Study and Analysis of Strength of GGBS Concrete

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Abstract- **Concrete is world's most used material after water for urban development. Concrete is made up of naturally occurring material such as Cement, Aggregate and Water. The cement is major ingredient of concrete and due to rapid production of cement, various environmental problems are occurred i.e. Emission of green house gases such as CO2. The production of Portland cement is energy intensive.**

Global warming gas is released when the raw material of cement, limestone and clay is crushed and heated in a furnace at high temperature of about 1500'C. Each year approximately 1.89 billion tons of cement has been produced world wide.

Every one ton of cement produced lead to about 0.9 tons of CO 2 emission and a typical cubic yard of concrete contains about 10% by weight of cement. There have been a number of article/ papers written about reducing the CO2 emission from concrete. Preliminary through the use of lower amount of cement and higher amount of supplementary cementanius material such as GGBS.

The researchers are currently found on use of waste material having cementations properties which can be added in cement concrete as a partial replacement of cement without compromising its strength and durability which result in decreases in cement production thus reduction in emission in green house gases i.e.CO2.The main purpose of this research will solve using minimum quantity of cement and replace balance quantity with other cementanious material. In addition to that the byproduct of industries will be utilized which is harmful to environmental also and management of waste will be easily achieved.

The ground granulated blast furnace slag is a waste product from iron manufacturing industry which may be used as partial replacement of cement in concrete due to its inherent cementanious properties. This paper presents experimental study of compressive and flexural strength of concrete prepared with ordinary Portland cement and PPC partial replaced by GGBS in different proportions varying from 0 % to 100 %. It is observed from investigation that the strength of concrete is inversely proportional to the 40% of replacement of cement with GGBS.

In this research effect of partial replacement of cement with GGBS on strength development of concrete and cured under summer and winter curing environments is established. Three levels of cement substitution i.e., 0% to 100% have been selected. Early-age strength of GGBS concrete is lower than the normal PC concrete which limits its use in the fast-track construction and post-tensioned beams which are subjected to high early loads. The strength gain under winter curing condition was observed as slower. By keeping the water cement ratio low as 0.35, concrete containing GGBS up to 100% can achieve high early-age strength. GGBS concrete gains more strength than the PC concrete after the age of 28 day till 90 day. The mechanical properties of blended concrete for various levels of cement replacement have been observed as higher than control concrete mix having no GGBS.

Cement is major constituent material of the concrete which produced by natural raw material like lime and silica. Once situation may occurs there will be no lime on earth for production of cement. This situation leads to think all people working in construction industry to do research work on cement replacing material and use of it. Industrial wastes like Ground Granulated Blast Furnace Slag (GGBS) show chemical properties similar to cement. Use of GGBS as cement replacement will simultaneously reduces cost of concrete and help to reduce rate of cement consumption. This study report of strength analysis of GGBS concrete will give assurance to encourage people working in the construction industry for the beneficial use of it.

Index terms- **Embodied, Slag, Partial Replacement, Compressive Strength, Curing, Modulus of Elasticity, Flexural Strength**

I.INTRODUCTION

The various construction activities performs at site and require several material such as concrete ,steel, bricks, stones, glass, clay, mud, wood, admixtures etc However the cement concrete remains the main construction material used in construction industries.

For its suitability and adoptability with respect to the changing environment economize and lead to proper utilization of energy. To achieve this major emphasis must be laid on the use of wastes and byproduct in cement and concrete used for new constructions.

The future global challenge for the construction industry is clearly to meet the worlds growing needs while at the same time limiting the impact of its burdens by drastic improvement activities.

Due to exponential growth of urbanization and industrialization byproduct from industries are becoming an increasing concern for recycling and waste management. Ground Granulated Blast Furnance slag (GGBS) is a byproduct from iron and steel industries. GGBS is very useful in the design and development of high quality cement paste/mortar and concrete. GGBS is a byproduct from the blast furnaces used to make iron or steel. Blast furnaces are fed with controlled mixture of Iron Ore, Coke and limestone and operated at a temperature of about 1500’ C.

When iron-Ore, coke and limestone melt in the blast furnace, two product are produced 1) The molten iron and 2) molten slag. The molten slag is lighter and floats on the top of the molten iron. The molten slag comprises of mostly silicates and alumina from the original iron Ore, combined with some oxides from limestone. The process of granulating the slag involves cooling of molten slag through high pressure water jet. This rapidly quenches the slag and forms granular particles generally not bigger than 5 mm. The rapid cooling prevents the formation of larger crystals and the resulting granular material compromise around 95 % non crystalline calcium-alumina silicates.

The granulated slag is further processed by drying and then grinding in a vertical roller mill or rotating ball mill to a very fine powder which is GGBS.GGBS reacts like a Portland cement when in contact with water. Bulk GGBS is stored and handled in conditions identical to that of Portland cement. Bulks storage is in watertight silos and Transportation is by bulk tankers as for Portland cement. GGBS can also be moved by air slider cement screws and bucket elevators. Dust control is the same as that required for Portland cement. GGBS dust does not prevent any fire or explosion hazards

METHODOLOGY

The study includes to analyses the strength properties of GGBS concrete in which cement is partly replace by GGBS. The tests of concrete carried out as per IS code. For successful investigation various tests are conduct on various proportions of GGBS and other ingradient. The tests are performs on normal concrete and GGBS Concrete with proportions of 20%, to 100 % cement replacement. The comparative report prepared before arriving at final conclusion of plain concrete and GGBS concrete with crush sand and natural sand.

