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THE DEVELOPMENT OF HIGH PERFORMANCED CONCRETE WHEN CEMENT & SAND ARE REPLACED BY GGBS AND ROBO SAND IN VARIOUS PROPORTIONS

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ABSTRACT:

Most popular and widely used building material is concrete in the field of construction. It was found suitable than any other materials and hence very important for the constructional developments. The consumption of the concrete is huge and increasing continuously all over the world. The normal concrete may not achieve the properties like uniformity and better performance hence the high performance concrete is becoming the need of time. Improvement in the quality leads to experimentation on the conventional material with addition of other materials. Addressing the problem related to the environment conservation while producing the cement is also the necessary. During the process the carbon dioxide gets produced in huge amount. Authors have concentrated on M35 concrete with part replacement of cement with Ground Granulated Blast furnace Slag (GGBS) and sand with the ROBO sand (crusher dust). The testing is carried out on the cube and cylinder to study the strength. The improvement in the sustainability of concrete by improving cement strength is the motive of the study carried out.

KEYWORDS: High Performance Concrete (HPC), Compressive Strength, Ground Granulated Blast furnace Slag (GGBS), ROBO sand, Tensile Strength.

INTRODUCTION:

High performance concrete conforms to a set of standards above those of the common applications such as high strength, high workability, high elastic modulus, low permeability and high durability. Concrete is generally a mixture of cement, fine and coarse aggregates. In order to minimize the cost of construction and to utilize the waste product from the iron industry beneficially, cement is replaced with Ground Granulated Blast Furnace Slag partially in various proportions. GGBS is a byproduct of the steel industry and is obtained when molten slag is quenched rapidly with the utilization water jets. GGBS is a non - hazardous and non - metallic waste of the iron industry is eco-friendly and helps in improving the strength, workability and durability characteristics of the concrete.

River sand which is one of the basic ingredients the manufacture of concrete has become highly scarce and expensive. Hence, the crusher dust which is also known as Robosand can be used as an alternative material for the river sand. Robosand possess similar properties as that of river sand and hence accepted as a building material. Robosand basically contains angular particles that pass through 4.75 mm sieve and possess rough surface texture. Lot of research has been done regarding the crusher dust as alternative materials for river sand.

CONSITUENTS OF CONCRETE:

2.1 GGBS (GROUND GRANULATED BLAST FURNACE SLAG):

For the strong building the GGBS is utilized with the conventional Portland cement and pozzolanic materials. It gives the better durability and extending lifespan of the building from 50 to 100 years and hence use extensively in Europe, USA and Asia. GGBS is mainly used for the cement production from 30 to 70% contents. It improves the quality of the cement and also gives better strength.

2.2 ROBO SAND:

The ecological solution that gives perfect substitute for the normal sand is robo sand. It has 0to 4.75 mm size. It is useful for the various construction projects. It has better holding abilities. It has more angular particles. The working ability of the concrete is influenced by this sand.

OBJECTIVE:

- To improve the strength of concrete construction.
- To produce the GGBS based concrete.
- To study the properties of concrete by using GGBS and quarry sand.

- To study the properties of concrete.

MATERIALS AND METHODS:

CEMENT:

Ordinary Portland cement of 53 grade conforming to IS 8112-1989 is used. The basic properties of cement showed in table.

FINE AGGREGATE:

Natural river sand of size below 4.75 mm conforming to zone II of IS 383-1970 is used as fine aggregate. The test results of basic properties of fine aggregates are showed in table.

COARSE AGGREGATE:

Natural crushed stone with 20 mm down size is used as coarse aggregate. The basic properties of coarse aggregates are showed in table.

GROUND GRANULATED BLAST FURNACE SLAG:

GGBS was collected from Steel Plant in Visakhapatnam. Below table shows the test results of basic properties of GGBS.

ROBO SAND:

Robo sand is manufactured sand which is eco-friendly solution that serves as perfect substitute for the fast depleting and excessively mined river sand. Robo sand with size 0- 4.75 mm is suitable for all concrete preparations.

