Ultimate Strength Determination Due to Addition of Polypropylene Fibre in Optimum Replacement of Cement by GGBS

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***Abstract*—Usually Ordinary Portland Cement concrete is used for making the civil structures. Portland cement can be replaced by Ground Granulated Blast Furnace Slag (GGBS). The Ground granulated Blast furnace slag (GGBS) is an industrial waste and a pozzolanic material that has received considerable attention in both research and application. It is a by-product of the steel industry. GGBS is produced when molten slag is quenched rapidly using water jets, which produces a granular glassy aggregate. It is suitable for concrete mix and improves properties of concrete like compressive strength, workability etc .The present investigation has been undertaken to study the effect of Ground granulated blast furnace slag on the properties of concrete when cement is replaced by GGBS in different percentages varying from 0% to 60% at an interval of 10%.After getting the optimum replacement percentage polypropylene fibre is added in varying proportions such as 0%, 0.25%, 0.5%, 0.75% and 1%. The main objective of this study is to determine the optimum strength obtained by addition of polypropylene fibre to mix corresponding to optimum cement replacement by GGBS under the Indian conditions to satisfy the strength requirements.**

Keywords—Polypropylene, GGBS, Shear strength

I. INTRODUCTION

OPC based concrete continues to be the pre-eminent construction materials for use in any type of civil engineering structures because of its easiness in construction, performance in strength requirements, better durability in normal environment, in comparison to other construction materials like steel, timber etc. At the same time some problems are also associated with this. At present the cement industries produced approximate 7% of total carbon dioxide produced in the world, which is very alarming to our protective Ozone layer. Second problem is the lower durability in aggressive environment. Use of mineral admixtures like Ground Granulated Blast Furnace Slag (GGBS), Silica Fume (SF), Fly Ash (FA) etc. in concrete may be the better solution in above conditions. These admixtures also offer benefits with respect to the cost of concrete.

A. Ground granulated blast furnace slag (GGBS)

Ground Granulated Blast Furnace Slag (GGBS) is a by-product of the steel industry. GGBS is produced when molten slag is quenched rapidly using water jets, which produces a granular glassy aggregate. Thus Ground Granulated Blast Furnace Slag is advantageous over various other cementing materials because of the following reasons:-

- Non-hazardous and non-metallic waste of the Iron industry.
- Eco-friendly and useful for construction work.
- Helps to improve the properties of concrete like compressive strength, workability etc.
- Low cost and easily available.

II. OBJECTIVE

Present experimental work explores the possibility of using GGBS as replacement of cement in concrete and polypropylene fibre to improve ductility. The main objective of this study is

- To develop a proper mix proportion for normal concrete and GGBS modified concrete mix.
- To study the workability and fresh concrete properties of normal concrete and GGBS modified concrete mix.
- To study the mechanical properties of normal concrete and GGBS modified concrete mix.
- To determine the optimum replacement percentage of GGBS modified concrete mix.
- To determine the optimum percentage of polypropylene fibre in the above determined concrete mix.

III. EXPERIMENTAL INVESTIGATION

This chapter deals with the experimental programmes conducted in the present study which include material characterization, mix design, properties of fresh concrete and properties of hardened concrete. The main objective of the study is to investigate the impact of polypropylene fibre on the mechanical properties and ultimate strength of concrete with optimum replacement of cement by GGBS under standard conditions.

A. Constituent materials

Cement: Ordinary Portland cement of 53 grade confirming to IS 12269:1987 was used for the study. For the cement the standard consistency test, initial setting time test, final setting time test and specific gravity test were conducted. The standard consistency of cement used is 36.25%.

Fine aggregate: M sand is used as fine aggregate. Msand passing through 4.75mm IS sieve conforming to grading zone II of IS 383:1970 was used. Specific gravity and fineness modulus of Sand used were 2.4 and 2.87 respectively.