The following methodology is adopted for this proposed work.

1. Collection of various journals papers presented and to get idea of research work conducted on proposed subject work.
2. To find the properties of the materials such as cement, sand, coarse aggregate, water and GGBS.
3. To obtain Mix proportions of OPC concrete for M20 by IS method (10262-2009).
4. To calculate the mix proportion with partial replacement such as 0%, 100% of GGBS with OPC.
5. To prepare the concrete specimens such as cubes for compressive strength, cylinders for split tensile test, prisms for flexural strength and also cubes for durability studies in laboratory with 0% to 100% replacement of GGBS with OPC for M20 grade concrete.
6. To cure the specimens for 28 days and 90 days.
7. To evaluate the mechanical characteristics of concrete such as compressive strength, split tensile test, flexural strength.
8. To evaluate the durability studies of M20 grade GGBS replacement concrete, with 1% and 5% concentrations of Hydro chloric acid (HCl) and Sulphuric acid (H2So4).
9. To evaluate and compare the results.
10. To check the economic viability of the usage of GGBS, Keeping in view of the safety measures.

II. PROPERTIES OF INGREDIENTS

3.1 Cement

The cements used in this experimental works are ordinary Portland cement. All properties of cement are tested by referring IS Specification for Ordinary

Portland cement. Test results are presented in Table 1.

Table 1. Physical Properties of Cement (Confirming to IS 12269 – 1987)

Sr. No.	Description of Test	Results
01	Fineness of cement	1 %
02	Specific gravity	3.15
03	Standard consistency of cement	30 %
04	Setting time of cement Initial setting time Final setting time	135 minute 288 minute

3.2 GGBS

The chemical composition of blast furnace slag consist essentially of silicates and alumino silicates of calcium. Portland cement is good catalyst for activation of slag because it contains the three main chemical components that activate slag ,lime ,calcium sulphate and alkalies.

The material has a glassy structure and is ground to less than 45 microns. The surface area is about 350 to 450 m2/Kg blaine. The ground slag is presence of water and activators which are commonly sulphates and / or alkalies that are supplied by ordinary Portland cement, react chemically with GGBS and hydrates and sets in manner similar to Portland cement.

Table 2. Chemical composition of GGBS

Sr No	Chemical formula	Percentage
1	Cao	30-45 %
2	SiO2	17-38%
3	Al2O3	15-25%
4	Fe2O3	0.5-2.0%
5	MgO	4.0 - 17%
6	MnO2	1-5 %
7	Glass	85-98%

Table 3. Physical Properties of GGBS

Characteristics Requirement	Requirement	Result
Fineness(M2/Kg)	275 (min)	400
Soundness Le-Chatelier Expansion (mm)	10.0 (max)	Nil
Initial Setting Time(min)	Not less than OPC Min. 30	Minutes 220
Compressive strength (N/mm2) After 7 days After 28 days	12.0 (min) 32.5(min)	34 53

3.3Water

Potable water available in laboratory is used for mixing and curing of concrete.

3.4 Tests on Aggregates

Natural sand from river confirming to IS 383- 1970 is used. Various tests such as specific gravity, water absorption, impact strength, crushing strength, sieve analysis etc. have been conducted on CA and FA to know their quality and grading. The above said test results are shown in Tables 3.2 to 3.4. Crushed black trap basalt rock of aggregate size 20mm down was used confirming to IS 383-1970.

Table 3.3: Physical Properties of Fine Aggregate (sand)

Sr. No	Property	Results
1.	Particle Shape, Size	Round, 4.75mm down
2.	Fineness Modulus	3.42
3.	Silt Content	1.67%
4.	Specific Gravity	2.6
5.	Bulking of Sand	4.16%
6.	Bulk Density	1793 Kg/m^3
7.	Surface Moisture	Nil

Table 3.4 Sieve Analysis for Course Aggregate

Sr. No	Property	Results
1.	Particle Shape, Size	Angular, 20mm.
2.	Fineness Modulus of 20mm aggregates	6.87
3.	Specific Gravity	2.9
4.	Water Absorption	0.55%
5.	Bulk density of 20mm aggregates	1603 Kg/ mm^3
6	Surface Moisture	Nil

3.1 Mix Design for M20 Grade Concrete

Then the mix proportion becomes 10262:1985-

Sr No	Cement	F.A.	C.A.	water
1	383.2	553.98	1313	191.6
2	1	1.45	3.42	0.5

III. TESTING OF SPECIMENS

Compressive strength of cubes are determined at 28 days using compression testing machine (CTM) of capacity 2000 KN. Flexural testing setup of UTM machine of capacity 40 tones was used to determine the flexural strength of beams.

4.1 Compressive Strength Test on Cube

A cube compression test was performed on standard cubes of plain and GGBS of size 150mm 150 mm at

28 days of immersion in water for curing. Results are shown in Table and graphical presentation between compressive strength and percentage GGBS volume fraction is shown.

