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An Exploratory Analysis on the New Generation Concrete Partial Replacement of Cement by GGBS and Glass Powder

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ABSTRACT
As industrialization developing exponentially, by-products from industries is increasing day to day. Ground Granulated Blast Furnace slag (GGBS) is a by-product from blast furnace of iron and steel industries. And GGBS is a high quality cement paste and gives strength, durability properties and Waste Glass Powder is also industrial waste which can be used for cement replacement. Pozzolanic reaction between cement hydration products and glass powders revealed that after 28 days the compressive strength of concrete was not affected with the cement substitution. This paper presents mainly use of GGBS and Waste Glass Powder (WGP). This experimental research held with partial substitution of cement with slag (GGBS) and mineral admixture (WGP) by weight. Glass Powder and GGBS were mixed with cement in different proportions to study the variation of strength in concrete. Results of normal mix concrete compared with results of partial substitution of GGBS and glass powder. The cement is substituted with GGBS accordingly with 10% and 20% by weight of cement for M25 mix. The cement is substituted with WASTE GLASS POWDER accordingly among range from 0% (without WGP), 5 % , 10 %, 15 %, 20 % and 25 % with weight of cement for M25 mixture. Compressive strength, Flexural strength, split tensile strength tests were conducted. This experiment shown that the mix combinations with certain percentages gave higher strengths compared to normal mix proportions.
KEYWORDS: Ground Granulated Blast Furnace slag, *Waste Glass Powder, Compressive strength, Flexural strength, Split tensile strength.*

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I. INTRODUCTION :

Concrete is a frequently utilizing composite material, which is composed of cement, coarser and finer aggregates along with potable water primarily. And Increasing demand of cement in present scenario is degrading the environment, in order to retard the utilisation of cement partially replacing it with industrial wastes like GGBS and WGP.

Concrete is the bulk individual material in the built environment. If the embodied energy of concrete can be decreased without effecting the performance and without increasing the cost. Portland cement contributes 12 percent of the concrete mass, but it comprises around 93 percent of strength to structure. Some studies from various researches revealed GGBS concrete can safeguard reinforcement steel more systematically, so it can protect steel from corrosion and whole structure. GGBS is an industrial waste, so the enactment of this concrete can curtail corrosion in an constructive method. More over GGBS can make the structure more durable with no change in cost. GGBS from thermal power plants usually does not need processing to being incorporated into concrete.

GGBS is a cementitious material that can behave as a partial replacement of Portland cement without reducing the compressive strength. In this project an attempt made to check the suitability of glass powder as mineral admixture and its effects on the concrete. The main motive of this experiment is to test the concrete under partial replacement of cement with WGP and GGBS to test the effects of results in concrete.

II. OBJECTIVE :

- To reveal the concrete strength parameters, by partial substitution of the cement with GGBS in proportions of 10% and 20% and for each proportion, cement is substituted with Waste Glass powder by 0%, 5%, 10%, 15%, 20%, 25% in normal concrete.
- To find out the performance of concrete made up of Glass Powder and GGBS as partial substitution of the cement.

III. MATERIALS USED :

The materials utilized for setting up the concrete mix. Physical as well Chemical Characteristics of relevant materials are shown in **Table no_1**.

i. Cement :-

- OrdinaryPortlandCement with 53 grade (Ultra Tech Company).
- Cement Physical characteristics as per IS 12269: 2013.
- Specific gravity of cement = 3.14.
- Normal consistency = 29 %
- Fineness of cement = 5.4% from 90 micron IS sieve as per IS : 4031 (Part 1).
- Initial setting time = 30 mnts ; Final setting time = 10 hours from VICAT needle test.