WATER:

Ordinary portable water is used in this investigation both for mixing and curing.

SUPER PLASTICIZERS:

Super plasticizers are used to develop the properties of concrete workability. Ceraplast 300 which is available in liquid form and brown in color and which is having a specific gravity of 1.2.

Table 1: Chemical Composition of GGBS

S.No	TESTS	MATERIALS				
		Cement	GGBS	F.A	Robo sand	C.A
1.	Fineness	3 %	2 %	----	----	----
2.	Initial Setting Time	120 minutes	210 minutes	----	----	----
3.	Final Setting Time	260	----	----	----	----
4.	Specific Gravity	3.15	2.86	2.60	2.68	2.65
5.	Crushing Strength	----	----	----	----	11.9
6.	Water Absorption	1.36 %	1.02 %	0.80 %	0.70 %	0.81 %
7.	Bulk Density	1400 kg/m³	1200 kg/m³	1720 kg/m³	1688 kg/m³	1625 kg/m3

Mix Proportions for M 35 Grade Concrete The Quantities of Mix design Proportions is Cement: Fine Aggregate: Coarse Aggregate: Water is **1: 1.99: 3.48: 0.4**.

Table 2: Test Results for Materials of Concrete

MIX IDENTITY	MIX PROPORTIONS							
	Category		Cement (%)	GGBS (%)	Fine Aggregate (%)		Coarse Aggregate (%)	
					Sand	Robosand	10 mm	20 mm
	Mix 1		100	0	100	0	66	34
	Mix 2	Phase 1	100	0	75	25	66	34
		Phase 2	70	30			66	34
		Phase 3	60	40			66	34
		Phase 4	50	50			66	34
		Phase 5	40	60			66	34
	Mix 3	Phase 1	100	0	50	50	66	34
		Phase 2	70	30			66	34
		Phase 3	60	40			66	34
		Phase 4	50	50			66	34
		Phase 5	40	60			66	34
	Mix 4	Phase 1	100	0	25	75	66	34
		Phase 2	70	30			66	34
		Phase 3	60	40			66	34
		Phase 4	50	50			66	34
		Phase 5	40	60			66	34
	Mix 5	Phase 1	100	0	0	100	66	34
		Phase 2	70	30			66	34
		Phase 3	60	40			66	34
		Phase 4	50	50			66	34
		Phase 5	40	60			66	34

Table 3: Various Combinations of Mixes

S.No	Parameter	GGBS in Percentage	As per IS : 12089 – 1987 (Reaffirmed 2008)	
1	Cao	40	----	
2	Al_2O_3	12	----	
3	Fe_2O_3	1.11	----	
4	SiO_2	35	----	
5	Magnesium Oxide (MgO)	8.71	Max 17.00 %	
6	Manganese Oxide (MnO)	0.02	Max 5.5 %	
7	Sulhide Sulphur	0.39	Max 2.0 %	
8	Loss On Ignition	1.41	----	
9	Insoluble Residue	1.59	Max 5 %	
10	Glass Content (%)	92	Min 85 %	
11	$\frac{CaO+MgO+1/3Al2O3}{SiO2+2/3Al2O3}$	1.07	≥ 1.0	The Presence of major Oxides with granulated slag shall satisfy at least one of the equation
	$\frac{CaO+MgO+Al2O3}{SiO2}$	1.60	≥ 1.0	

QUANTITIES:

5.1 For cube size of 150mm X 150 mm X 150 mm is

Volume of cube 0.15 X 0.15 X 0.15 = 0.003375
Cement = 350 X 0.15^3 = 1.181 Kg = 1.82 Kg.
F.A = 698 X 0.15^3 = 2.356 Kg = 2. 36Kg.
C.A = 1218.0 X 0.15^3 = 4.111 Kg = 4.12 Kg.
Water = 140 X 0.15^3 = 0.47 lt

5.2 For cylinder size of 150mm X 300 mm is

Volume of cylinder **$\pi R^2 H$**
Cement = 350 X π $(0.15/2)^2$ X 0.3 = 1.855 Kg = 1.86 Kg.
F.A = 698 X π $(0.15/2)^2$ X 0.3 = 3.704 Kg = 3.71 Kg.
C.A = 1218.0 X π $(0.15/2)^2$ X 0.3 = 6.457 Kg = 6.46 Kg.
Water = 140 X π $(0.15/2)^2$ X 0.3 = 0.742 Kg = 0.75 kg.