The compressive strength of specimen was calculated by the following formula:

Fc =Pc / A

Where,

Pc = Failure load in compression, kN A = Loaded area of cube, mm2

4.2 Flexural Test on Plain Concrete and GGBS

Standard beams of size 100 x 100 x 500 mm were supported symmetrically over a span of 400 mm subjected central point's loading till failure of the specimen.

Experimental flexural strength:

Maximum experimental flexural strength of the beam specimen was computed by the following equation from theory of strength of materials. The flexural strength of concrete beam specimen was calculated as:

Fb= 3P x a/bd2 if a<20 Where,

Fb=flexural stress in MPa,

b =measured width in cm of the specimen ,d=depth in mm of the specimen.

l=length in mm of the span on which the specimen was supported and

p=maximum load in kg applied to the specimen.

4.3 Split Tensile Test on Cylinder

Cylinders of size 150mm diameter of height 300 mm were tested in CTM and calculate the split tensile strength 7 days and 28 days curing.

$T = 2P/\pi DL$

4.4 Durability Studies with H2SO4 and HCl

Concrete cubes of 150 x 150 x 150 mm3 size were cast for durability studies for grades M20 of concrete. 1% H2SO4, 1% HCl concentration for 90 days curing and 5% H2SO4, 5% HCl concentration for 28 days curing were considered for durability studies. Each grade consists of 0%, to 100% and hence each grade contains 120 cubes placed in individual tubs for each concentration. The normality of the solution was checked for every 2 days. The Compressive strength of cubes exposed to H2SO4 and HCl are tested for compressive strength.

IV. ANALYSIS OF STRENGTH CHARACTERISTICS

This chapter gives us information of strength performance analysis of GGBS concrete which is obtained from experimental setup.

5.1 Compressive Strength of GGBS Concrete

The compressive strength performance of M20 GGBS concrete is studied for different percentage of GGBS to compare with normal plain cement concrete. Study contains comparison between compressive strength of GGBS concrete with changing type of cement as PPC and OPC. Also compare the compressive strength of GGBS concrete with natural sand and crush sand. The main objective of the study is to find best proportion of replacement of cement, for which concrete shows best performance characteristics. To full proof of the results also study the compressive strength analysis for M-20 grade GGBS concrete with same percentage of replacement.

Table 5.1 Compressive strength of M20 concrete over different percentage GGBS for 7 days using cement as PPC & Natural sand

Sr. no.	% of the GGBS	Compressive strength of GGBS concrete in N/mm^2	Compressive strength of P.C.C. N/mm^2	Percentage increased in compressive strength
1	20	17.95	17.64	1.76
2	30	17.71		0.40
3	40	20		13.38
4	50	16.1		-8.73
5	60	16.03		-9.13
6	70	15.81		-10.37
7	80	15.33		-13.10
8	90	15.21		-13.78
9	100	14.86		-15.76

Table 5.2 Compressive strength of M20 concrete over different percentage GGBS for 28 days using cement as PPC & Natural sand

Sr. no.	% of the GGBS	Compressive strength of GGBS concrete in N/mm^2	Compressive strength of P.C.C. N/mm^2	Percentage increased in compressive strength
1	20	28.16	26.97	4.41
2	30	27.10		0.48
3	40	29.33		8.75
4	50	24.78		-8.12
5	60	24.70		-8.42

6	70	24.34		-9.75
7	80	24.10		-10.64
8	90	23.9		-11.38
9	100	23.30		-13.61

Table 5.3 Compressive strength of M20concrete over different percentage GGBS for 7 days using cement as OPC & Natural sand

Sr. no.	% of the GGBS	Compressive strength of GGBS concrete in N/mm2	Compressive strength of P.C.C. N/mm2	Percentage increased in compressive strength
1	20	20.51	18.91	8.46
2	30	19.52		3.23
3	40	20.20		6.82
4	50	18.56		-1.85
5	60	17.40		-7.99
6	70	17.25		-8.78
7	80	17.12		-9.47
8	90	16.88		-10.74

Table 5.4 Compressive strength of M20 concrete over different percentage GGBS for 28 days using cement as OPC & Natural sand

Sr. no.	% of the GGBS	Compressive strength of GGBS concrete in N/mm^2	Compressive strength of P.C.C. N/mm^2	Percentage increased in compressive strength
1	20	31.10	29.11	6.84
2	30	31.30		7.52
3	40	32.25		10.79
4	50	28.72		-1.34
5	60	27.70		-4.84
6	70	27.58		-5.26
7	80	27.46		-5.67
8	90	27.10		-6.90
9	100	26.90		-7.59

Table 5.5 Compressive strength of M20concrete over different percentage GGBS for 7 days using cement as OPC & Crush sand

Sr. no.	% of the GGBS	Compressive strength of GGBS concrete in N/mm^2	Compressive strength of P.C.C. N/mm^2	Percentage increased in compressive strength
1	20	18.17	16.65	9.13
2	30	19.15		15.02
3	40	16.91		1.56
4	50	16.01		-3.84
5	60	15.96		-4.14
6	70	15.8		-5.11
7	80	15.66		-5.95
8	90	15.51		-6.85
9	100	15.3		-8.11

Table 5.6 Compressive strength of concrete over different percentage GGBS for 28 days using cement as OPC & Crush sand

