Study on the Effects of Polyproylene Fibers by the Partial Replacement of Cement by GGBS

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Abstract: - The present study is a spotlight for the partial replacement of cement by GGBS which is an unwanted material or by-product from the manufacturing processes. The ground granulated blast furnace slag (GGBS) is a waste product from iron manufacturing industries and due to its rich cementitious property, it can be used as a partial replacement to cement. This study also includes the usage of polypropylene fibers due to its enough resistance to cracking & strengthening of concrete. Polypropylene fibers are able to hold the concrete together even after wider cracking. The real contribution of polypropylene fibers is to increase the toughness of concrete. In this experimental stretch, workability test for determining the workability of concrete & also tests like compressive strength, split tensile strength, flexural strength test to determine the hardened properties of concrete were conducted by adding ground granulated blast furnace slag (GGBS) in various percentages like 0%, 25%, 50% & 75% to the weight of cement & polypropylene fibers of 2% by the weight of cementitious material. The grade of concrete used was M20 grade. From the overall study it can be concluded that, replacing cement by an alternative material like GGBS can also help in the attainment of target strength (M20 grade). It was observed that increase in the GGBS content leads to the increase in the compressive strength of concrete. It was noticed that the maximum compressive strength of 23.62Mpa was achieved at 75% of GGBS with 2% of polypropylene fibers & also it can be concluded that there was a decrease in the workability of concrete due to the inclusion of polypropylene fibers. This combination of materials proves to be economical and thereby reducing the carbon footprint emissions due to the reduction in the utilization of cement.

Key Words: — ***Concrete, Polypropylene fibers, Strength, GGBS, Workability, Compressive strength.***

I. Introduction

Concrete plays an essential role in construction industry. Cement being the major constituent of concrete, its production process is a more energy consuming process, which results in emission of carbon dioxide and other greenhouse gases, these gases adversely effect on the environment [1]. The ground granulated blast furnace slag (GGBS) is an unused or discarded product from the iron manufacturing industry, meritoriously this GGBS is a pozzolanic material and this could be utilized to produce Geopolymer concrete with the assistance of alkaline activator solution [3]. On the other hand, there are serious disposal problems for the Ground Granulated Blast Furnace Slag (GGBS), a waste residue left over in the steel plant [2].

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The production cost of cement is increasing and natural resources giving the raw material for its manufacturing are decreasing. Fly ash, GGBS, Rice Husk Ash, Silica Fume are some of the other pozzolanic materials which can be incorporated with concrete as partial replacement for cement. Concrete being the most majorly used structural material around the world, because of its increased compressive strength, low cost and can be easily manufactured with the locally available ingredients, but concrete is weak in tensile strength. So, to increase the tensile property and resistance to cracks fibers are added, such type of concrete is termed as the fiber reinforced concrete. Fiber reinforced concrete enhances the toughness and durability properties of concrete. Fiber reinforced concrete (FRC) is concrete that comprises of fibrous material which increases its structural bonding. It contains small discrete fibers that are uniformly dispersed and randomly oriented [4]. GGBS is a waste or unwanted product obtained in the manufacture of iron by blast furnace. The molten slag is unheavy and be suspended on the top of the molten iron. The procedure for granulating the slag includes cooling the molten slag through high-pressure water jets. This expeditious cooling of the slag results in formation of granular particles which in general are not larger than 5 mm in diameter. The granulated slag is again processed by drying and then ground to a very fine powder, which is GGBS (ground granulated blast furnace slag). Further Grinding of the granulated slag is carried out in the rotating ball mill [4].

Objectives of the Study:

- The main aim is to reduce the consumption of cement in concrete.
- The objective of this project is to find out the effects of concrete composites when cement is partially replaced by GGBS and when Polypropylene fibers added to the composites.
- To assess the feasibility of polypropylene fibers on properties of concrete such as Compressive strength, Split Tensile strength and Flexural strength.
- To overcome the environmental issues caused by manufacturing of cement.

