Indo-Iranian Journal of Scientific Research (IIJSR)
Volume 1, Issue 1, Pages 01-11, October-December 2017

An Experimental Study on Strength and Durability of Concrete with Partial Replacement of Coarse Aggregate with Cupola Slag

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Article Received: 03 October 2017 *Article Accepted: 19 October 2017* *Article Published: 27 October 2017*

ABSTRACT

In the present scenario, the emphasis is on the avoidance of waste generation, recycling and reuse of waste, and minimizing the adverse impact of waste disposal on the environment. With increasing capacities, disposal of large quantities of slag becomes a big environmental concern and a critical issue for industries. Aggregates are the main ingredient of concrete occupying approximately 75% of its volume and directly affecting its fresh as well as hardened properties. Cutting and screening out of coarse aggregate makes the conventional concrete more costly and scarce due to small sized limited quantity of natural materials which is used. In the current work is to utilize the Cupola furnace slag as partial replacement to coarse aggregates in the concrete mix and to study the effect on strength and durability properties of concrete.

Keywords: Environment Protection, Mechanical Properties, Cupola Furnace slag, Blast furnace slag and Concrete Production.

1. INTRODUCTION

There are around 6000 Cupola furnaces installed in India. Since the first cupola patent was taken out in England in the late eighteenth century; the furnace has remained the pre-dominant melting unit in iron foundries. Over the two intervening centuries, the basic operations of coke fired cupola have remained relatively unchanged, although the understanding of the process involved has improved considerably. Most of the cupola furnaces are of conventional design which produces a huge amount of slag due to the impurities present in the raw material. The problem of slag disposal is increasing day-by-day due to the decreased availability of free land which is creating a serious problem for the foundry industries.

In the cupola furnace, for every production of 1Ton of molten metal, 50 kg of slag is produced approximately i.e. 5% of the molten metal produced. In general, the cupola operates for the duration of 7-8 hrs/heat producing 20-25T of molten metal/heat depending on the size of cupola furnace. The amount of slag generated is around 1000 - 1200 kg/ heat.

Aggregates are the main ingredient of concrete occupying approximately 75% of its volume and directly affecting the fresh & hardened properties. Concrete being the largest man made material used on earth is continuously requiring good quality of aggregates in large volumes. A need was felt to identify potential alternative source of aggregate to fulfill the future growth aspiration of Indian construction industry. Use of slag as aggregates provides great opportunity to utilize this waste material as an alternative to normally available aggregates. The proper use of waste materials fundamentally affects our economy and environment. Over a period of time, waste management has become one of the most complex and challenging problems in India affecting the environment. The waste byproducts are generated which are environmentally hazard and create problems of storage due to rapid growth of industrialization. The construction industry has always been at forefront in consuming these waste products. The consumption of slag, which is waste generated by foundry industry, in concrete not only helps in reducing greenhouse gases but also helps in making environmental friendly material. Slag is a nonmetallic inert by-product primarily consisting of silicates, alumina silicates, and calcium-alumina-silicates.

2. MATERIALS USED

Cement - Ordinary Portland cement, 53 Grade conforming to IS: 269 – 1976. It will be used for casting all the specimens. The compressive strength measured in standard mortar at 28 days was 54MPa. The physical properties are conforming to IS 12269-1987. The choice of brand and type of cement affects the rate of hydration, so that the strengths at early ages can be considerably influenced by the particular cement used.

Aggregate - Locally available crushed blue granite stones conforming to graded aggregate of nominal size 14 mm-20 mm as per IS: 383 – 1970. The specific gravity was 2.7 and retained on 13.2mm sieve and passing through 16mm.Several investigation concluded that as the aggregate size increase compressive strength of the mix decreases. Bulk density of aggregate is 1737 Kg/m3

Water - Water utilized for blending ought to be compact drinking water having pH values between 6 to 8 and it ought to be free from natural matters and the strong substance ought to be inside as far as possible according to IS 456-2000 and fitting in with IS 3025-1964. In the present test concentrate the water accessible inside the school grounds is utilized for all reasons.