Coarse aggregate: Coarse aggregate of maximum size 20 mm from local source was used.

Ground Granulated Blast Furnace Slag: Different laboratory tests were conducted on GGBS to determine standard consistency, Fineness, Specific Gravity. The standard consistency of GGBS used is 35.55%. The chemical composition of GGBS as shown in table 1

TABLE 1 CHEMICAL COMPOSITION OF GGBS

Sl. No.	Chemical Composition	%Weight
1	Glass	85-98
2	Silica(SiO_2)	17-38
3	Lime(CaO)	3.84
4	Iron Oxide	0.5-2
5	Magnesia(MgO)	4-17
6	Alumina	15-20
7	MnO_2	1-5

Polypropylene Fibre: Polypropylene fibres of length 12mm was used for the study. Physical properties of polypropylene are given by the manufacturer as shown in table 2.

TABLE 2 PROPERTIES OF POLYPROPYLENE

Sl. No.	Properties	Values
1	Type of Fibre	Virgin Polypropylene Homo-Polymer
2	Length of Fibre (mm)	12
3	Diameter of Fibre (μm)	37.7
4	Aspect Ratio	318
5	Ultimate Tensile Strength(MPa)	550-600
6	Specific Gravity	0.91

Superplasticizer: In order to achieve the desired workability, poly carboxylate ether based new range water reducing admixture, Cera Hyperplast XR–W40 was used as the superplasticizer. Cera Hyperplast XR–W40 is available in liquid, which is dispensed into the concrete along with water.

Water: Potable water is generally considered as being acceptable.

Reinforcement: High Yield Strength Deformed Steel bars of 6 mm, 8 mm and 10mm diameter were used for the study.

B. Preliminary laboratory work

This work was done to find the optimum replacement of cement by GGBS.

TABLE 3 DETAILS OF SPECIMEN FOR GGBS MIXES

Mix Designation	Description	Cube	Cylinder	Beam
GGBS0	0% cement replaced by GGBS	6	3	3
GGBS1	35% cement replaced by GGBS	6	3	3
GGBS2	40% cement replaced by GGBS	6	3	3
GGBS3	45% cement replaced by GGBS	6	3	3
GGBS4	50% cement replaced by GGBS	6	3	3
GGBS5	55% cement replaced by GGBS	6	3	3
GGBS6	60% cement replaced by GGBS	6	3	3
TOTAL		42	21	21

1) Tests on specimens

a) Compressive strength

TABLE 4 COMPRESSIVE STRENGTH

Sl. No	Mixes	Average compressive strength (N/mm^2)	
		28days	56 days
1	GGBS0	32.33	32.55
2	GGBS1	31.33	33.22
3	GGBS2	30.55	35
4	GGBS3	29.66	36.55
5	GGBS4	28.55	35.66
6	GGBS5	27.77	33.66
7	GGBS6	25.67	32.78

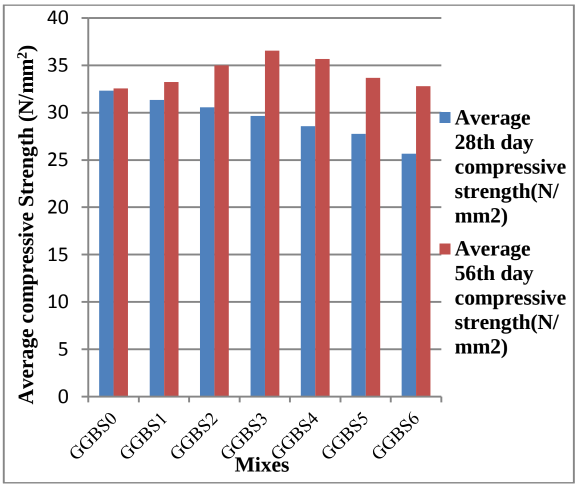

Fig.1. Variation of compressive strength for different mix

b) Splitting Tensile Strength Test

TABLE 5 SPLITTING TENSILE STRENGTH OF CONCRETE

Sl. No	Mixes	Average Splitting Tensile Strength (N/mm^2)
1	GGBS0	2.3
2	GGBS1	2.51
3	GGBS2	2.69
4	GGBS3	3.25
5	GGBS4	2.97
6	GGBS5	2.65
7	GGBS6	2.49