II. Materials And Methodology

A. Cement

Ordinary Portland Cement (OPC) is the basis cement which is best suited for use in general concrete construction. In the present investigation, BIS mark 53 grade cement was used for all concrete mixes. The cement used was fresh and had no lumps. Testing of cement was done as per BIS: 12269-2010. The various tests results conducted on the cement are tabulated below.

Table.1. Test results for Cement

Sl. No	Characteristics	Value Obtained	As per BIS:12269-2010
1.	Normal Consistency (%)	34.%	–
2.	Initial setting time (minutes)	43 min	Not less than 30
3.	Final setting time (minutes)	300 min	Less than 600
4.	Fineness (%)	6.43 %	Max 10
5.	Specific Gravity	3.1	3.15

B. GGBS

Ground Granulated Blast Furnace Slag (GGBS) is procured by snuffing out (quenching) the molten iron slag (a product of iron and steel making) from a blast furnace in water or steam, to obtain a glassy, granulated gritty product which is then dried and ground & converted to a fine powdered form. The GGBS used for this study was purchased in JSW Cement Ltd. Table below shows the properties of GGBS.

Table.2. Test results for GGBS

Sl. No	Properties	Values
1.	Specific Gravity	2.67
2.	Appearance	Grayish white

Fig 1. Image of GGBS bag purchased

C. Fine Aggregates

The sand used for this study was locally procured and conformed to grading zone III as per BIS: 383-2007. The sand was first sieved through a standard 4.75 mm sieve to remove any particles greater than 4.75 mm and then was washed to remove the dust. The results of physical properties of the fine aggregates are represented below.

Table.3. Test results for fine aggregate

Sl. No	Characteristics	Value
1.	Type	Manufactured
2.	Specific Gravity	2.4
3.	Packing Factor	1.08
4.	Density	1620 kg/m3
5.	Fineness Modulus	2.41
6.	Grading Zone	Zone III

D. Coarse Aggregates

The crushed stone are mainly used as aggregates in concrete. Locally available coarse aggregates having the maximum size of 20mm passing and 16mm retained were used in this experimental work. Testing of coarse aggregates was carried out as per the stipulations of BIS: 2386-1963. The results of physical properties of coarse aggregate are described in the table below.

Table.4. Test results for coarse aggregate

Sl. No	Tests	Results	As per BIS 2386-1963
1.	Specific gravity	2.63	2.5-2.9
2.	Crushing Value	23.35%	Max 30%
3.	Abrasion Value	21.5%	Max 35%
4.	Impact Value	14%	Max 30%
5.	Elongation Index	8.8%	Max 2%
6.	Flakiness Index	3.2%	Max 30%

E. Polypropylene Fibers

The polypropylene fibers used in this project is a macro-synthetic fiber which are designed specifically for the reinforcement of concrete and other cementitious mixes. Fibers have an excellent engineered profile, which serves to effectively anchor the fibers into the concrete thus helping in resisting matrix pull-out enhancing the concrete performance even it has developed stress cracks. The properties of the polypropylene fiber are as shown in table below.

