, the obtained fragments are ground to reach the same fineness as Portland cement. The glass content of slags suitable for blending with Portland cement typically varies between 90-100% and depends on the cooling method and the temperature at which cooling is initiated. The glass structure of the quenched glass largely depends on the proportions of network-forming elements such as Si and Al over network-modifiers such as Ca, Mg and to a lesser extent Al. Increased amounts of network-modifiers lead

to higher degrees of network depolymerization and reactivity. Common crystalline constituents of blast-furnace slags are merwinite and melilite. Other minor components which can form during progressive crystallization are belite, monticellite, rankinite, wollastonite and forsterite.

2.1.3 Sand

Locally available natural river sand is used. It is accepted fact that sand plays a very important role in the production of concrete. The features of workability, strength and durability are directly dependent on the properties of the sand used in the making of concrete. Physical properties of fine aggregate are Fineness modulus = 2.88 and specific gravity = 2.65, Density (loose) = 16 kN/m³.

2.1.4 ROBO Sand

ROBO sand (crusher dust) is a perfect substitute for river sand. Eco-friendly products whose usage helps conserve nature by preventing depletion of ground water levels. Robo Sand's unique properties are cubicle particle shape, consistent gradation. The imperative need for clean sand, eliminating the constraints of river sand like availability, price fluctuation etc, have made ROBO sand the perfect substitute for river sand. ROBO sand of size 0-4.75mm is suitable for all concrete preparations and is used across all segments such as Independent Houses, Builders, RMC Plants, Concrete Batching Plants and Infrastructure Concrete Works. ROBO Sand passed through 2.36mm and retained in 150 micron is used in this project.

2.1.5 Coarse Aggregate

Locally available coarse aggregate of size 12.5mm was used. Physical properties of coarse aggregate where studied fineness modulus = 5.25, specific gravity = 2.7, Density (loose) = 14.4 kN/m³.

2.1.6 Superplasticizer

To improve the high-strength concrete workability, super plasticizer in the form of a High range water reducer (conplast SP430) was used. It also conforms to ASTM C-494 Type 'F' and type 'G', depending on the dosages used. The rate of addition is 0.5 to 2 liters / 100kg of cements. Usage of super plasticizer reduces the water cement ratio and low porosity resulting in substantially improved water penetration resistance.

2.1.7 Water

Potable water was used for present investigation for mixing and curing. Water used for mixing and curing should be free from harmful materials.

2.2 Methods

Methodology is given in the form of flow chart in Figure 1. Numerous test has to be performed for successful investigation and results should be studied carefully before final conclusion.

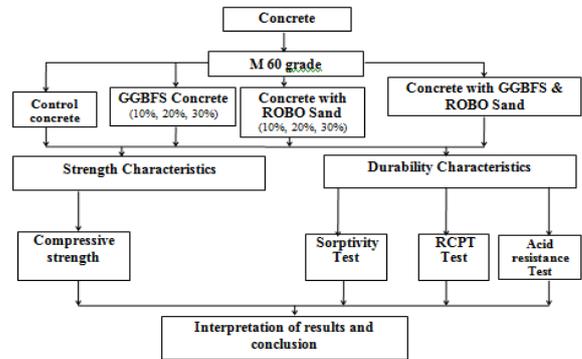


Figure 1: Flow Chart – Methodology

III. EXPERIMENTAL INVESTIGATION

3.1 Mix Proportion

Grade of concrete = 60

(a) Design Stipulation

Target strength = 60MPa

Max size of aggregate used = 12.5 mm

Specific gravity of cement = 3.15

Specific gravity of fine aggregate (F.A) = 2.6

Specific gravity of Coarse aggregate (C.A) = 2.64

Dry Rodded Bulk Density of fine aggregate = 1726 kg/m³

Dry Rodded Bulk Density of coarse aggregate = 1638 Kg/m³

Step-1

Calculation for weight of Coarse Aggregate:

From ACI 211.4R Table 4.3.3 Fractional volume of oven dry

Rodded C.A for 12.5mm size aggregate is 0.68m³

Weight of C.A = 0.68*1638 = 1108.13 kg/m³

Step-2

Calculation for Quantity of Water:

From ACI 211.4R Table 4.3.4

Assuming Slump as 50 to 75mm and for C.A size 12.5 mm the
Mixing water = 148 ml

Void content of FA for this mixing water = 35%

Void content of FA (V)

$V = \{1 - (\text{Dry Rodded unit wt} / \text{specific gravity of FA} * 1000)\} * 100$

