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EXPERIMENTAL INVESTIGATION ON STRENGTH AND DURABILITY CHARACTERISTICS OF HIGH PERFORMANCE CONCRETE USING GGBS AND MSAND

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ABSTRACT

Cement is the major constituent of concrete which is produced by natural raw materials like limestone rock, clay and chalk etc. These are produced by blasting quarries. Industrial wastes like Ground Granulated Blast Furnace Slag (GGBS) show chemical properties similar to cement. Use of pozzolanic material like GGBS will reduced the cost of concrete and helps to reduce rate of cement consumption. This research explains about strength and durability analysis of GGBS concrete which gives assurance to encourage people working in the construction industry for the beneficial use of it. This research work focuses on strength and durability characteristics of M40 grade concrete with replacement of cement by GGBS with 10%, 20%, 30%, 40% and 50% and replacement of natural sand by Msand with 50% and compares it with conventional concrete. Compressive, split and flexural test were conducted on concrete specimens for strength analysis and for durability studies RCPT, Sorptivity and Acid attack test were conducted. HPC mixes have also indicated better resistance to chloride when tested in RCPT (Permeability Test), Sorptivity and to the attack of chemical such as HCL acid when the HPC mixes were exposed to this acid for 30 days period.

Keywords: ground granulated blast furnace slag, manufactured sand, workability, compression, split tensile, flexural strength, rapid chloride penetration test (RCPT), sorptivity, durability.

INTRODUCTION

Concrete may be defined as a mixture of cement (binding material, aggregates (both coarse and fine), water, which when placed in suitable forms and allowed to cure under appropriate conditions, hardens like stone. It is used as a safe, strong and simple building material around the world. It is used in all types of buildings (from residential to multi-storey office blocks) and in infrastructure projects (roads, bridges, e.t.c). Despite its widespread use, many people around the world aren't aware of the considerations involved in providing high strength, quality and durable concrete. In order to reduce environmental effects pozzolanic materials like Ground Granulated Blast Furnace Slag (GGBS) has been used in the concrete.

LITERATURE REVIEW

M-sand is satisfying the requirements of fine aggregate such as strength, gradation, shape, angularity etc. In 50% replacement it gives maximum strength. Usage of good quality river sand with consistency to manufacture concrete has become increasingly difficult now a day. Depletion of resources has not only made good quality river sand a scarce material but also directs to look for better alternative in order to prevent ecological damage. The concrete using Ggbs will increase the tensile strength and compressive strength with partial replacement of cements about 20%, 30%, and 40% [1]. In 50% replacement with natural sand by manufactured sand increases the compressive strength by 7.5%.[2].It is observed that GGBS-based concretes have achieved an increase in strength for 20%replacement of cement at the age of 28 days. Increasing strength is due to filler effect of GGBS. The degree of workability of concrete was normal with the addition of GGBS up to 40% replacement level for M35 grade concrete [4]. It is proved that GGBS can be used as an alternative material for cement, reducing cement consumption and reducing the cost of construction. Use of industrial waste products saves the environment and conserves natural resources.

EXPERIMENTAL PROGRAM

Ground granulated blast furnace slag of which is a waste product obtained from thermal power plants and ordinary Portland cement according to IS:12269-1987 are been used as binder. River sand according to IS: 383-1970 having specific gravity of 2.54 and fineness modulus of 2.87 was used and Manufactured sand which is obtained by crushing rocks from quarries of uniform size are used as partial replacement of natural sand its specific gravity is 2.58. Crushed angular aggregate of size 12.5 mm and 20 mm were used as coarse aggregate of specific gravity 2.66 and 2.72 respectively. Portable water as per IS: 456-2000 was used. Water cement ratio was taken as 0.40 and admixture dosage is taken as 0.7% based on many trails.