ii. Conventional Coarse aggregate :-

- CA (Coarse Aggregate) maximum size = 20mm which validates IS 383 - 1970 .
- CA specific gravity - 2.702 which validates to IS 2386 (Part 4)-1963.
- Water absorption - 0.25%

iii. Fine aggregate(Sand) :-

- Natural sand which is passing through 4.75mm IS Sieve as per IS-383-1970 it belongs to zone-II.
- Locally available sand from Chitravathi river near Batthalapally.
- Specific gravity of fine aggregate = 2.63
- Fineness modulus = 2.46 %
- Water absorption of sand = 0.5%

iv. GGBS :-

- GGBS is a residual by-product material left after the burning of lime stone, coke and ore of iron in a combination at 1500^0 C.
- The low-density molten slag comes up on the surface and easily separated from rest of the mass. Afterwards it is cooled down by the action of water. The water pressure during the cooling process breaks down the slag into a size less than five milli meters. Slag powder is then obtained by grinding the dried slag mass almost fully non-crystalline, glassy form known as granulated slag.
- It consist hydraulic characteristics, When finely grinded slag mixed with Portland cement (PC), it shows much good binding characteristics. This mix is less reactive than pure Portland Cement (PC), but It has same chemical characteristics as that of cement.
- It hydrates on adding water just like the Portland cement and mostly in combination with Portland cement. The blends can either be factory made or formed in the mixer by adding Portland cement and GGBS each from its own silo.
- Concrete containing GGBS & PC mix may be slow in reacting than pure Portland Cement concrete, but it has improved durability.

v. WASTE GLASS POWDER :-

- Waste glass bottles gathered from local resources were milled to powder form.
- Grinded powder size maintained as per cement standards which is less than 0.075 mm. Glass bottles are shown in ***Figure_1*** and smoothly grinded powder from is shown in ***Figure_2***.

Figure 1. Waste Glass Bottle

Figure 2. Milled Glass Powder

vi. Water :-

- Locally available potable water used for blending concrete and curing purpose.
- Water is free from salts and contaminations.

Table no_1: Characteristics of Cement (OPC), GGBS and Waste Glass Powder

Properties	*WGP*	*GGBS*	*CEMENT(OPC)*
Specific Gravity	2.55	2.79	3.14
$Si\ O_2$	70.22	34.4	20.6
Al_2O_3	3.52	9.0	4.0
fe_2O_3	1.77	2.58	3.1
Ca O	10.59	44.8	62.8
$S\ O_3$	0.03	2.26	3.1
Mg O	1.56	2.6	4.43
K_2O	0.89	0.5	-
Na_2O	10.46	0.62	-
Loss On Ignition	0.60	1.32	1.8

IV. PROCEDURE OF EXPERIMENT :

An experimental study taken on concrete with optimum partial replacements, such that cement is substituted with GGBS in the amounts of 0%, 10%, 20% and same cement partial replaced with Waste Glass Powder in the amounts of 0%, 5%, 10%, 15%, 20%, 25%

i) Cubes size – 15 cm x 15 cm x 15 cm – Three specimens to compressive test.

ii) Cylinders size - 15 cm (dia) x 30 cm (height) – Three specimens to split-tensile test.

iii) Beams size – 10 cm X 10 cm X 50 cm - Three specimens to flexural test.

4.1 Mix Proportions :

In this experiment, exploration works on M25 grade. Mix design adopted as per the IS 10262 (2009) and IS 456-2000 to get the M25 mix which gives a mixing ratio as **1 : 1.66 : 2.87** for the constant W/C ratio of **0.46** maintained. By using the mentioned mix ratio, 18 mixes were cast, and these split into three sets. Each set contain six mix proportions, and detailed proportions mentioned in the **Table no_2.**

Table no_2 : Mixing ratio in detail

Group 1							
S. No	**Name of the Mix**	**Cement(%)**	**GGBS(%)**	**WGP (%)**	**No of specimens casted and tested**		
					Cubes	**Cylinders**	**Beams**
1	TM 1	100	0	0	3	3	3
2	TM 2	95	0	5	3	3	3
3	TM 3	90	0	10	3	3	3
4	TM 4	85	0	15	3	3	3
5	TM 5	80	0	20	3	3	3
6	TM 6	75	0	25	3	3	3