5.3 For cube size of 500 mm X 150 mm X 150 mm is

Volume of cube 0.5 X 0.15 X 0.15 = 0.01125 m^3
Cement = 350 X 0.01125 = 3.9375 Kg = 3.94 Kg.
F.A = 698 X 0.01125 = 7.852 Kg = 7.86Kg.
C.A = 1218.0 X 0.01125 = 13.702 Kg = 13.71 Kg.
Water = 140 X 0.01125 = 1.575 lt = 1.56 lt.

Table 4: Various Combinations of Mixes for All Types of Specimens

Moulds	Cement	GGBS	Fine Aggregate		Coarse Aggregate		W/C RATIO (0.4)
			Sand	R.S	10 mm	20 mm	
$(0.15)^3$	75.35	39.31	60.18	88.50	94.31	166.12	29.61
0.15x0.3	77.00	40.18	94.61	139.13	146.51	260.47	47.25
0.15^2x0.5	163.12	85.10	200.43	294.75	310.94	552.79	98.28
Total	**315.47**	**164.59**	**355.22**	**522.38**	**551.76**	**979.37**	**175.14**

TEST RESULTS:

6.1 WORKABILITY:

This section describes the results of the tests carried out to investigate the various properties of the different concrete mixes prepared in contrast with the control mixes. In the succeeding parts, the results for workability, unit weight, compressive strength test, Split tensile strength test, and flexural strength test are presented. Analysis and discussions are also made on the findings.

Table 5: Results of Workability by SLUMP

S.No	MIX IDENTITY (GGBS-Robo Sand Replacement)	SLUMP (mm)
1.	Mix 1 (0-0)	128
2.	Mix 2 (60-0)	120
3.	Mix 3 (60-25)	125
4.	Mix 4 (60-50)	125
5.	Mix 5 (60-75)	115
6.	Mix 6 (60-100)	112

6.2 COMPRESSIVE STRENGTH:

Compression test was carried out on 150 x 150 x 150 mm size cubes. The specimens were loaded at a constant strain rate until failure. The compressive strength is decreased with an increase in the percentage of GGBS and Robo Sand in Cement and Fine aggregate. Results for compressive strength of cubes for 3 days, 7 days and 28 days N/mm^2.

6.3 SPLIT TENSILE STRENGTH:

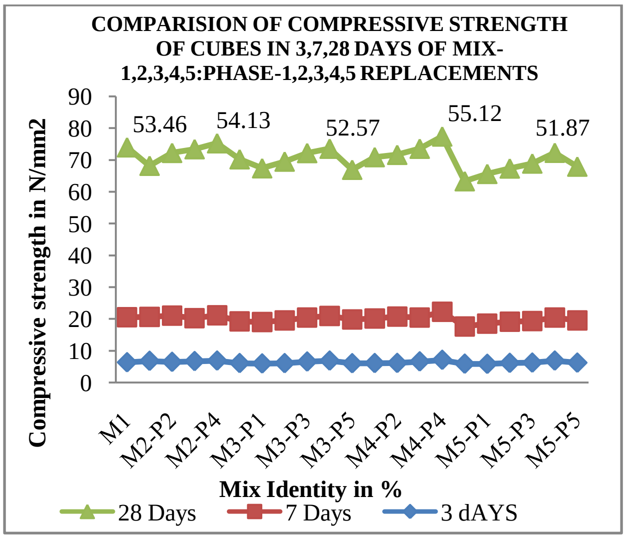
The test method covers the determination of the splitting tensile strength of cylindrical concrete specimens of size 150 mm dia and 300 mm height, such as molded cylinders. This test method consists of applying a diametral compressive force along the length of a cylindrical concrete specimen at a rate that is within a prescribed range until failure occurs.