A. Cement

Ordinary Portland cement of grade 53 conforming to IS 1269-1987 was used as binding material. Their physical and chemical properties are mentioned in the table below:

Requirements of IS: 12269-1987			
Physical properties		**Chemical properties**	
Fineness	225	Lime saturated factor	0.8-1.02
Setting time		Alumina Modulus	0.66(min)
Initial (min)	30 min	Insoluble residue %	4(max)
Final (max)	600 min	Magnesia %	6(max)
		Sulphuric anhydride %	3(max)
		Loss on ignition %	4 (max)
		Chloride %	(max)

B. Ground granulated blast furnace slag

GGBS is a latent hydraulic material which can directly react with water, as an alternative material. The chemical properties of the GGBS are tabulated below.

Chemical composition of GGBS	
Component	**GGBS**
SiO_2	33.45
CaO	41.74
$Fe2O_3$	0.31
Al_2O_3	13.46
MgO	5.99
K_2O	0.29
Na_2O	0.16
TiO_2	0.84
P_2O_5	0.12
Mn_2O_3	0.40
SO_3	2.74

C. Fine aggregate

Locally available river sand was used as fine aggregate and sieve analysis was done as per IS: 383-1970 and was categorized as zone-II. Manufactured sand from local quarry was used conforming to zone II.

Sieve sizes	**River sand % passing**	**Msand % passing**
10 mm	100	100
4.75 mm	90-100	90-100
2.36 mm	75-100	70-75
1.18 mm	55-90	45-50
600µ	35-59	35-50
300µ	10-30	10-30
150µ	0-10	0-20

D. Coarse aggregate

Crushed angular aggregate of size 20 mm and 12mm as per IS 383:1970 were used.

E. Super plasticizer

Conplast SP430 super plasticizer got from FORSOC chemicals was used in concrete mix for workability. Based on trial and error, the optimum percentage of super plasticizer was found to be 0.7%.

F. Casting

The materials mentioned were taken in proper proportion for making concrete. The materials were mixed in dry state and water along with admixture were added and mixed thoroughly. Cubes (150x150x150 mm), Cylinders (75x150 mm), prism (100x100x500 mm) were casted for strength characteristics. For durability studies cubes (100x100x100) for Acid attack, Cylinders (100x200) are casted for RCPT and Sorptivity were casted. Specimens were kept under water curing for 28 days and were taken for testing .specimens were prepared as per IS: 516-1999 for cubes and IS: 5816-1999 for cylinders.

Type of mix	Binder (Kg/m^3)		Fine aggregate (kg/m^3)		Coarse aggregate (kg/m^3)		Water (litre)
	Cement	GGBS	River sand	M sand	20 mm	12 mm	
Control mix	420	0	710	0	569	554	189
Mix 1	378	42	355	355	569	554	189
Mix 2	336	84	355	355	569	554	189
Mix 3	294	126	355	355	569	554	189
Mix 4	252	168	355	355	569	554	189
Mix 5	210	210	355	355	569	554	189

Mix 1-10% GGBS and 50% Msand, Mix 2-20% GGBS and 50% Msand, Mix 3- 30% GGBS and 50% Msand, Mix 4-40% GGBS and 50% Msand, Mix 5-50% GGBS and 50% Msand.

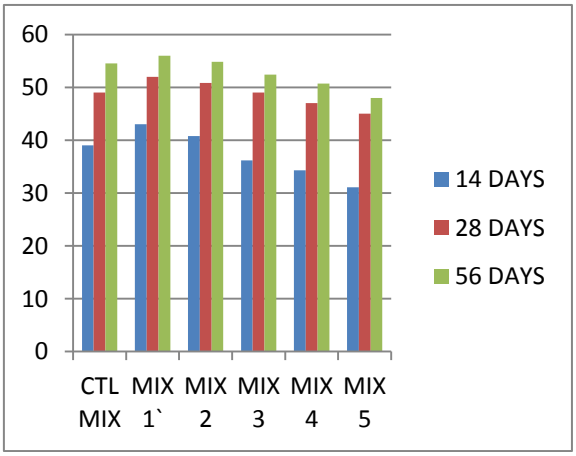
G. Testing

Specimens were taken from curing tank and dried as per IS 516:1959. Specimens were tested for compressive, Split tensile and Flexural strength for strength aspects and for durability studies RCPT, Sorptivity and Acid attack test were conducted. The values were recorded based on 3 trails.