Group 2							
S. No	**Name of the Mix**	**Cement(%)**	**GGBS(%)**	**WGP(%)**	**No of specimens casted and tested**		
					Cubes	**Cylinders**	**Beams**
1	TM 7	90	10	0	3	3	3
2	TM 8	85	10	5	3	3	3
3	TM 9	80	10	10	3	3	3
4	TM 10	75	10	15	3	3	3
5	TM 11	70	10	20	3	3	3

6	TM 12	65	10	25	3	3	3
Group 3							
S. No	**Name of the Mix**	**Cement(%)**	**GGBS(%)**	**WGP (%)**	**No. of specimens casted and tested**		
					Cubes	**Cylinders**	**Beams**
1	TM 13	80	20	0	3	3	3
2	TM 14	75	20	5	3	3	3
3	TM 15	70	20	10	3	3	3
4	TM 16	65	20	15	3	3	3
5	TM 17	60	20	20	3	3	3
6	TM 18	55	20	25	3	3	3

In the above table M 1 mix denotes conventional concrete.
Hence the specimens casted and tested were 162 in total.

V. TESTING ON CONVENTIONAL CONCRETE

5.1. Compressive test results on cubes :

To find out the cube compressive strength of concrete 15 cm x 15 cm x 15 cm dimention cube specimens used. After 28 days curing, Compressive test conducted for the specimens as per the IS516:1959(2004) with help of 2000KN capacity Compressive Testing Machine. Load was applied gradually avoiding impact and the pace maintained as 14 N/mm^2/Sec. Test extended till the sample cube fails then final loads are noted down. Results are represented in **Table no_3** and graph is in ***Figure_3***.