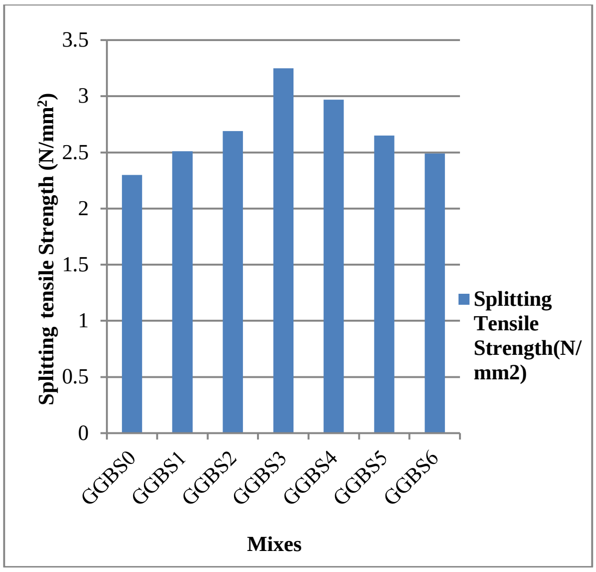

Fig.2. Variation of splitting tensile strength for different mixes

c) Flexural Strength Test

Sl. No	Mixes	Average Flexural Strength (N/mm^2)
1	GGBS0	6
2	GGBS1	6.2
3	GGBS2	6.4
4	GGBS3	6.8
5	GGBS4	5
6	GGBS5	4.6
7	GGBS6	4

TABLE 6 FLEXURAL STRENGTH OF CONCRETE

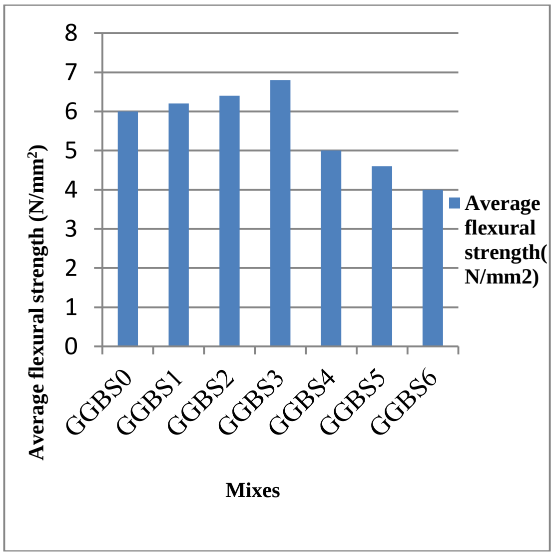

Fig.3. Variation of flexural strength for different mixes

On account of these mechanical properties of GGBS mixes, the mix obtained by cement replaced with 45% GGBS was taken as the optimum mix. A compressive strength of 56.55N/mm2 was obtained for this mix, which is almost in double of 25 N/mm^2 being the design mix. Hence for further studies on polypropylene fibre reinforced GGBS mixes, specimens were cast with cement replaced with 45% GGBS and varying percentages of polypropylene fibre as 0, 0.1, 0.2, 0.3, 0.4 and 0.5%.

C. Experimental works for flexural & shear behavior

Experimental work of my thesis for the determination of effect of polypropylene fibre includes casting of twenty four beam specimens of 100mm breadth, 150mm depth and 1200mm length. Out of these, twelve specimens are used to study flexural behaviour and the remaining twelve specimens for the study of shear behaviour. The variables considered in this study are six different values of weight fraction of polypropylene fibres 0%, 0.1%, 0.2%, 0.3%, 0.4%, and 0.5%.

