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A Study on Influence of GGBFS on Micro and Macro Polypropylene Fibre Reinforced Concrete

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ABSTRACT

Polypropylene fibres are the new form of chemical fibres. Addition of polypropylene fibres decreases the unit weight of concrete and increases its strength. In this paper the behaviors of the normal concrete and concrete with different types of fibres such as macro-polypropylene and micro-polypropylene fibres have been studied. These fibres were added to the concrete at 0.5%, 1%, 2% and 4% with respect to the volume of concrete. Replacement of cement by a pozzolanic material, by-product from steel manufacturing industries known as Ground Granulated Blast Furnace Slag (GGBFS). The present study is to evaluate the mechanical properties of GGBFS as partial cement replacement in micro and macro polypropylene fibre reinforced concrete. Cement replaced with 40% GGBFS with 1% micro polypropylene fibre and 2% macro polypropylene fibre shows higher compressive strength. Bond strength of various mixes was determined by using pullout test.

***Key Words**: Micro ppfibres, Macro ppfibres, GGBFS, Compressive strength,Split tensile strength,Flexural strength and Pull out test.*

I. INTRODUCTION

Concrete's availability, durability, sustainability and economy have made it the world's most widely used construction material. It is obtained by mixing cementitious materials, water, aggregate and admixtures in required proportions. Concrete has the ability to withstand deterioration and better resistance in compression. But it is weak in tension so that reinforcement in the concrete takes tensile strength. Conventional concrete is limited to ductility, tensile strength, volume instability, low strength to weight ratio and little resistance to cracking. To improve the post cracking behaviour, strength and ductility, the addition of short discontinuous and discrete fibres may provide a better solution.

Fibre reinforced concrete (FRC) can be defined as a composite material consisting of mixtures of cement, mortar or concrete and discontinuous, discrete, uniformly dispersed suitable fibres that are uniformly distributed and randomly oriented. Fibres are classified into steel fibres, glass fibres, synthetic fibres and natural fibres. Polypropylene fibres are one of the synthetic fibre. The polypropylene fibres are used as secondary reinforcement. The tremendous use of polypropylene fibre is increased in the construction field because, addition of fibres in concrete improves the toughness, flexural strength, tensile strength and impact strength. The various application of polypropylene fibre reinforced concrete in pavements, tunnel lining, bridge decks, off shore structures, machine foundations etc. In the last three decades, supplementary cementitious materials such as fly ash, silica fume, metakaolin and ground granulated blast furnace slag are some of the pozzolanic materials have been utilized as the cement replacement materials to enhance the strength and durability characteristics of concrete while comparing with ordinary Portland cement (OPC). Also it used to overcome the problem of disposal of waste from steel industries.

The present study is based on the behaviour of micro and macro polypropylene fibre reinforced concrete with partial cement replacement by GGBFS in comparison with conventional concrete. Saidani et al. [1]proposed the behaviour of the normal concrete and concrete with different types of fibre (steel, macro-polypropylene and micro-polypropylene fibres) have been studied. The results show that the use of steel, macro-fibre, and micro polypropylene change the failure types to ductile failures, thus overcoming the brittleness problem of the concrete, and improves the split tensile strength.Alhozaimy et al. [2] has been studied the mechanical properties of polypropylene fibres and the effect of pozzolans. They was found that the effect of polypropylene fibre volume fraction provide a negative impact on compressive strength and flexural strength while effect of pozzolan increased average compressive strength of about 17% and 23% for plain and fibrous concrete. He concluded that fibres are more effective in the presence of pozzolans.Yap et al. [3] focused the study on the enhancement of mechanical properties of oil palm shell concrete (OPSC) with the addition of nylon and polypropylene fibres. Result shows polypropylene fibres improved the mechanical properties of OPSC without reduction in density than nylon fibres.Behfarnia et al. [4] investigated that the application of high performance polypropylene fibers (HPP fibers) in concrete lining of water tunnels. The results also showed that with application of HPP fibers, durability and serviceability of the concrete linings can be improved.Mo et al. [5] studied that effective utilization of Ground Granulated Blast Furnace Slag GGBS in Oil Palm Shell Concrete (OPSC). The result shows that compressive strength of OPSC decreased by the increase of GGBS content for 28 days in the range of 33-44 MPa. Split tensile strength was found to be in the range of 2.3-3.5 MPa and flexural strength decreased with the increase of replacement of OPC with GGBS.Arivalagan et al. [6] studied the replacement of cement by GGBS of 20%, 30% and 40% by weight of cement. It was found that 20% of cement replacement by GGBS shows high compressive strength, flexural strength and split tensile strength. Strength was increased due to the filler effects of GGBS. Workability of concrete was also increased by the increasing amount of GGBS. Karri et al. [7] selected varying dosage of GGBFS such as 30%, 40% and 50% by weight of cement for M20 and M40 grade concrete. It was found that 40% replacement of cement by GGBFS shows maximum compressive strength, split tensile strength and flexural strength. Pandey et al. [8] studied that workability increases with increasing GGBFS replacement level. Compressive strength, flexural strength and split tensile strength decreases with increasing dosage of GGBFS at early ages and increasing strength at later ages.