Cupola slag – Cupola slag tends to be dense, solid, vitrified material that varies in color from cream to black, but the predominant colouration would be green to brown. Light coloured slag is sometimes associated with high basicity materials and darker slag with more oxidizing conditions in the furnace.

If the iron content is too high and the lime level too low, the slag converts to Aero-chocolate appearance instead of being solid. Some slags will exhibit light coloured grains in their makeup which are usually refractory particles eroded from the furnace lining. The physical condition of the slag is also influenced by the collection practice followed. Conventional cold blast cupolas are usually operated such that any slag produced is tapped from the furnace either into slag bogeys or into pits in the floor of the foundry. In either case the slag solidifies in relatively large pieces subsequently it may break down into various sized lumps. Alternatively, some large furnaces operate with a wet slag granulation system where the slag exiting the furnace tapping/slagging box is broken up by a water stream. The slag resulting from this type of operation is relatively fine compared with slag pieces produced by conventional slagging practice

Superplasticizers - Superplasticizers, also known as high range water reducers, are chemicals used as admixtures where well-dispersed particulate suspension are required. These are used as dispersants to avoid particle aggregation, and to improve the flow characteristics(rheology) of suspensions such as in concrete applications. Their addition to concrete or mortar allows the reduction of water to cement ratio, not affecting the workability.

3. MIX PROPORTION

Based on ACI 522R-06

Pervious concrete of strength M60pa

Design average cube strength at 28 days

Optimum W/C ratio = 0.29

Density of Concrete = 2500 Kg/m3

Bulk Density of Cement = 504.21 Kg/m3

Bulk Density of coarse aggregate=1108.13 Kg/m3

Cement: Aggregate: Water 1: 1.35: 0.29

Quantities of materials per m3 concrete:

Cement: 476.64 Kg/m3

Coarse aggregate: 577.02 Kg/m3

Water: 138.23 Kg/m3

Superplasitizer:2.86lit

4. EXPERIMENTAL ANALYSIS

A. COMPOSITION

The quality and conduct of cement essentially relies on the materials utilized and its arrangement additionally fluctuates as needs be. Pervious cement was threw for 7, 14, 28 days test with two admixtures of glass fiber and silica seethe as a halfway substitution of concrete and coarse total was mostly supplanted with flotsam and jetsam. Rate of Glass fiber utilized is 1% and 2% as for the volume of cement. Bond was supplanted with 10% of silica smoke. Coarse total was supplanted mostly with 20% with debris.

B. MIX PROPORTION

Cement	Fine Aggregate	Coarse Aggregate	Water
591	705.95	933.88	0.32
1	1.35	2.19	0.29

C. 0% CUPOLA SLAG

For 12 cubes,12 cylinders and 12 Prism

Materials	Cube (Kg)	Cylinder (Kg)	Prism(kg)
Cement	19.61	30.78	29.05
Coarse aggregate	44.47	69.82	65.89
Fine Aggregate	30.25	47.50	44.82
Water	5.69	8.93	8.42
Cupola Slag	0.00	0.00	0.00

D. 10% CUPOLA SLAG

For 12 cubes,12 cylinders and 12 Prism

Materials	Cube (Kg)	Cylinder (Kg)	Prism(kg)
Cement	19.61	30.78	29.05
Coarse aggregate	40.03	37.49	37.89
Fine Aggregate	30.25	47.50	44.82
Water	5.69	8.93	8.42
Cupola Slag	4.45	6.98	6.59

E. 20% CUPOLA SLAG

For 12 cubes,12 cylinders and 12 Prism

Materials	Cube (Kg)	Cylinder (Kg)	Prism (kg)
Cement	19.61	30.78	29.05
Coarse aggregate	35.58	30.51	31.30
Fine Aggregate	30.25	47.50	44.82
Water	5.69	8.93	8.42
Cupola Slag	8.89	13.96	13.18

F. 30% CUPOLA SLAG

For 12 cubes,12 cylinders and 12 Prism

Materials	Cube (Kg)	Cylinder (Kg)	Prism (kg)
Cement	19.61	30.78	29.05
Coarse aggregate	31.13	23.53	24.71
Fine Aggregate	30.25	47.50	44.82
Water	5.69	8.93	8.42
Cupola Slag	13.34	20.95	19.77