Sr. no.	% of the GGBS	Compressive strength of GGBS concrete in N/mm^2	Compressive strength of P.C.C. N/mm^2	Percentage increased in compressive strength
1	20	27.11	25.61	5.86
2	30	29.78		16.28
3	40	26.37		2.97
4	50	25.3		-1.21
5	60	25.1		-1.99
6	70	24.98		-2.46
7	80	24.56		-4.10
8	90	24.3		-5.12
9	100	24.1		-5.90

Table 5.7 Compressive strength of M20concrete over different percentage GGBS for 7 days using cement as OPC & Natural sand

Sr. no.	% of the GGBS	Compressive strength of GGBS concrete in N/mm^2	Compressive strength of P.C.C. N/mm^2	Percentage increased in compressive strength
1	20	24.51	22.97	6.70
2	30	25.77		12.19
3	40	23.9		4.05
4	50	22.5		-2.05
5	60	22.35		-2.70
6	70	22.1		-3.79
7	80	22		-4.22
8	90	21.96		-4.40
9	100	21.65		-5.75

Table 5.8 Compressive strength of M20 concrete over different percentage GGBS for 28 days using cement as OPC & Natural sand

Sr. no.	% of the GGBS	Compressive strength of GGBS concrete in N/mm^2	Compressive strength of P.C.C. N/mm^2	Percentage increased in compressive strength
1	20	37.71	35.70	5.63
2	30	40.69		13.98
3	40	36.77		3.00
4	50	35.6		-0.28
5	60	35.3		-1.12
6	70	35.1		-1.68
7	80	34.96		-2.07
8	90	34.68		-2.86

9	100	34.48		-3.42

Figure no. 5.1- Compressive strength of GGBS concrete with PPC cement and OPC cement for M20 grade in natural sand for 7 days

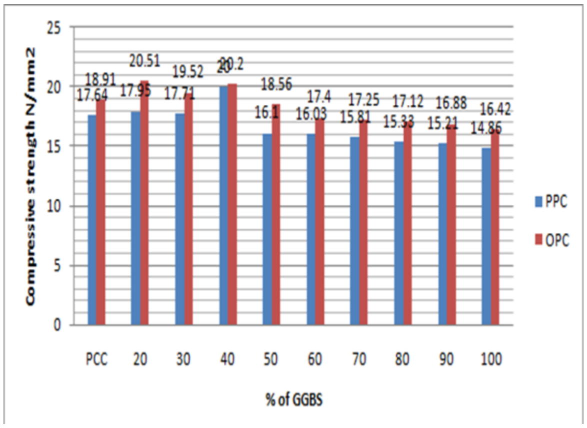


Figure no. 5.2- Compressive strength of GGBS concrete with PPC cement and OPC cement for M20 grade in natural sand for 28 days

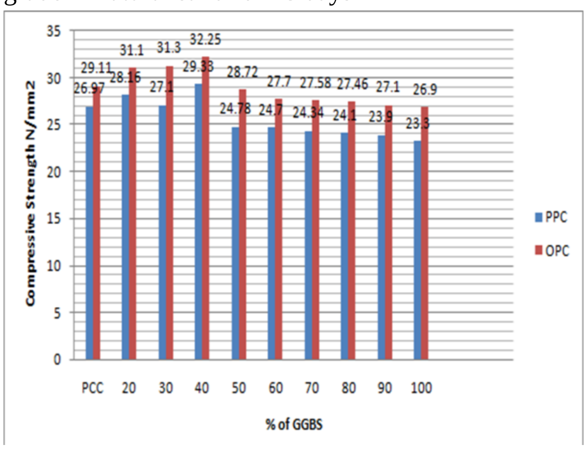


Figure no. 5.3- Compressive strength of GGBS concrete with PPC cement and OPC cement for M20 grade in Crush sand for 7 days

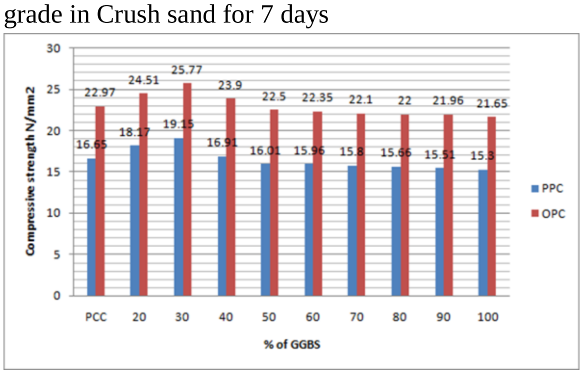
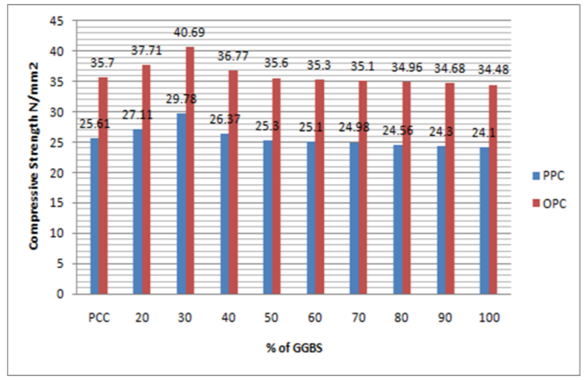


Figure no. 5.4- Compressive strength of GGBS concrete with PPC cement and OPC cement for M20 grade in Crush sand for 28 days



5.2Split Tensile Strength of GGBS Concrete

The split tensile strength performance of GGBS concrete is studied for different percentage of GGBS. The split tensile strength of plain cement concrete is found to be maximum tensile strength of GGBS concrete for 40 % replacement for different nature of ingredients. This data is plotted graphically in figure.5.5 to 5.8 which shows that there is increase in split tensile strength up to 40% of GGBS content thereafter it decreases.