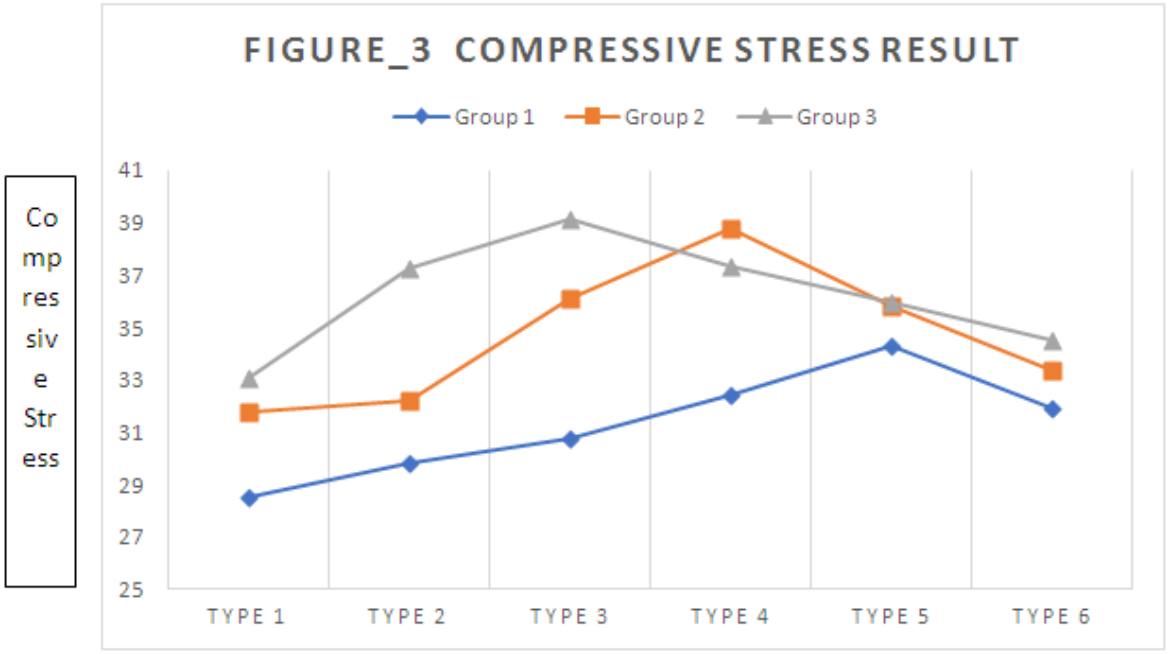
Table no_3 : Compressive strength

S. No	Name of the Mix	% of cement replaced with GGBS and WGP Cement % + GGBS % + WGP %	Compressive Strength of Cubes (N/mm^2) (28 days)
1	TM 1	100 % + 0 % + 0 %	28.55
2	TM 2	95 % + 0 % + 5 %	29.80
3	TM 3	90 % + 0 % + 10 %	30.75
4	TM 4	85 % + 0 % + 15 %	32.42
5	TM 5	80 % + 0 % + 20 %	34.28
6	TM 6	75 % + 0 % + 25 %	31.91

	Name of the Mix	% of cement replaced with GGBS and WGP	Compressive Strength of the Cubes (N/mm^2) After 28 days
1	TM 7	90% + 10% + 0%	31.80
2	TM 8	85% + 10% + 5%	32.24
3	TM 9	80% + 10% + 10%	36.14
4	TM 10	75% + 10% + 15%	38.75
5	TM 11	70% + 10% + 20%	35.81

6	TM 12	65% + 10% + 25%	33.36

S.No	Name of the Mix	% of cement replaced with GGBS and WGP	Compressive Strength of the Cubes (N/mm^2) After 28 days
1	TM 13	80% + 20% + 0%	33.09
2	TM 14	75% + 20% + 5%	37.29
3	TM 15	70% + 20% + 10%	39.12
4	TM 16	65% + 20% + 15%	37.36
5	TM 17	60% + 20% + 20%	35.94
6	TM 18	55% + 20% + 25%	34.49



5.2. Split Tensile test results :

To find the split tensile strength of specimens length 30 cm and diameter 15 cm were prepared. Specimens are tested as per IS - 5816 : 1999 (2004).

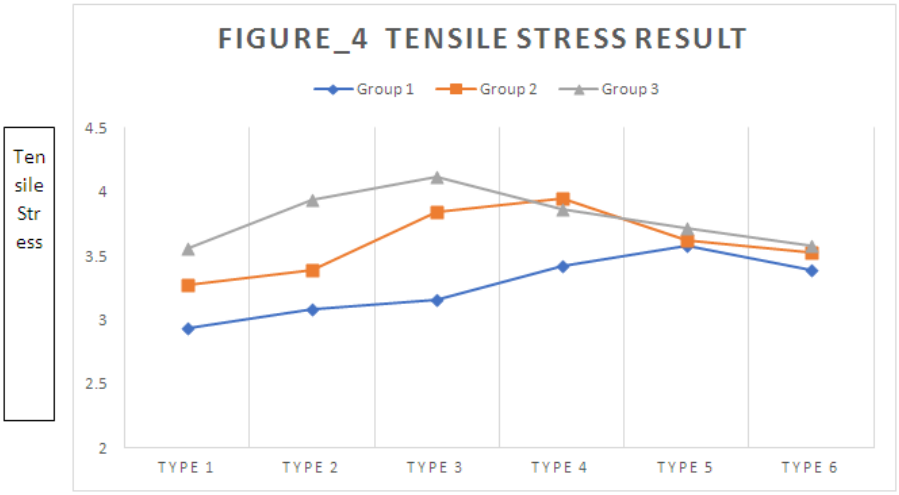
Table no_ 4

S.No	Name of the Mix	% of cement replaced with GGBS and WGP Cement % + GGBS % + WGP %	Tensile Strength of the Cylinders (N/mm^2) After 28 days
1	TM 1	100 % + 0 % + 0 %	2.94
2	TM 2	95 % + 0 % + 5 %	3.08
3	TM 3	90 % + 0 % + 10 %	3.16
4	TM 4	85 % + 0 % + 15 %	3.42