a) Compressive strength

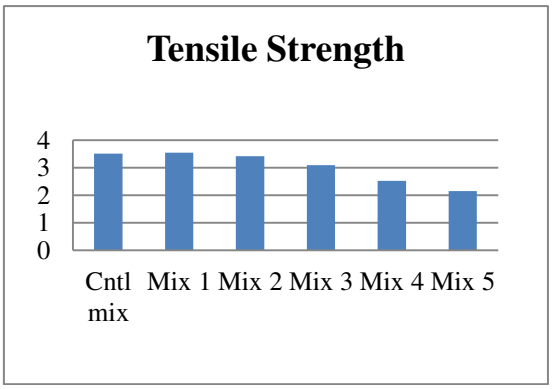
Compressive testing Machine was used for testing cubes. Testing was done for specimens kept for curing of 14, 28 and 56 days.

Type of mix	Compressive strength (N/mm^2)		
	14 days	28 days	56 days
Control mix	39	49	53
Mix 1	43	52	56
Mix 2	40.75	50.8	54.8
Mix 3	36.2	49	52.4
Mix 4	34.28	47	50.7
Mix 5	31.09	45	48



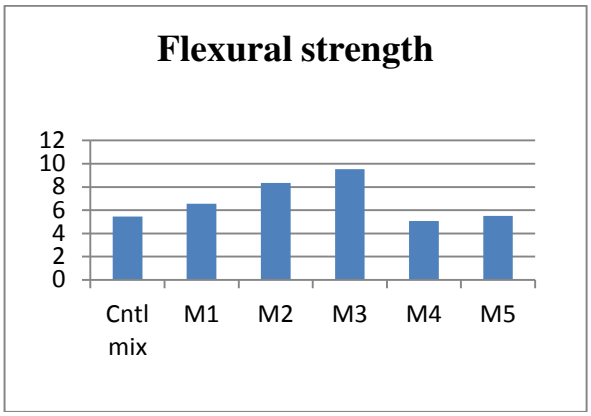
b) Spilt tensile strength

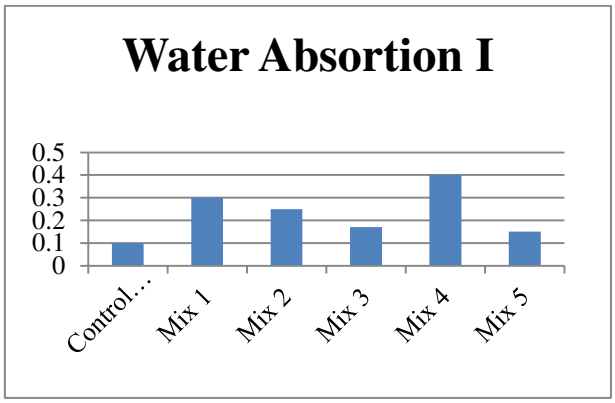
Split tensile strength is the basic property of the concrete. The main aim of this test is to determine the load at which the concrete member may crack. The results of the Split tensile strength at 28 days are showed in form of graphical presentation.



c) Flexural strength

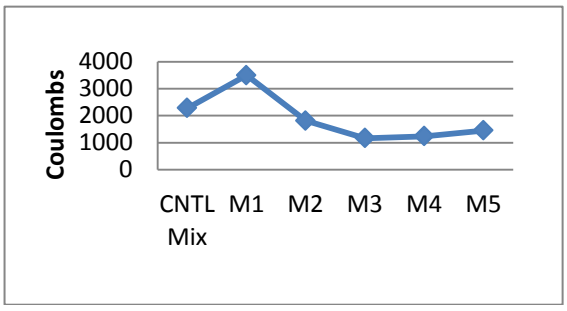
Flexural Strength testing was performed on a universal testing machine which was fully computerized control. The specimens were testing at 28 days subjected to two point loading.