Fig.2. Image of polypropylene fibers

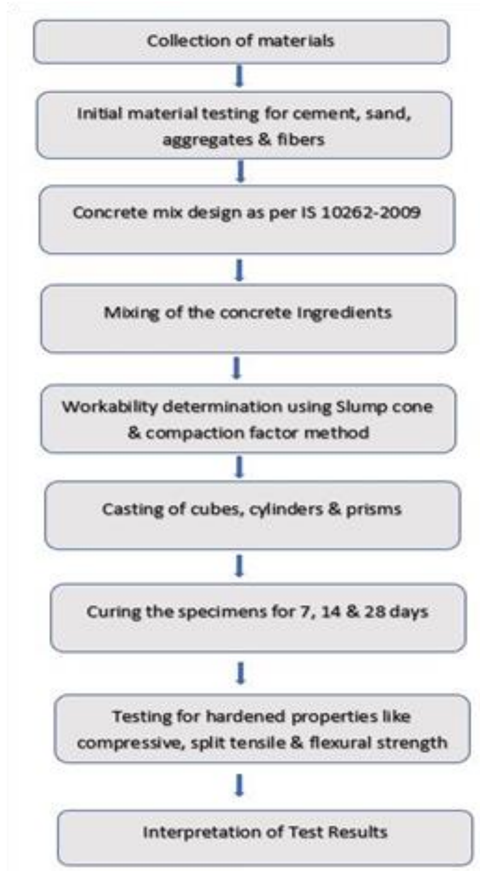
Table.5. Properties of PP fibers

Sl. No	Properties	Values
1.	Length	50 mm
2.	Width	1.51 mm
3.	Thickness	0.50 mm
4.	Tensile strength	420-600 Mpa
5.	Number of fibers in Kg	53,000
6.	Specific gravity	0.91
7.	Melting point	163oC

F. Water

Water is the most important ingredient of a concrete as hydration of cement is possible only in the presence of water. It helps in creating a bond between the cementitious materials and the aggregates. Portable water confirming to the requirements as per IS 456-2000 which is free from salts and impurities is used for washing aggregates, mixing and curing purposes.

G. Experimental Programme



III. Result And Discussion

A. Workability Test

The concrete immediately after mixing was tested for workability by Slump cone & compaction factor method & the following observations were recorded.

Table.6. Variation in Workability by Slump cone method

Sl. No	% of Replacement	Slump in mm
1	0%	50
2	25%	30
3	50%	25
4	75%	15

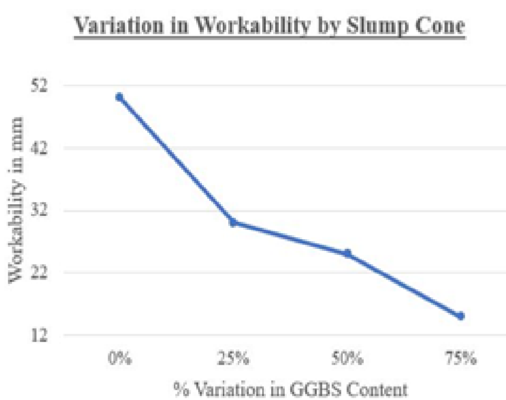


Fig .3. Graphical representation of variation in workability by slump cone method

Table.7. Variation in Workability by compaction factor method

Sl. No	% of Replacement	Compaction Factor
1	0%	0.85
2	25%	0.87
3	50%	0.93
4	75%	0.82

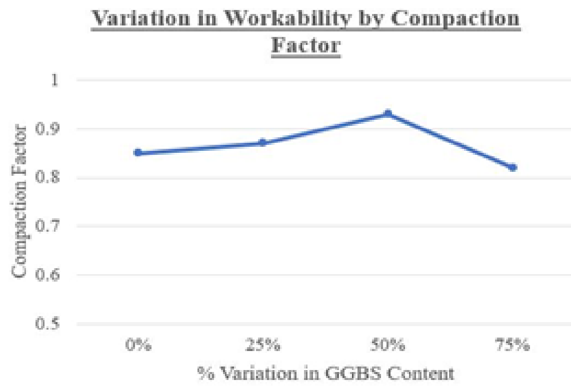


Fig.4. Graphical representation of variation in workability by compaction factor method

B. Compressive Strength Test

Compressive strength test was carried on the specimens after a curing period of 7, 14 & 28 days and the following observations were made.

The variation of compressive strength at a period of **7 days** are as represented in the tabulated form below.