$= [1 - (1726 / 2.6 * 1000)] * 100$

$= 34.62\%$

Adjustment in mixing water = $(V-35) * 4.55$
 $= (34.62 - 35) * 4.55$
 $= -1.725 \text{ ml}$

Total water required = $148 + (-1.725) = 146.28 \text{ ml}$

Step-3

Calculation for weight of cement

From ACI 211.4R Table 4.3.5(b)

Take W / C ratio = 0.29

Weight of cement = $146.28 / 0.29 = 504.21 \text{ kg/m}^3$

Step-4

Calculation for weight of Fine Aggregate:

Cement = $504.21 / 3.15 * 1000 = 0.1616$

Water = $146.28 / 1 * 1000 = 0.1462$

CA = $1108.13 / 3 * 1000 = 0.3690$

Entrapped Air = $2 / 100 = 0.020$

Total = 0.7376 m^3

Volume of Fine Aggregate = $1 - 0.7376$

Weight of Fine Aggregate = $0.2624 * 2.6 * 1000 = 683.24 \text{ kg/m}^3$

Step-5

Super plasticizer:

For 0.8% = $(0.8 / 100) * 583.53 = 4.668 \text{ ml}$

Step-6

Correction for water:

Weight of water (For 0.8%) = $146.28 - 4.668 = 141.61 \text{ kg/m}^3$

Requirement of materials per Cubic meter

Cement = 504.21 kg/m^3

Fine Aggregate = 683.24 kg/m^3

Coarse Aggregate = 1108.13 kg/m^3

Water = 141.61 kg/m^3

Super plasticizers = 4.668 kg/m^3

So the final ratio becomes

Cement: Fine agg (kg/m^3) : Coarse agg (kg/m^3) : Water (l/m^3):

Superplasticizer (l/m^3)

1: 1.35 :2.19 :0.29 :0.8

Age of curing is 28 days and 56 days respectively.

3.2 Schedule and testing of specimens

Cement replaced by GGBFS for different percentage such as 10%, 20%, 30% and sand replaced by ROBO sand for different percentage such as 10%, 20%, 30% respectively. Compressive strength testing is done on hardened concrete. 3 cubic specimens of 100mm were done for each mixture to determine the compressive strength of concrete. Curing is done for 28days and 56days respectively and the specimens are taken out of water and compressive strength is done and the final results were compared with control concrete.

IV. RESULT AND DISCUSSION

4.1 Result and Discussion

In this research test results are shown in Table 1, 2, 3 & 4 as follows:

Table 1: Test Result for 28 Days Curing

S. No	Specimen	Avg. Compressive strength (N/mm ²)
1	CONTROL	61.5
1	GGBFS 10 %	61.3
2	GGBFS 20 %	60.9
3	GGBFS 30 %	60.1
1	Robo sand 10 %	60.5
2	Robo sand 20 %	60.0
3	Robo sand 30 %	59.4
1	GGBFS 10% and RS 10%	60.7
2	GGBFS 10% and RS 20%	60.4
3	GGBFS 10% and RS 30%	58.8
1	GGBFS 20% and RS 10%	59.7
2	GGBFS 20% and RS 20%	59.1
3	GGBFS 20% and RS 30%	58.9
1	GGBFS 30% and RS 10%	59.0
2	GGBFS 30% and RS 20%	58.6
3	GGBFS 30% and RS 30%	56.4

Table 2: Strength Comparison for 28 Days

S. No	Replacement	Difference in Strength (%)
1	GGBFS 10 %	0.325
2	GGBFS 20 %	0.976
3	GGBFS 30 %	2.276
4	ROBO sand 10 %	1.626
5	ROBO sand 20 %	2.439
6	ROBO sand 30 %	3.415
7	GGBFS 10 % and RS 10 %	1.301
8	GGBFS 10 % and RS 20 %	1.789
9	GGBFS 10 % and RS 30 %	4.390
10	GGBFS 20 % and RS 10 %	2.927
11	GGBFS 20 % and RS 20 %	3.902
12	GGBFS 20 % and RS 30 %	4.227
13	GGBFS 30 % and RS 10 %	4.065
14	GGBFS 30 % and RS 20 %	4.715
15	GGBFS 30 % and RS 30 %	8.292

Table 3: Test Result for 56 Days Curing

S. No	Specimen	Avg. Compressive strength (N/mm ²)
1	CONTROL	72.0
1	GGBFS 10 %	71.5
2	GGBFS 20 %	71.9
3	GGBFS 30 %	71.3
1	Robo sand 10 %	71.5
2	Robo sand 20 %	70.0
3	Robo sand 30 %	68.0
1	GGBFS 10% and RS 10%	68.4
2	GGBFS 10% and RS 20%	68.9
3	GGBFS 10% and RS 30%	67.1
1	GGBFS 20% and RS 10%	71.0
2	GGBFS 20% and RS 20%	69.9
3	GGBFS 20% and RS 30%	69.2
1	GGBFS 30% and RS 10%	69.0
2	GGBFS 30% and RS 20%	68.2
3	GGBFS 30% and RS 30%	67.9