6.4 FLEXURAL STRENGTH:

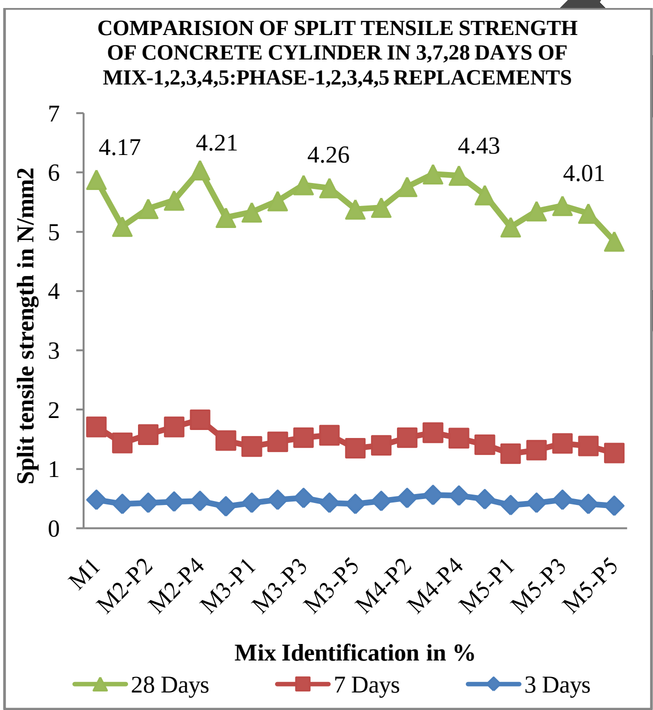
Flexural strength is one measure of the tensile strength of concrete. It is a measure of an unreinforced concrete beam or slab to resist failure in bending. It is measured by loading 6 x 6 – inch (150 x 150 – mm) concrete beams with a span length at least three times the depth. The flexural strength is expressed as modulus of rupture (MR) in psi (MPa) and is determined by standard test method ASTM C 78 (third-point loading) or ASTM C 293 (center point loading).

Table 6: Results of All Strengths of Specimens for 28 Days for Different Mix Identities

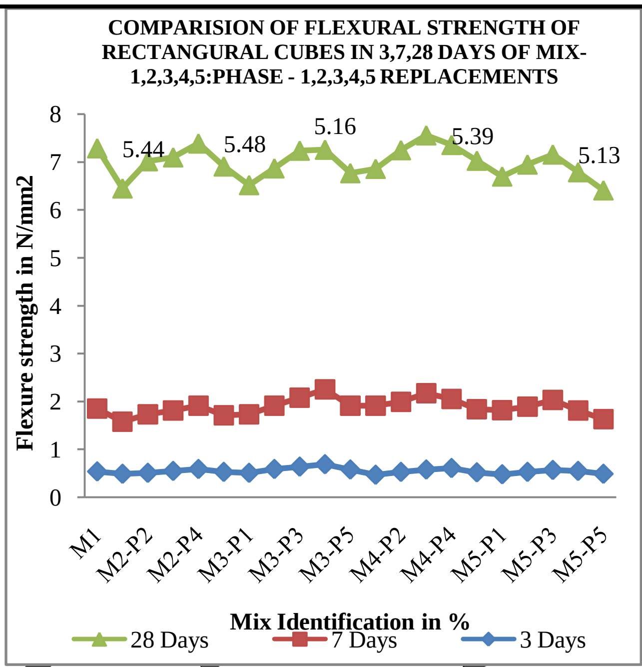
S.No	CATEGORY		STERENGTHS FOR 28 DAYS		
			COMPRESSIVE	SPLIT TENSILE	FLEXURAL
1	Mix 1		53.46	3.96	5.29
2	Mix 2	Phase 1	54.13	4.12	5.87
3		Phase 2	47.53	3.82	5.44
4		Phase 3	51.17	3.32	4.45
5		Phase 4	53.19	3.65	5.20
6		Phase 5	51.01	3.81	5.79
7	Mix 3	Phase 1	51.72	4.06	5.91
8		Phase 2	48.36	3.84	6.09
9		Phase 3	49.97	3.57	4.89
10		Phase 4	52.57	3.72	5.39
11		Phase 5	47.13	4.12	6.12
12	Mix 4	Phase 1	50.83	4.01	6.09
13		Phase 2	50.76	3.92	6.34
14		Phase 3	53.13	3.65	5.44
15		Phase 4	55.12	3.98	5.39
16		Phase 5	45.71	4.21	6.31
17	Mix 5	Phase 1	48.16	3.82	5.92
18		Phase 2	47.09	3.74	5.89
19		Phase 3	49.51	3.67	5.91
20		Phase 4	54.87	3.92	6.32
21		Phase 5	48.07	4.32	6.55