Table.8. Variation in 7 days compressive strength for 0% GGBS content

Trial No	% mix	Failure load in KN	Compressive stress in N/mm^2	Average compressive stress in N/mm^2
1	0%	270.01	12.00	11.74
2		253.19	11.25	
3		269.09	11.95	

Table .9. Variation in 7 days compressive strength for 25% GGBS content

Trial No	% mix	Failure load in KN	Compressive stress in N/mm^2	Average compressive stress in N/mm^2
1	25%	293.4	13.04	13.71
2		335.92	14.93	
3		296.32	13.17	

Table.10. Variation in 7 days compressive strength for 50% GGBS content

Trial No	% mix	Failure load in KN	Compressive stress in N/mm^2	Average compressive stress in N/mm^2
1	50%	311.62	13.85	15.19
2		358.42	15.93	
3		355.5	15.80	

Table.11. Variation in 7 days compressive strength for 75% GGBS content

Trial No	% mix	Failure load in KN	Compressive stress in N/mm^2	Average compressive stress in N/mm^2
1	75%	428.17	19.03	18.94
2		396.67	17.63	
3		454.05	20.18	

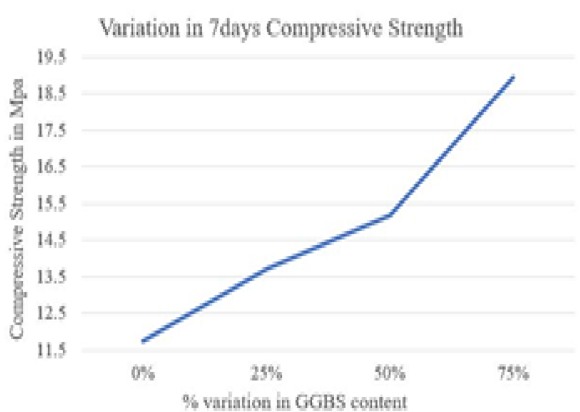


Fig.5. Graphical representation of variation in 7days Compressive strength

The variation of compressive strength at a period of **14 days** are as represented in the tabulated form below.

Table.12. Variation in 14 days compressive strength for 0% GGBS content

Trial No	% mix	Failure load in KN	Compressive strength in N/mm^2	Average Compressive strength in N/mm^2
1	0%	319.05	14.18	14.51
2		367.20	16.32	
3		361.12	16.05	

Table.13. Variation in 14 days compressive strength for 25% GGBS content

Trial No	% mix	Failure load in KN	Compressive strength in N/mm^2	Average Compressive strength in N/mm^2
1	25%	384.52	17.09	17.83
2		409.05	18.18	
3		409.95	18.22	

Table.14. Variation in 14 days compressive strength for 50% GGBS content

Trial No	% mix	Failure load in KN	Compressive strength in N/mm^2	Average Compressive strength in N/mm^2
1	50%	401.17	17.83	18.04
2		411.07	18.27	
3		405.45	18.02	

Table.15. Variation in 14 days compressive strength for 75% GGBS content

Trial No	% mix	Failure load in KN	Compressive strength in N/mm^2	Average Compressive strength in N/mm^2
1	75 %	436.27	19.39	18.37
2		443.70	19.72	
3		360.00	16.00	

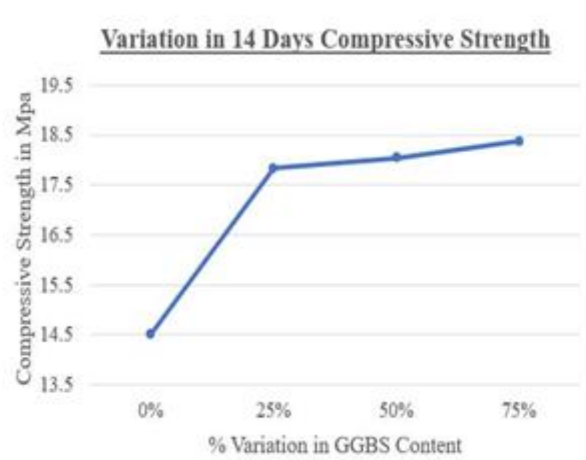


Fig.6. Graphical representation of variation in 14days Compressive strength

The variation of compressive strength at a period of **28 days** are as represented in the tabulated form below.