G. 40% CUPOLA SLAG

For 12 cubes,12 cylinders and 12 Prism

Materials	Cube (Kg)	Cylinder (Kg)	Prism (kg)
Cement	19.61	30.78	29.05
Coarse aggregate	26.28	16.54	18.12

Fine Aggregate	30.25	44.82	18.46
Water	5.69	8.93	8.42
Cupola Slag	17.79	27.93	26.36

H. 50% CUPOLA SLAG

For 12 cubes,12 cylinders and 12 Prism

Materials	**Cube (Kg)**	**Cylinder (Kg)**	**Prism (kg)**
Cement	19.61	30.78	29.05
Coarse aggregate	22.24	9.56	11.53
Fine Aggregate	30.25	47.50	44.82
Water	5.69	8.93	8.42
Cupola Slag	22.24	34.91	32.94

I. TOTAL QUANTITY OF MATERIAL

For 12 cubes,12 cylinders and 12 Prism

Materials	**Quantity**	**Unit**
Cement	476.64	Kg
Coarse aggregate	577.02	Kg
Fine Aggregate	706.36	kg
Water	138.23	lit
Cupola Slag	270.28	Kg
Admixture (1.4% of cement	2.86	Lit

5. CONCRETE CASTING

Casting **-** The round and hollow form and cubical shape of standard example size is utilized for the throwing reason.

Cube shaped form – 150*300 mm

Cylindrical form – 150*150*150 mm

At first the solid is threw for various test outcomes and the casting depends on routine, in part utilizing silica rage, supplanting flotsam and jetsam with silica smolder, somewhat supplanting totals with garbage of 1% and supplanting trash with 2% along the glass fiber is threw. While throwing legitimate blending and less water substance is utilized as a part of specific.

The casting system is same for the all blend extents and it is important to apply oil before throwing.

Compacting - Normally standard cement requires more compaction where great compaction will bring about great quality angle though in pervious the whole cement is took into account less compaction as over compaction will diminish the porousness of water stream level.

Curing - Curing is took into consideration three diverse days and according to standard curing for 7 days,14 days, and 28 days is permitted according to (ACI).The test results are acquired for nowadays and results demonstrates a significant increment in the quality in 14 and 28 days contrasting with 7 day quality outcome where 28 days curing is recommended for the great quality level.

6. TEST ON HARDENDED CONCRETE

A. COMPRESSIVE STRENGTH TEST

Out of many test applied to the concrete, this is the utmost important which gives an idea about all the characteristics of concrete. By this single test one judge that whether Concreting has been done properly or not. Compressive strength of concrete depends on many factors such as water-cement ratio, cement strength, quality of concrete material, quality control during production of concrete etc. For cube test two types of specimens either cubes of 15 cm X 15 cm X 15 cm or 10cm X 10 cm x 10 cm depending upon the size of aggregate are used. For most of the works cubical moulds of size 15 cm x 15cm x 15 cm are commonly used.

The compressive strength is calculated by using the formula.

$$\text{Compressive strength} = \frac{\textbf{load (P)}}{\textbf{area(A)}}$$

Where,

P - load is in KN

A - Area of cube in mm^2.

B. SPILT TENSILE STRENGTH TEST

The tensile strength of concrete is one of the basic and important properties. Splitting tensile strength test on concrete cylinder is a method to determine the tensile strength of concrete. The concrete is very weak in tension due to its brittle nature and is not expected to resist the direct tension. The tensile strength of the specimen is calculated using the mentioned formula.

$$\text{Split Tensile Strength} = \frac{2P}{\pi DL}$$

Where ,

P = compressive load on the cylinder,

L = Length of the cylinder,

D = Diameter of the cylinder.