Flexural beams were provided with two numbers of 10mm diameter high yield strength deformed bars at bottom and two numbers of 8mm diameter bars at top. Two legged stirrups of 6mm diameter @ 90mm c/c have been used as shear reinforcement. Shear beams were provided with two numbers of 10mm diameter high yield strength deformed bars at bottom and two numbers of 8mm diameter bars at top. Two legged 6mm diameter stirrups were provided at the supports.

Fig.4. Reinforcement cage for flexural behaviour

Fig.5. Reinforcement cage for shear behaviour

TABLE 7 DETAILS OF SPECIMENS FOR TESTING FLEXURAL AND SHEAR BEHAVIOUR

Sl. No	Beam Designation	Polypropylene Fibre Weight (%)	No. of specimens (flexure+shear)
1	GGBSP0	0	2x2
2	GGBSP1	0.1	2x2
3	GGBSP2	0.2	2x2
4	GGBSP3	0.3	2x2
5	GGBSP4	0.4	2x2
6	GGBSP5	0.5	2x2
Total			12x2=24

C. Test setup

A two point flexural bending system is adopted for the tests. Specimens are tested in a loading frame of 2000 kN (200 t) capacity with an effective span of 1100 mm. Load cell of 200kN capacity with a least count of 1kN is used to measure the applied load.

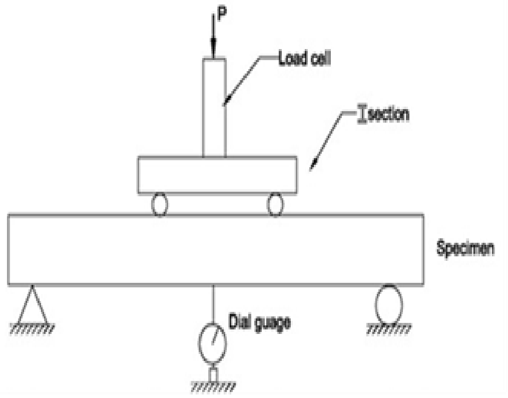

Fig.6. Schematic diagram of loading

IV. RESULTS AND DISCUSSION

TABLE 8 PROPERTIES OF FRESH CONCRETE

Sl. No	Mixes	Workability	
		Slump (mm)	Compacting factor
1	GGBSP0	30	0.85
2	GGBSP1	29	0.83
3	GGBSP2	28	0.81
4	GGBSP3	26	0.78
5	GGBSP4	25	0.75
6	GGBSP5	24	0.73

TABLE 9 TEST RESULTS FOR FLEXURAL BEAM SPECIMENS

Sl. No	Beam Designation	First Crack Load (kN)	Ultimate Load (kN)	Deflection at Ultimate Load (mm)
1	GGBSP0	25	30	7.1
2	GGBSP1	39	44	7.4
3	GGBSP2	34	38	7.2
4	GGBSP3	28	33	6.9
5	GGBSP4	22	28	7
6	GGBSP5	18	26	6.8

TABLE 10 ENERGY ABSORPTION CAPACITY AND DUCTILITY INDEX

Sl. No	Beam Designation	Energy absorption (kNm)	Ductility index
1	GGBSP0	0.186	0.94
2	GGBSP1	0.276	1.32
3	GGBSP2	0.231	1.14
4	GGBSP3	0.193	1
5	GGBSP4	0.132	0.84
6	GGBSP5	0.105	0.78