d) Rapid Chloride Penetration Test (RCPT)

Chloride penetrates crack-free concrete by a variety of mechanisms in which of this diffusion is predominant. The chloride penetration causes a serious damage to the reinforcement present in the concrete. The diffusion rate of chloride ions can be found out by RCPT apparatus. RCPT has results that correlate well. Standardized testing procedures conforming to AASHTO T277 or ASTM 1202 are used. The results of rapid chloride permeability test are given below in form of line graph.



e) Sorptivity

Cylinders of Size 100x200 are cut into 3 small cylinder specimen of size 100 mm diameter and 50 mm thickness in accordance with ASTM C 1585-04. Epoxy coating is given around the sides of the specimen and the top portion is also covered. This is to ensure that water enters through the bottom of the specimen. Dry weight of the specimen is noted. The specimen is kept in water in slight immersed condition such as the bottom of the specimen is just 5mm below the water level. The weights of the specimens were measured after 1, 5,10,20,30 and every 30 minutes interval upto 6 hours. The rate of water absorption I is calculated by formula

$I = w_t/axd$

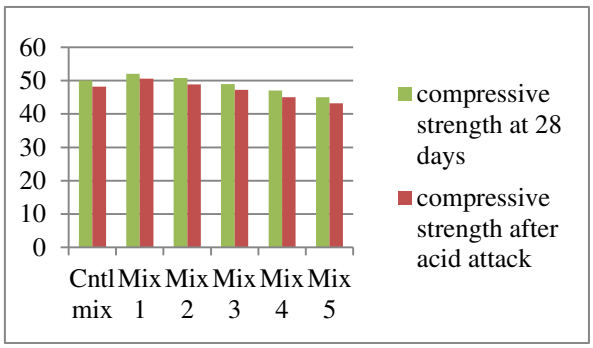
Where w_t = different in weight

a = area of the specimen

d = density of the specimen

f) Acid attack test

For durability performance of HPC in chloride environment after initial curing of 28 days, these specimens are kept immersed in 5% HCL Acid solution for a period of 30 days. The crushing loads were noted and the average compressive strength of the three specimens is determined and results were compared with compressive strength of different mixes at 28 days. The comparative graph after acid attack is given below,



RESULTS AND DISCUSSIONS

a) Based on the compressive strength results, the maximum compressive strength at all ages of testing was obtained at (M1)10% Ggbs and 50% Msand optimum replacement, corresponding to an increase of 10.25%, 6.12% and 5.66% compared to the 14-days, 28-days and 56-days compressive strength of conventional concrete.

b) While comparing the split tensile strength results, HPC mix containing 10% Ggbs and 50% Msand (M1) achieved greater split tensile strength when compared with conventional concrete. High performance concrete mix (M1) has achieved 0.85% higher value than conventional concrete.

c) The flexural strength results have shown that high performance concrete with 30 % Ggbs and 50% Msand (M3) has got highest flexural strength compared with conventional concrete. The percentage increase in flexural strength is 75.36% higher when compared with conventional concrete.

d) Based on results from rcpt graph, it is understood that the chloride diffusion is moderate in M1 (10% Ggbs and 50% Msand) and control mix. The chloride

diffusion is very low in M2, M3, M4, M5 mixes. Thus the chloride is not easily permeable making the Ggbs incorporated concrete to be used in off shore structure.

e) Based on the results, it is understood that the Sorptivity for Control Mix, Mix 1, Mix 2, and Mix 3 are low when compared to Mix 4 and Mix 5. The rate of water absorption is maximum at the bottom of the concrete samples for Mix 4 and Mix 5.

f) It is understood that there is slight decrease in compressive strength of all the mixes after acid curing for 30 days. The M1 mix is enhanced resistance to chloride attack. The compressive strength of concrete incorporating 10% Ggbs and 50% Msand is reduced only by 3.55% as compared with the reduction of strength of control mix specimen by 4.38%.

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