The objective of this paper is to study mechanical properties of GGBFS as partial cement replacement in micro and macro polypropylene fibre reinforced concrete and to find out the bond strength of specimen using pull out test. Comparing results with control mix.

2.. MATERIALS

The materials used in the experimental study are locally available cement, sand, coarse aggregate, mineral and chemical admixtures. The chemicals used in the present investigation are of commercial grade.

A. Cement

Ordinary Portland Cement grade 53 was used for this investigation. The cement used was dry, powdery and free from lumps. All possible contact with moisture was avoided while storing cement. The properties of cement were shown in the Table 1.

Table 1 Properties of cement

Properties	Results
Cement	53 grade OPC
Specific gravity	3.15
Fineness	3.24%
Initial setting time	92 minutes
Final setting time	440 minutes
Standard consistency	32%

B. Aggregates

The crushed gravels were used as coarse aggregate of maximum size 20mm. The specific gravity of coarse aggregate was 2.70 and fineness modulus was 7.09. The rounded shape sand of size less than 4.75mm was used. It comes under zone II. The specific gravity and fineness modulus of fine aggregate was 2.62 and 3.19 respectively.

C. Water

Tap water has been used for mixing of concrete ingredients and curing of concrete specimens.

D. Polypropylene (pp) Fibres

- Micro- polypropylene fibre: The fibre consists of monofilament polypropylene fibre have a length of 6mm and diameter of 18µm. Specific gravity of micro ppfibre was 0.91g/cm^3. It reduces frequency of plastic cracking, improve durability and reduce permeability and decrease plastic settlement cracking over rebar. Fig. 1 a illustrates micro polypropylene fibres.

- Macro- polypropylenefibre: This fibre is also known as macro synthetic fibre or plastic polypropylene fibre. It has a length of 50mm and 1mm diameter shown in Fig. 1 b. Specific gravity of macro ppfibre was 0.92g/cm^3. It consists of continuous corrugated profile throughout its length.

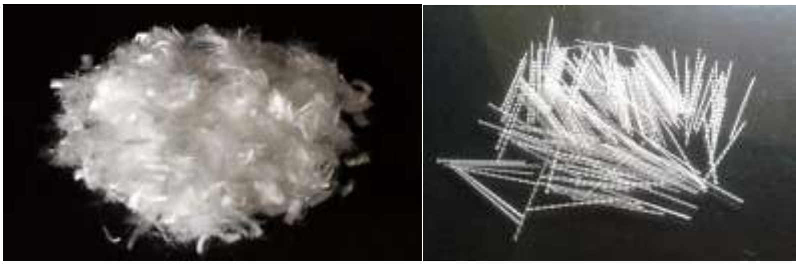

Fig. 1 Different type of fibres used in concrete (a) Micro-polypropylene fibre (b) Macro-polypropylene fibre

E. GGBFS

Ground Granulated Blast Furnace Slag (GGBFS) is the by-product from the steel industries used for the replacement of cement. The colour was off white as shown in Fig. 2. The specific gravity of GGBFS was 2.85.