Table .16. Variation in 28 days compressive strength for 0% GGBS content

Trial No	% mix	Failure load in KN	Compressive strength in N/mm^2	Average Compressive strength in N/mm^2
1	0%	439.27	19.52	19.70
2		445.68	19.80	
3		445.68	19.80	

Table.17. Variation in 28 days compressive strength for 25% GGBS content

Trial No	% mix	Failure load in KN	Compressive strength in N/mm^2	Average Compressive strength in N/mm^2
1	25 %	453.60	20.16	18.67
2		421.20	18.72	
3		385.87	17.15	

Table.18. Variation in 28 days compressive strength for 50% GGBS content

Trial No	% mix	Failure load in KN	Compressive strength in N/mm^2	Average Compressive strength in N/mm^2
1	50 %	436.27	19.39	19.05
2		443.70	19.72	
3		406.35	18.06	

Table .19. Variation in 28 days compressive strength for 75% GGBS content

Trial No	% mix	Failure load in KN	Compressive strength in N/mm^2	Average Compressive strength in N/mm^2
1	75 %	517.50	23.00	23.62
2		578.02	25.69	
3		498.82	22.17	

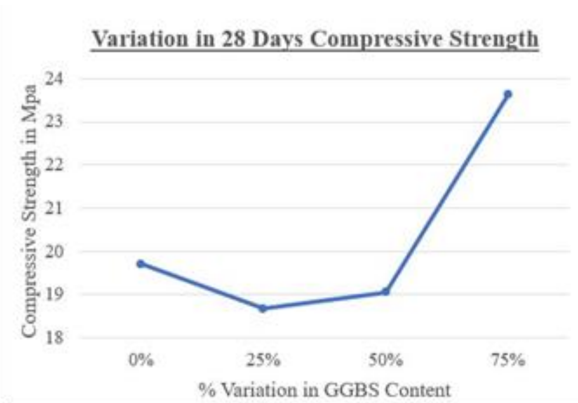


Fig .7. Graphical representation of variation in 28 days Compressive strength

C. Split Tensile Strength Test

This test was carried on the cylinder specimens of 150mm dia & 300mm height after a curing period of 14 & 28 days and the following observations were made.

The variation of compressive strength at a period of **14 days** are as represented in the tabulated form below.

Table.20. Variation in 14days tensile strength

% of replacement	Failure load in KN	Tensile strength in N/mm^2
0	190.60	2.69
25	214.80	3.03
50	225.70	3.19
75	158.00	2.23

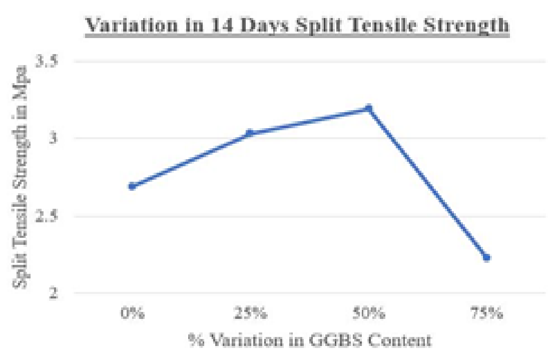


Fig.8. Graphical representation of variation in 14 days tensile strength

The variation of compressive strength at a period of **28 days** are as represented in the tabulated form below.

Table.21. Variation in 28 days tensile strength

% of replacement	Failure load in KN	Tensile strength in N/mm^2
0	215.2	3.04
25	209.1	2.95
50	212.6	3.00
75	166.5	2.35

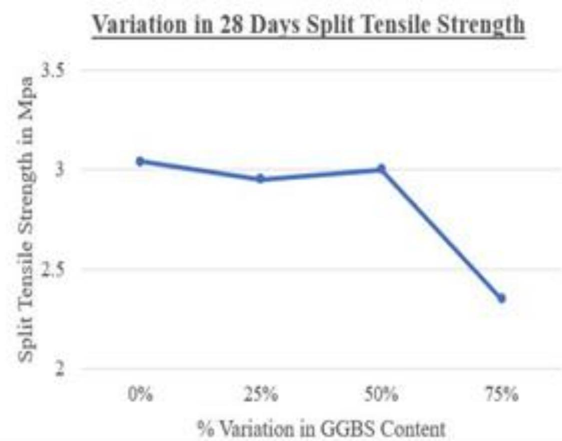


Fig .9. Graphical representation of variation in 28 days tensile strength

D. Flexural Strength Test

This test was carried on the prisms of size 700*100*100mm after a curing period of 14 & 28 days and the following observations were made.