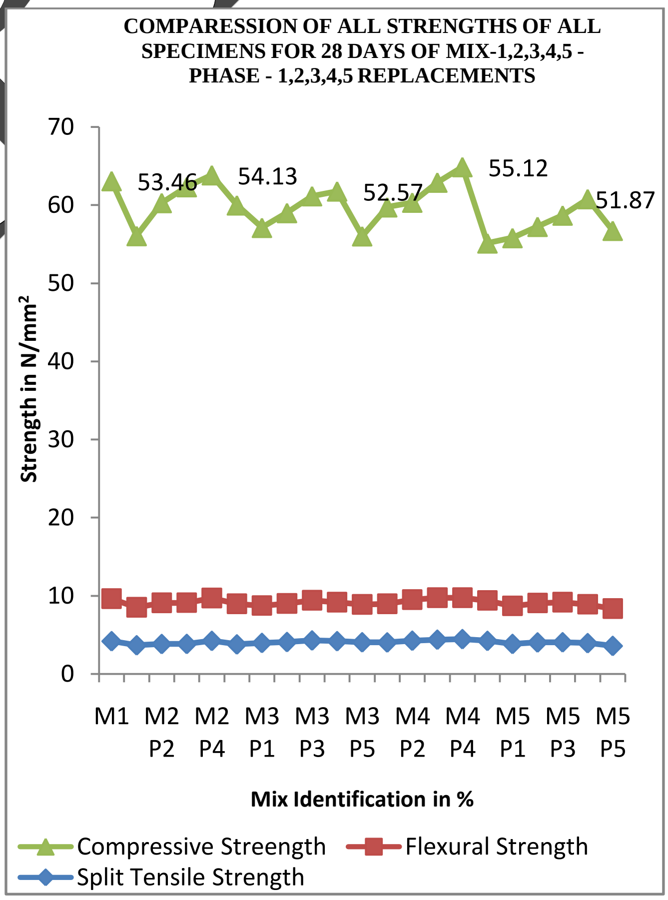
From the above **Graph 1** we observe that compressive strength is increased upto to Phase 4 replacement, but suddenly decreased in Phase 5. So we adopt the replacement of GGBS & ROBO SAND in cement and fine aggregate of sufficient quantity for maintain the strength of the concrete.



From the above **Graph 2** we observe that Split Tensile strength of concrete is increased upto to Phase 2 replacement, then decreased in Phase 3, 4, 5. So we adopt the replacement of GGBS & ROBO SAND in cement and fine aggregate of sufficient quantity for maintain the strength of the concrete.



From the above **Graph 3** we observe that Flexural strength of concrete is decreased due to increase in GGBS and ROBO SAND in concrete. So we adopt the replacement of sufficient quantity for maintain the strength of the concrete.