5	TM 5	80 % + 0 % + 20 %	3.58
6	TM 6	75 % + 0 % + 25 %	3.39

S.No	Name of the Mix	% of cement replaced with GGBS and WGP	Tensile Strength of the Cylinders (N/mm^2) After 28 days
1	TM 7	90% + 10% + 0%	3.27
2	TM 8	85% + 10% + 5%	3.39
3	TM 9	80% + 10% + 10%	3.84
4	TM 10	75% + 10% + 15%	3.95
5	TM 11	70% + 10% + 20%	3.62
6	TM 12	65% + 10% + 25%	3.53

S.No	Name of the Mix	% of cement replaced with GGBS and WGP	Tensile Strength of the Cylinders (N/mm^2) After 28 days
1	TM 13	80% + 20% + 0%	3.56
2	TM 14	75% + 20% + 5%	3.94
3	TM 15	70% + 20% + 10%	4.12
4	TM 16	65% + 20% + 15%	3.87
5	TM 17	60% + 20% + 20%	3.72
6	TM 18	55% + 20% + 25%	3.58



5.3. Flexural Bending test results on Beams :

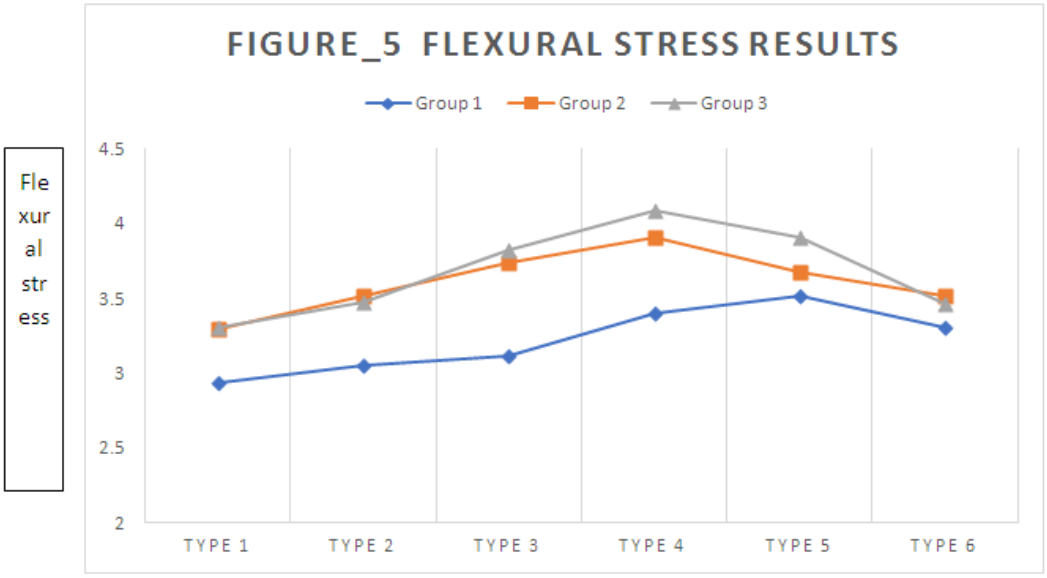
To find out the bending strength of specimens length 50 cm, width 10 cm and depth 10 cm were prepared. flexural tensile strength test was performed in accordance with IS 5816 : 1999 (2004).

Table no_5

S.No	Name of the Mix	% of cement replaced with GGBS and WGP Cement % + GGBS % + WGP %	Flexural Strength of the Beams (N/mm^2) After 28 days
1	TM 1	100% + 0% + 0%	2.94
2	TM 2	95% + 0% + 5%	3.05
3	TM 3	90% + 0% + 10%	3.12
4	TM 4	85% + 0% + 15%	3.40
5	TM 5	80% + 0% + 20%	3.52
6	TM 6	75% + 0% + 25%	3.31