Table 5.9 Split tensile strength of M20 concrete over different percentage GGBS for 7 days using cement as PPC & Natural sand

Sr. no.	% of the GGBS	Split Tensile strength of GGBS concrete in N/mm^2	Split Tensile strength of P.C.C. N/mm^2	Percentage increased in Split Tensile strength
1	20	2.15		4.88
2	30	2.27		10.73
3	40	2.31		12.68
4	50	2.09		1.95
5	60	2.01	2.05	-1.95
6	70	1.99		-2.93
7	80	1.81		-11.71
8	90	1.73		-15.61
9	100	1.65		-19.51

Table 5.10 Split tensile strength of M20 concrete over different percentage GGBS for 28 days using cement as PPC & Natural sand

Sr. no.	% of the GGBS	Split Tensile strength of GGBS concrete in N/mm^2	Split Tensile strength of P.C.C. N/mm^2	Percentage increased in Split Tensile strength
1	20	3.15		8.25
2	30	3.19		9.62
3	40	3.37	2.91	15.81
4	50	3.07		5.50
5	60	2.85		-2.06
6	70	2.74		-5.84
7	80	2.66		-8.59
8	90	2.5		-14.09
9	100	2.41		-17.18

Table 5.12 Split tensile strength of M20 concrete over different percentage GGBS for 28 days using cement as OPC & Natural sand

Sr. no.	% of the GGBS	Split Tensile strength of GGBS concrete in N/mm^2	Split Tensile strength of P.C.C. N/mm^2	Percentage increased in Split Tensile strength
1	20	3.63	3.09	17.48
2	30	3.47		12.30
3	40	3.77		22.01
4	50	3.32		7.44
5	60	3.05		-1.29
6	70	2.95		-4.53
7	80	2.85		-7.77
8	90	2.74		-11.33
9	100	2.65		-14.24

Table 5.13 Split tensile strength of M20concrete over different percentage GGBS for 7 days using cement as OPC & Crush sa

Table 5.14 Split tensile strength of concrete over different percentage GGBS for 28 days using cement as OPC & Crush sand

Sr. no.	% of the GGBS	Split Tensile strength of GGBS concrete in N/mm^2	Split Tensile strength of P.C.C. N/mm^2	Percentage increased in Split Tensile strength
1	20	3.35	3.10	8.06
2	30	3.33		7.42
3	40	3. 51		13.22
4	50	3.09		-0.32
5	60	2.95		-4.84
6	70	2.86		-7.74
7	80	2.71		-12.58
8	90	2.45		-20.97
9	100	2.10		-32.26

Table 5.15 Split tensile strength of M20concrete over different percentage GGBS for 7 days using cement as OPC & Natural sand

Sr. no.	% of the GGBS	Split Tensile strength of GGBS concrete in N/mm^2	Split Tensile strength of P.C.C. N/mm^2	Percentage increased in Split Tensile strength
1	20	2.62	2.56	2.34
2	30	2.73		6.64
3	40	2.79		8.98
4	50	2.63		2.73
5	60	2.50		-2.34
6	70	2.45		-4.30
7	80	2.30		-10.16
8	90	2.10		-17.97
9	100	1.85		-27.73

Figure no. 5.5 Split Tensile strength of GGBS concrete with PPC cement and OPC cement for M20 grade for Natural Sand 7 days

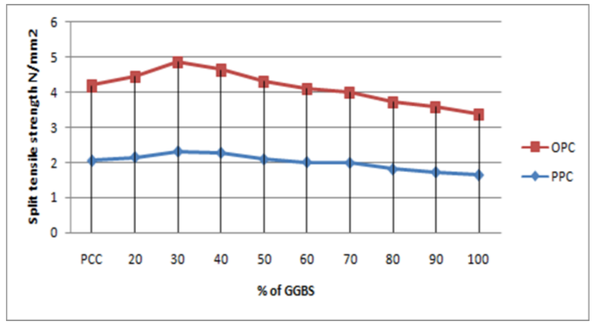


Figure no. 5.6 Split Tensile strength of GGBS concrete with PPC cement and OPC cement for M20 grade for Natural Sand 28 days

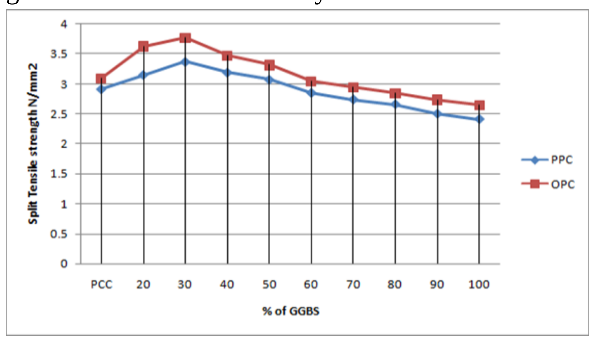


Figure no. 5.7 Split Tensile strength of GGBS concrete with PPC cement and OPC cement for M20 grade for Crushed Sand 7 days