The variation of compressive strength at a period of **7days** are as represented in the tabulated form below.

Table.22. Variation in 7 days flexural strength

% of replacement	Flexural strength in N/mm^2
0	5.83
25	3.17
50	2.50
75	1.67

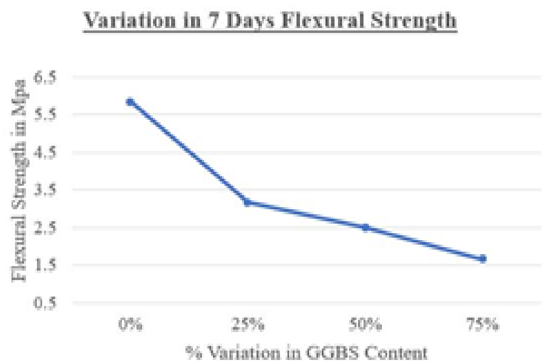


Fig.10. Graphical representation of variation in 7days flexural strength

The variation of compressive strength at a period of **14 days** are as represented in the tabulated form below.

Table.23. Variation in 14 days flexural strength

% of replacement	Flexural strength in N/mm^2
0	6.01
25	7.50
50	8.50
75	6.67

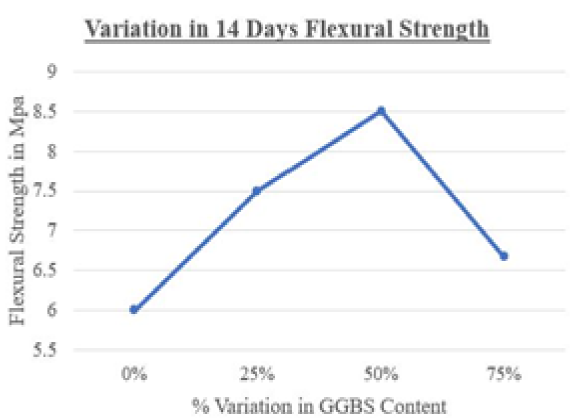


Fig.11. Graphical representation of variation in 14days flexural strength

The variation of compressive strength at a period of **28 days** are as represented in the tabulated form below.

Table.24. Variation in 28days flexural strength

% of replacement	Flexural strength in N/mm^2
0	8.67
25	8.83
50	8.67
75	7.67

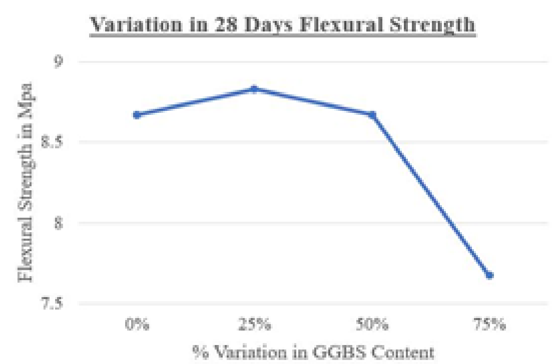


Fig.12. Graphical representation of variation in 28 days flexural strength

IV. CONCLUSION

The test results reveal that the fiber content in the concrete mix has brought about increased compressive strength, flexural strength, abrasion resistance & fiber crack control effect. Hence the addition of fibers in more helpful for the increase in strength. The rate of gain of strength of GGBS incorporated concrete is slow in the initial stage & as the curing period increases the strength also increases. As cement & GGBS are micro fine materials, more surface area is required for hydration of cement & therefore it led to the increase in the strength. From the above graphical interpretations it is clearly evident that it is possible to achieve the same target strength & even more by reducing the cement content & incorporating some other cementitious materials thereby leading to reduction in the emissions of harmful gases produced by the cement production process & also this type of works leads to saving the cost too.

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