C. PERMEABILITY TEST

The permeability test is a measure of the rate of the flow of water through soil. In this test, water is forced by a known constant pressure through a soil specimen of known dimensions and the rate of flow is determined. The coefficient of permeability (k) was determined by Equation:

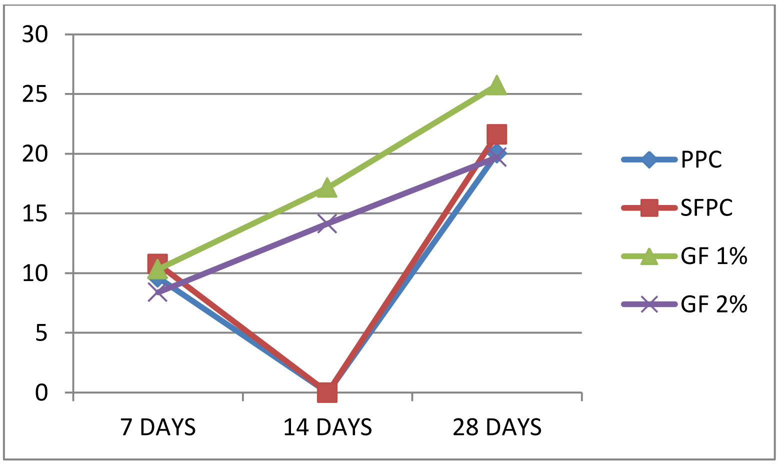
$$k = (aL/At)LN(h1/h2)$$

Where,

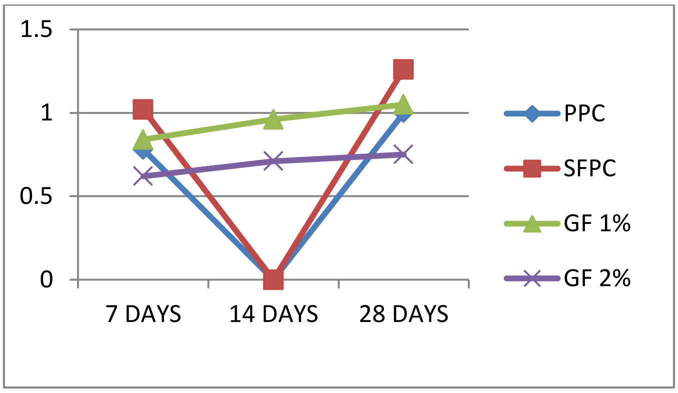
k = coefficient of permeability (mm/min), a = cross sectional area of the standpipe (mm^2), L = length of the specimen (mm), A = cross sectional area of the specimen (mm^2), t = time for water level to reach from h1 to h2 (sec.), h1 = initial water level (mm), h2 = final water level (mm)

7. RESULT ANALYSIS

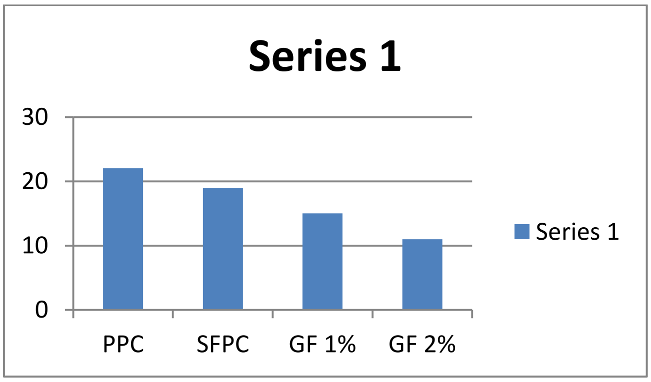
A. COMPRESSIVE STRENGTH



B. SPLIT TENSILE STRENGTH



C. PERMEABILITY TEST ON CYLINDER



8. FUTURE SCOPE

For the future work, the continuation of project research with experimental approach to compare the properties of Conventional concrete and Cupola Slag concrete. Material testing has been carried out for Cement, Fine Aggregate, Coarse Aggregate, Cupola Slag and Water. Strength tests such as compressive strength test, split tensile strength, flexural strength test and durability tests such as Water absorption tests, Sulphate attack test, Chloride test, and Acid attack test has been conducted to find optimum storage of Cupola Slag & effectiveness of concrete by the partial replacement of Coarse Aggregate using Cupola Slag.

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