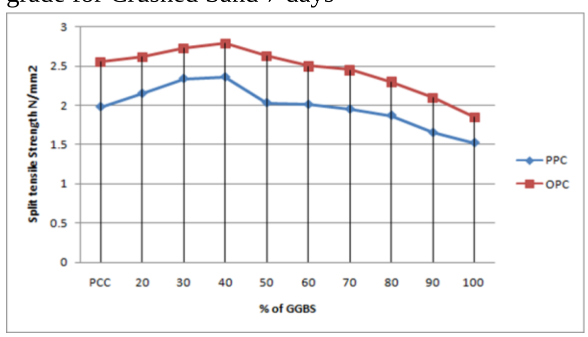
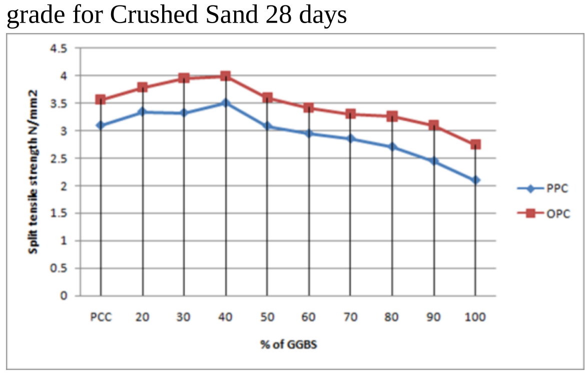


Figure no. 5.8 Split Tensile strength of GGBS concrete with PPC cement and OPC cement for M20 grade for Crushed Sand 28 days



5.3 Flexural Strength of GGBS Concrete

The flexural strength performance of GGBS concrete is studied for different percentage of GGBS by using central point load test on beams. The flexural strength of plain cement concrete is found to be maximum strength of GGBS concrete for 40 % replacement for different nature of ingredients. This data is plotted graphically which shows that there is increase in split tensile strength up to 40% of GGBS content thereafter it decreases.

Table 5.17 Flexural strength of M20 concrete over different percentage GGBS for 7 days using cement as PPC & Natural sand

Sr. no.	% of the GGBS	Flexural strength of GGBS concrete in N/mm^2	Flexural strength of P.C.C. N/mm^2	Percentage increased in Flexural strength
1	20	2.46	2.17	13.36
2	30	2.50		15.21
3	40	2.52		16.13
4	50	2.33		7.37
5	60	2.15		-0.92
6	70	2.13		-1.84
7	80	2.03		-6.45
8	90	2.01		-7.37
9	100	1.95		-10.14

Table 5.18 Flexural strength of M20 concrete over different percentage GGBS for 28 days using cement as PPC & Natural sand

Sr. no.	% of the GGBS	Flexural strength of GGBS concrete in N/mm^2	Flexural strength of P.C.C. N/mm^2	Percentage increased in Flexural strength
1	20	3.53	3.06	15.36
2	30	3.59		17.32
3	40	3.68		20.26
4	50	3.39		10.78
5	60	3.15		2.94
6	70	3.10		1.31
7	80	3.04		-0.65
8	90	2.96		-3.27
9	100	2.89		-5.56

Table 5.19 Flexural strength of M20concrete over different percentage GGBS for 7 days using cement as OPC & Natural sand

Sr. no.	% of the GGBS	Flexural strength of GGBS concrete in N/mm^2	Flexural strength of P.C.C. N/mm^2	Percentage increased in Flexural strength
1	20	2.54	2.23	13.90
2	30	2.65		18.83
3	40	2.77		24.22
4	50	2.29		2.69
5	60	2.15		-3.59
6	70	2.08		-6.73
7	80	2.00		-10.31
8	90	1.93		-13.45
9	100	1.88		-15.70

Table5.20 Flexural strength of M20 concrete over different percentage GGBS for 28 days using cement as OPC & Natural sand

Sr. no.	% of the GGBS	Flexural strength of GGBS concrete in N/mm^2	Flexural strength of P.C.C. N/mm^2	Percentage increased in Flexural strength
1	20	3.62	3.18	13.84
2	30	3.77		18.55
3	40	3.85		21.07
4	50	3.42		7.55
5	60	3.16		-0.63
6	70	3.09		-2.83
7	80	3.00		-5.66
8	90	2.95		-7.23
9	100	2.86		-10.06

Table 5.21 Flexural strength of M20concrete over different percentage GGBS for 7 days using cement as OPC & Crush sand

Sr. no.	% of the GGBS	Flexural strength of GGBS concrete in N/mm^2	Flexural strength of P.C.C. N/mm^2	Percentage increased in Flexural strength
1	20	2.41	2.14	12.62
2	30	2.48		15.89
3	40	2.53		18.22
4	50	2.17		1.40
5	60	2.10		-1.87
6	70	2.06		-3.74
7	80	1.98		-7.48
8	90	1.92		-10.28
9	100	1.87		-12.62

Table 5.22 Flexural strength of concrete over different percentage GGBS for 28 days using cement as OPC & Crush sand