Table 4: Strength Comparison for 28 Days

S. No	Replacement	Difference in Strength (%)
1	GGBFS 10 %	0.694
2	GGBFS 20 %	0.139
3	GGBFS 30 %	0.972
4	Robo sand 10 %	0.694
5	Robo sand 20 %	2.778
6	Robo sand 30 %	5.556
7	GGBFS 10 % and RS 10 %	5.000
8	GGBFS 10 % and RS 20 %	4.306
9	GGBFS 10 % and RS 30 %	6.806
10	GGBFS 20 % and RS 10 %	1.389
11	GGBFS 20 % and RS 20 %	2.917
12	GGBFS 20 % and RS 30 %	3.889
13	GGBFS 30 % and RS 10 %	4.167
14	GGBFS 30 % and RS 20 %	5.278
15	GGBFS 30 % and RS 30 %	5.694

In this research, for the age of 28 days Strength comparison for control concrete versus concrete with GGBFS, ROBO sand and GGBFS+ ROBO Sand for different percentage are found to be less than 10% reduction in strength. For the age of 56 days strength comparison for control concrete versus concrete with GGBFS, ROBO sand and GGBFS + ROBO Sand for different percentage are found to be less than 6% reduction in strength.

V. CONCLUSIONS

Based on the results obtained from the experimental work and from the analysis of the results the following conclusions were drawn.

- Using of admixture can improve the compressive strength of concrete.
- From the above experimental results it is proved that GGBFS can be used as an alternative material for cement and ROBO Sand can be used as an alternative material for sand.
- Strength difference for replacement of GGBFS, ROBO sand and GGBFS+ ROBO is reduced within 10% for 28 days curing and 6% for 56 days curing. As the curing period increases the strength reduction percentage decreases.
- GGBFS can be used as an alternative material for cement, the cost of GGBFS is 50% of cost of cement.
- Strength characteristics of concrete have shown good performance for different percentage of replacement of GGBFS, ROBO sand and GGBFS and ROBO sand.
- Usage of GGBFS and ROBO sand is eco friendly, but setting time of slag based concrete needs more time than conventional concrete.

REFERENCES

- Pazhani, K., and Jeyaraj, R. 2010. Study on durability of high performance concrete with industrial wastes. ATI - Applied Technologies & Innovations, 2 (2), 19-28.
- Venu Malagavalli and Rao, P.N. 2010. High Performance Concrete with GGBFS and ROBO Sand. International Journal of Engineering Science and Technology, 2(10), 5107-5113.
- Barathkumar, B. H., Narayanan, R., Raghuprasad, B. K., and Ramachandramurthy, D. S. 2001. Mix proportioning for High Performance Concrete. Cement and Concrete Composites, 23, 71-80.
- Mohd Shariq, Jagdish Prasad and Amjad Masood. 2010. Effect of GGBFS on time dependent compressive strength of concrete. Construction and Building Materials 24, 1469-1478.
- Aitcin, P.C. 2003. The durability characteristics of high performance concrete: a review. Cement and Concrete Composites, 25, 409-420.
- Shannag, M. J., Shaia, A. and Hussein. 2003. Sulphate resistance of high-performance concrete. Cement and Concrete Composites, 3(25), 363-369.
- Ganesh Babu, K., and Sree Rama Kumar, V. 2000. Efficiency of GGBS in concrete. Cement and Concrete Research, 7(30), 1031-1036.

- [8] Oner, A., and Akyuz, S. 2007. An experimental study on optimum usage of GGBS for the compressive strength of concrete. *Cement and Concrete Composites*, 6(29), 505-514.
- [9] Hosam El-Din Seleem, H., Alaa Rashad, M., and Basil El-Sabbagh, A. 2010. Durability and strength evaluation of high-performance concrete in marine structures. *Construction and Building Materials*, 6(24), 878-884.
- [10] Eva Vejmelková, Milena Pavlíková, Zbyněk Keršner, Pavla Rovnaníková, Michal Ondráček, Martin Sedlmajer and Robert Černý. 2009. High performance concrete containing lower slag amount: A complex view of mechanical and durability properties. *Construction and Building Materials*, 6(23), 2237-2245.



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