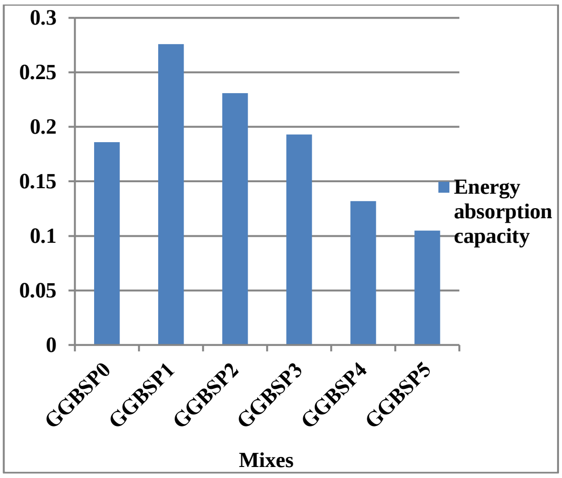

Fig.7. Variation of energy absorption capacity for flexural beams

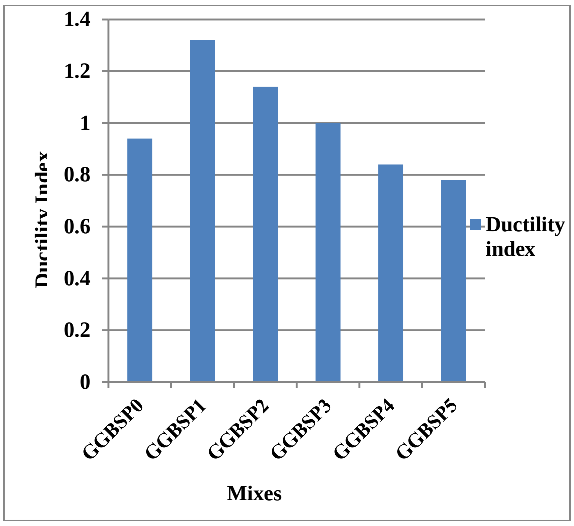

Fig.8. Variation of ductility Index for flexural beams

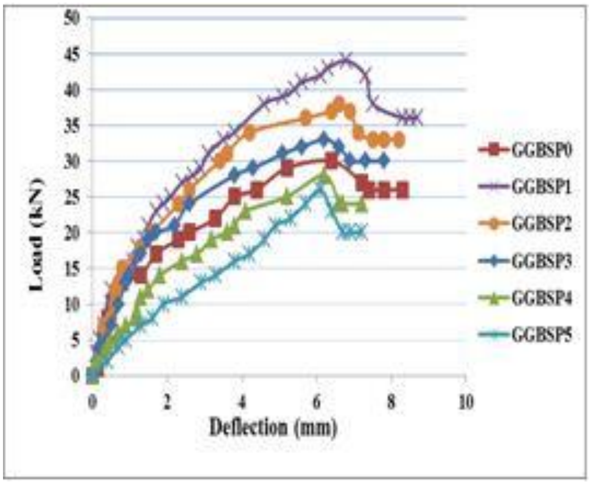

Fig.9. Comparison of load versus deflection curve for flexural beams

TABLE 11 TEST RESULTS FOR SHEAR SPECIMENS

Beam Designation	First Crack Load (kN)	Ultimate Load (kN)	Deflection at Ultimate Load (mm)
GGBSP0	20	28	7.1
GGBSP1	29	39	7.4
GGBSP2	24	36	7.2
GGBSP3	19	32	6.9
GGBSP4	15	24	7
GGBSP5	11	22	6.8

ISSN: 2278-0181

TABLE 12 ENERGY ABSORPTION CAPACITY FOR SHEAR SPECIMENS

Sl. No	Beam Designation	Energy absorption (kNm)
1	GGBSP0	0.102
2	GGBSP1	0.166
3	GGBSP2	0.145
4	GGBSP3	0.116
5	GGBSP4	0.087
6	GGBSP5	0.076