Sr. no.	% of the GGBS	Flexural strength of GGBS concrete in N/mm^2	Flexural strength of P.C.C. N/mm^2	Percentage of increased in Flexural strength
1	20	3.45	3.02	14.24
2	30	3.48		15.23
3	40	3.51		16.23
4	50	3.12		3.31
5	60	2.98		-1.32
6	70	2.92		-3.31
7	80	2.86		-5.30
8	90	2.77		-8.28
9	100	2.75		-8.94

Table 5.23 Flexural strength of M20concrete over different percentage GGBS for 7 days using cement as OPC & Natural sand

Sr. no.	% of the GGBS	Flexural strength of GGBS concrete in N/mm^2	Flexural strength of P.C.C. N/mm^2	Percentage of increased in Flexural strength
1	20	2.69	2.67	0.75
2	30	2.76		3.37
3	40	2.88		7.87
4	50	2.65		-0.75
5	60	2.60		-2.62
6	70	2.56		-4.12
7	80	2.51		-5.99
8	90	2.44		-8.61
9	100	2.39		-10.49

Table 5.24 Flexural strength of M20 concrete over different percentage GGBS for 28 days using cement as OPC & Natural sand

Sr. no.	% of the GGBS	Flexural strength of GGBS concrete in N/mm^2	Flexural strength of P.C.C. N/mm^2	Percentage of increased in Flexural strength
1	20	3.92	3.87	1.29
2	30	4.01		3.62
3	40	4.11		6.20
4	50	3.9		0.78
5	60	3.80		-1.81
6	70	3.72		-3.88
7	80	3.68		-4.91
8	90	3.65		-5.68
9	100	3.62		-6.46

Figure no. 5.9 Flexural strength of GGBS concrete with OPC cement and PPC cement for M20 grade for natural sand in 7 days

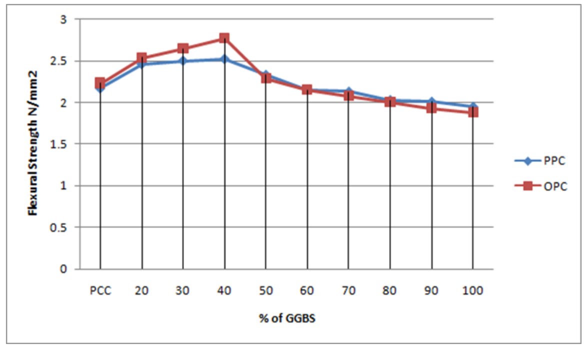


Figure no. 5.10 Flexural strength of GGBS concrete with OPC cement and PPC cement for M20 grade for natural sand in 28 days

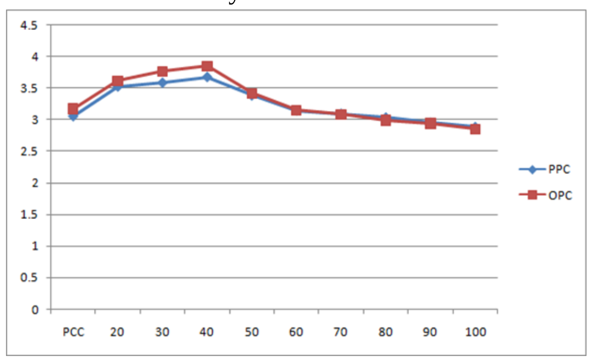


Figure no. 5.11 Flexural strength of GGBS concrete with OPC cement and PPC cement for M20 grade for Crush sand in 7 days

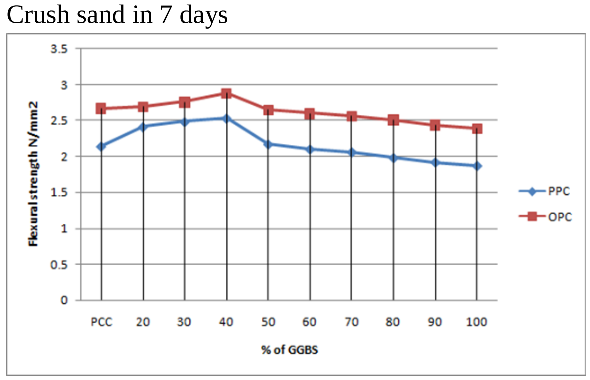
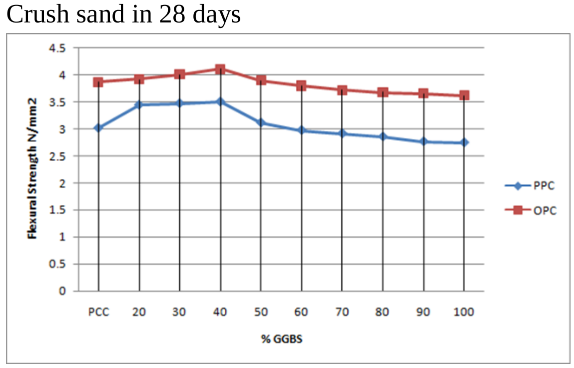


Figure no. 5.12 Flexural strength of GGBS concrete with OPC cement and PPC cement for M20 grade for Crush sand in 28 days



5.4 Durability Studies with H2SO4 and HCl

Concrete cubes of 150 x 150 x 150 mm3 size were cast for durability studies for grade M20 of concrete. 1% H2SO4, 1% HCl concentration for 90 days curing and 5% H2SO4, 5% HCl concentration for 28 days curing were considered for durability studies. Each grade consists of 0%, to 100% and hence each grade contains 96 cubes placed in individual tubs for each concentration. The normality of the solution was checked for every 2 days. The Compressive strength of cubes exposed to H2SO4 and HCl are tested for compressive strength and results were presented for 0%, to 100% of GGBS concrete for M20 grades of concrete at room temperature for 28 and 90 days respectively. Following Figure shows acid affected concrete cubes.