From the above **Graph 4** we observe that the Strengths of concrete is decreased due to increase in percentage of replacement GGBS and ROBO SAND in concrete. So we adopt the replacement of sufficient quantity for maintain the strength of the concrete.

RESULTS & CONCLUSIONS:

Based on this experimental study, it can be concluded that

- As percentage of Robosand replacing River Sand is increased, the workability of the mix decreases irrespective of percentage of GGBS replacing the cement.
- At constant percentage replacement of River Sand with Robosand, the workability of the concrete does not get effected as percentage GGBS replacing the cement is varied.
- The admixture concrete has shown improvement in workability with GGBS. Hence, observed that mineral admixtures varies the workability and strength upto certain limit. Addition of Robo sand shows improvement in workability and strengths.
- Robosand can replace River Sand 100% without effecting Compressive Strength.
- The optimum percentage of GGBS replacing cement is 50% for getting maximum compressive strength and the maximum Compressive Strength obtained is 55.12 N/mm^2.
- The Split Tensile Strength increases with the increase in percentage of GGBS as well as with the increase in percentage of Robosand and the maximum Tensile Strength obtained is 4.43 N/mm^2.
- The Flexural Strength also increases with the increase in percentage of GGBS as well as with the increase in percentage of Robosand and the maximum Flexural Strength obtained is 5.48 N/mm^2.
- The maximum increase in Compressive Strength, Split Tensile Strength, and Flexural Strength is higher than compared to that of the conventional mix at the age of 28 days.

DISCUSSIONS:

By comparing all the Test values of different strength mainly for 28 Days is

Table 7: Strengths for Different Mix Identities for 28 Days

Strength for 28 Days	Mix Identities					
Compressive Strength	Mix 1	53.46				
Split Tensile Strength		4.17				
Flexural Strength		5.40				
		P 1	P 2	P 3	P 4	P 5
Compressive Strength	Mix 2	47.53	51.17	53.19	**54.13**	51.01
Split Tensile Strength		3.65	3.81	3.82	**4.21**	3.76
Flexural Strength		4.87	5.29	5.29	**5.48**	5.20
Compressive Strength	Mix 3	48.36	49.97	51.72	**52.57**	47.13
Split Tensile Strength		3.95	4.06	**4.26**	4.17	4.03
Flexural Strength		4.79	4.96	**5.16**	5.01	4.86
Compressive Strength	Mix 4	50.76	50.83	53.13	**55.12**	45.71
Split Tensile Strength		4.01	4.23	4.36	**4.43**	4.21
Flexural Strength		4.95	5.26	**5.39**	5.31	5.19
Compressive Strength	Mix 5	47.09	48.16	49.51	**51.87**	48.37
Split Tensile Strength		3.82	**4.03**	4.01	3.92	3.57
Flexural Strength		4.88	5.06	**5.13**	4.98	4.78

From the above results observed that for compressive strength mostly in all the mix identities M2, M3, M4, M5, Phase 4 (50 – 50) is getting higher values, i.e., for the replacement of Cement-GGBS by 50 – 50 percent and Fine Aggregate – Robo Sand by 25-75 percentage.

By considering Split tensile strength of the concrete is equal to 10 % to the compressive strength and at the percentage of replacement of Cement – GGBS and Fine Aggregate – Robo sand, is getting higher values in all mix identities at phase 3 (60-40) and Phase 4 (50 – 50) percentage.

By considering Flexural strength of the concrete is also equal to 10 % to the compressive strength and at the percentage of replacement of Cement – GGBS and Fine Aggregate – Robo sand, is getting higher values in all mix identities at phase 3 (60-40) and Phase 4 (50 – 50) percentage.

Therefore from the above strength values we adopt the percentage of GGBS and Robo Sand replacements in Cement and Fine Aggregate is upto 50 percent of GGBS in Cement and 75 percent of Robo sand in Fine Aggregate is more advisable to use in the construction.

(a)

(b)

(c)

Figure a, b, c : Tests for all type of Concrete Moulds

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