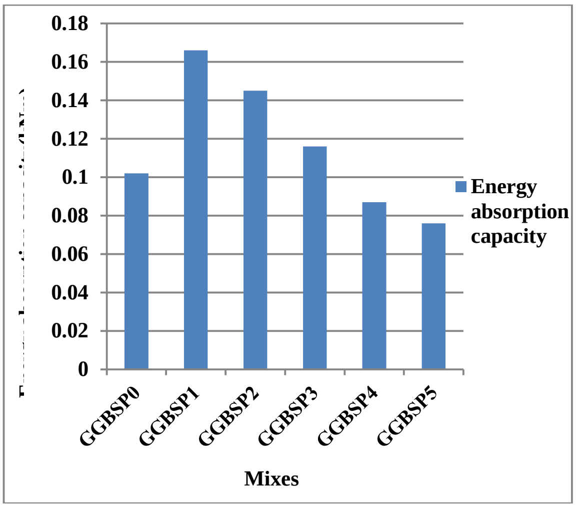

Fig.10. Variation of energy absorption capacity for shear beams

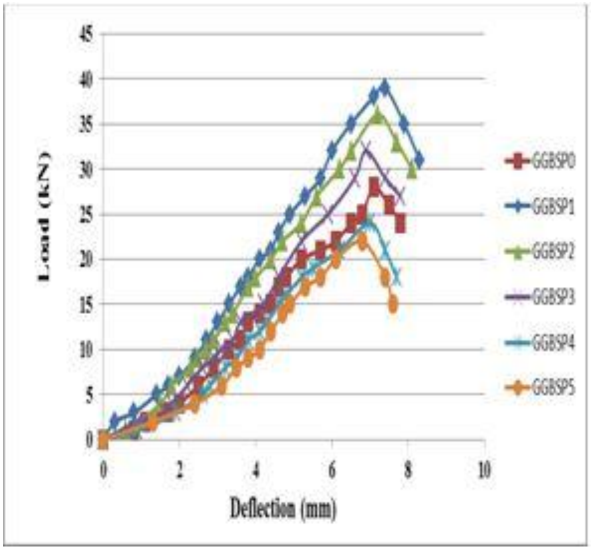

Fig.11. Comparison of load versus deflection for shear beams

Workability of concrete mix decreases with percentage addition of fibre. Compressive strength, flexural strength and splitting tensile strength increases by addition of up to 0.1% by weight of concrete. Percentage increase in 28th day compressive strength is 18% and 56th day compressive strength is 12%. Percentage increase in splitting tensile strength of concrete is 55.5%. Percentage increase in flexural strength of concrete is 48.27%.

The addition of fibres up to 0.1% by weight of concrete improved the first crack load and ultimate load in case of flexural failure. The first crack load was found to have increased by about 56% at 0.1% weight fraction of fibres when compared to the specimens without fibres. The increase in ultimate load was found to be only 46.67%.

The toughness of reinforced concrete beams, increased as the weight fraction of polypropylene fibres increased up to 0.1%. Test results showed that the ductility increased significantly (16%) for beams with addition of polypropylene fibre 0.1% by weight of concrete. The addition of fibre also improved ultimate load by 39.29% and first crack load by 45% in case of shear failure of specimen up to 0.1% addition of polypropylene fibre. Crack width and number of cracks were less in case of fibre reinforced beam.

V. CONCLUSION

- When fibre is added to concrete, the mix becomes stiff. So the workability is decreased with addition of fibre. The workability can be improved by adding super plasticizer to some extent.
- The concrete mix starts clogging beyond the 0.1% addition of fibre. So the mechanical properties are decreased above 0.1% by weight of concrete.
- The fibre distributes the strain more evenly in concrete and improves the tensile strength, thereby causing the increase in first crack load and ultimate load until clogging starts.
- When fibres are added to concrete, crack propagation is arrested and this results in improving load carrying capacity and energy absorption capacity up to a certain limit. So the toughness and ductility is improved with the addition of percentage of polypropylene fibre up to the limit.
- Load deflection behaviour curve shows that ductility of fibres increases up to the limit.

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ISSN: 2278-0181
NCRACE-2015 Conference Proceedings

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