Fig 5.13 Normal cube Fig5.14 Acid affected cube

Table 5.25 Compressive strength for M 20 grade concrete after H2SO4 acid curing

Sr No	% of GGBS	Compressive Strength (N/mm2)	
		28 days (5% H2SO4)	90 days (1 % of H2SO4)
1	0	26.40	36.6
2	20	27.80	37.9
3	30	30.10	42.80
4	40	32.92	46.92
5	50	28.50	37.88
6	60	28.30	37.53
7	70	28.15	37.10
8	80	27.63	36.89
9	90	27.33	36.50
10	100	27.10	35.35

Table 5.26 Compressive strength for M 20 grade concrete after HCL acid curing

Sr No	% of GGBS	Compressive Strength (N/mm2)	
		28 days (5% HCL)	90 days (1 % of HCL)
1	0	26.56	37.92
2	20	27.89	40.25
3	30	29.74	42.79
4	40	33.50	47.95
5	50	29.15	44.39
6	60	29.52	44.10
7	70	29.10	42.56
8	80	28.46	42.15
9	90	27.33	40.30
10	100	27.10	40.15

Effect of H2SO4 and HCl Acids on Durability of Concrete

Concrete cubes of 0% to 100% of GGBS concrete of M20 grade concrete exposed to H2SO4 and HCl of 1% and 5% concentrations are tested for compressive strength for 90 days and 28 days respectively. The results are presented in Figure 15, 16.

Figure no. 5.15 Compressive strength of Cubes after acid test for 28 days

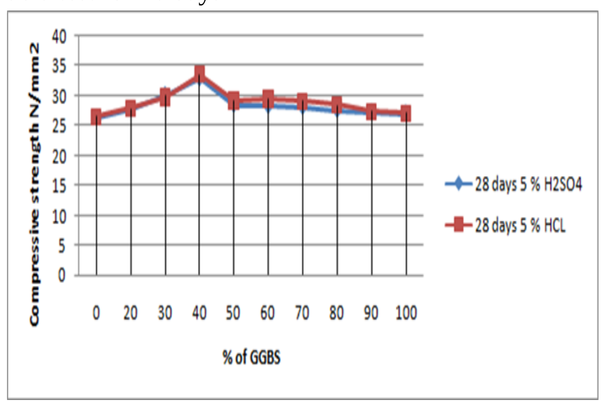
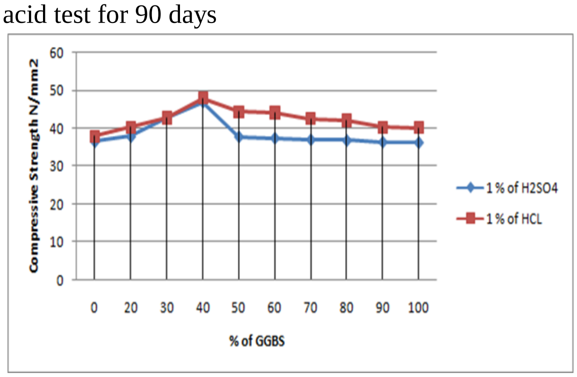


Figure no. 5.16 Compressive strength of Cubes after acid test for 90 days



V. CONCLUSIONS

6.1 Conclusions

The following conclusions are drawn from the test results and discussion of this investigation:

1. The degree of Workability of concrete increases with the increase in GGBS replacement level. So the GGBS can be used as substitute for cement

which will reduce the cost of cement in concrete and also reduce the consumption of cement. Since we are using industrial waste which helps to minimise environmental pollution.

2. The compressive strength of concrete increased when cement is replaced by GGBS for M20 grade of concrete. At 40% replacement of cement by GGBS the concrete attained maximum compressive strength for both M20 and M40 grade of concrete.
3. The split tensile strength of concrete is increased when cement is replaced with GGBS. The split tensile strength is maximum at 40% of replacement.
4. The flexural strength of concrete is also increased when the cement is replaced by GGBS. At 40% replacement, the flexural strength is maximum.
5. The compressive strength values of acid effected concrete decreases on comparison with of normal concrete, but the effect of acid on concrete decreases with the increase of percentage of GGBS. At 40% replacement of GGBS the resistance power of concrete is more.
6. The compressive strength values of GGBS concrete effected to HCl were greater than the GGBS concrete effected to H_2SO_4. The effect of HCl on strength of the concrete is lower than the effect of H_2SO_4 on strength of the concrete.

6.2 Scope for Future Work

The present work has good scope for future research. Some of the research areas are as follows.

[1] Behaviour under marine and acidic environment for GGBS concrete.
[2] Behaviour with replacement of sand by artificial sand.
[3] Behaviour under temperature effect for same GGBS concrete.