S.No	Name of the Mix	% of cement replaced with GGBS and WGP	Flexural Strength of the Beams (N/mm^2) After 28 days
1	TM 7	90% + 10% + 0%	3.29
2	TM 8	85% + 10% + 5%	3.52
3	TM 9	80% + 10% + 10%	3.74
4	TM 10	75% + 10% + 15%	3.91
5	TM 11	70% + 10% + 20%	3.68
6	TM 12	65% + 10% + 25%	3.52

S.No	Name of the Mix	% of cement replaced with GGBS and WGP	Flexural Strength of the Beams (N/mm^2) After 28 days
1	TM 13	80% + 20% + 0%	3.30
2	TM 14	75% + 20% + 5%	3.82
3	TM 15	70% + 20% + 10%	4.09
4	TM 16	65% + 20% + 15%	3.91
5	TM 17	60% + 20% + 20%	3.74
6	TM 18	55% + 20% + 25%	3.46



VI. SUMMARY AND CONCLUSIONS :

From assess of compressive test, split-tensile test, flexural test results following conclusions are given.

- Compressive strength of conventional concrete raised, when the partial substitution of Cement (OPC) with GGBS up to 20% and Waste Glass Powder (WGP) up to 10% at 28days of curing for M25 grade mix ratio.
- Flexural and split tensile strengths were increased, when the OPC partially replaced with GGBS up to 20% and WGP up to 10% at 28 days of curing for the M25 grade mix.
- From the partial replacement of cement by 20% GGBS and 10% WGP of M25 grade concrete, compressive, tensile, flexural strengths were observed greater than the target mean strengths of normal M25 mix proportion.
- Substitution of cement in concrete by GGBS and Glass powder, facilitates the better economy in the construction field also provides environment friendly dispose of the waste slag and glass powder which generated in huge amounts from industries.
- The optimum replacement of Glass powder and GGBS as cementation distinguished by good compressive strength, less heat of hydration, Suitability, better workability performance, resistance to chemical attack of M25 grade concrete

REFERENCES

[1]. Santosh Kumar Karri, G. V. Rama Rao, P. Markandeya Raju "Strength and Durability Studies on GGBS Concrete", SSRG International Journal of Civil Engineering (SSRG - IJCE), V2 (10), 34-41 October 2015. ISSN: 2348 – 8352.

[2]. Martin O. Connell, Ciaran McNally, and Mark G. Richardson. (2012). "Performance of Concrete Incorporating GGBS in Aggressive Wastewater Environments. Construction and Building Materials", 27 (1), 368-374.

[3]. Pazhani .K., Jeyaraj .R —"Study on durability of high-performance concrete with industrial wastes ATI - Applied Technologies & Innovations" Volume 2 | Issue 2 | August 2010 |pp. 19-28.

[4]. G. Vijayakumar, H. Vishaliny, D. Govindarajulu, "Studies on Glass Powder as Partial Replacement of Cement in Concrete Production," International Journal of Emerging Technology and Advanced Engineering , Vol. 3, Issue 2, Febraury 2013, pp. 153-157.

[5]. Ankur Meena and Randheer Singh Karnik, "Comparative Study of Waste Glass Powder as Pozzolanic Material in Concrete," B. Tech. thesis, National Institute of Technology, Rourkela, 2012.

[6]. Mojtaba Valinejad Shoubi, Azin Shakiba Borough, and Omidreza Amirsoleimani. (2013). . . "Assessment of the Roles of Various Cement Replacements in Achieving Sustainable and High-Performance Concrete". International Journal of Advances in Engineering and Technology, 6 (1): 68-77.

[7]. IS CODES OF PRACTICE :

1. IS 10262-2009, Specifications of mix proportion for concrete

2. IS 456-2000, Plain and reinforced Concrete – code of practice
3. IS 2386 [part 3]: 1963, Aggregate test method c for concrete
4. IS 383: 1970, Fine aggregate and coarse aggregate specification.
5. IS 516: 1959, Compressive strength specifications.
6. IS 5816: 1999, Split tensile strength specifications.

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