Fig. 2 GGBFS

F. Super plasticizer

CONPLAST SP430 was used as super plasticizer. The effect of super plasticizer lasts only for 30 to 60 minutes depending on composition and dosage and is followed by rapid loss in workability. It facilitates production of high quality concrete. The colour was brown and was in liquid form. Specific gravity was 1.220 to 1.225 by weight of cement.

G. Mix proportion

The mix design was conducted based on IS 10262:2009. The grade of concrete prepared for the experimental study was M25. The proportion used in the investigation, after necessary adjustments made on the trial mixes, it shown in Table 2.

Table 2 Mix proportion details

Mix	C: F.A : C.A	w/c	% fibre added	% GGBFS added	Cement (Kg/m^3)	Fine aggregate (Kg/m^3)	Coarse aggregate (Kg/m^3)	Water (Kg/m^3)
M25	1 : 2 :2.10	0.40	0-4	30-60	442.5	885.56	912.6	177

3.RESULTS AND DISCUSSIONS

The procedure was taken in two stages. First, optimum calculation of micro ppfibre and macro ppfibre reinforced concrete. Second, tests on concrete mix with GGBFS content.

A. Optimum calculation of micro pp fibre and macro pp fibre reinforced concrete

Micro ppfibres and macro ppfibresin concrete with different percentages i.e. 0.5%, 1%, 2% and 4% by the volume of concrete and study the 7 days and 28 days compressive strength. Based on the results, the optimum content was determined.

- **Test on fresh concrete**

The workability of various mixes was assessed by determining the slump cone test as per the IS 1199:1959 specification.With high volume fraction of the macro-polypropylene fibres of 50mm length and the micro-polypropylene fibres of 6mm length, both types decrease the workability of the concrete. From this it is clear that macro fibre concrete is more workable when comparing with micro fibre concrete. The Fig 3 shows the slump cone test results.

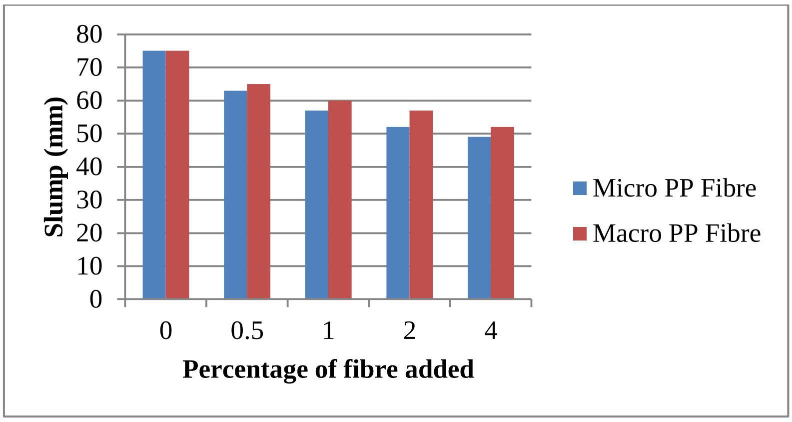

Fig. 3 Slump variation with fibre dosage variation

The normal concrete slump was observed within the range at 75mm. With the 1% fibre content of micro-fibres, the slump decreased compared to the normal concrete. With the increase of the macro-fibre dosage to more than 2%, the slump dropped. Micro fibre content more than 1%, mix appeared to be sticky and relatively dry after the removal of slump cone. From the workability test, large amount of water sucked by micro fibres and the aggregate particles were segregated. The macro-polypropylene fibre was easier to consolidate and did not dry the concrete mixture.

- **Cube compressive strength**

The concrete cube specimens of size 150×150×150 mm were tested for each mix. The cube compressive strength of the mixes was observed for 7 and 28 days. The tests were according to the I.S Specifications. Fig 4 shows the variation as the fibre dosage increases with age.

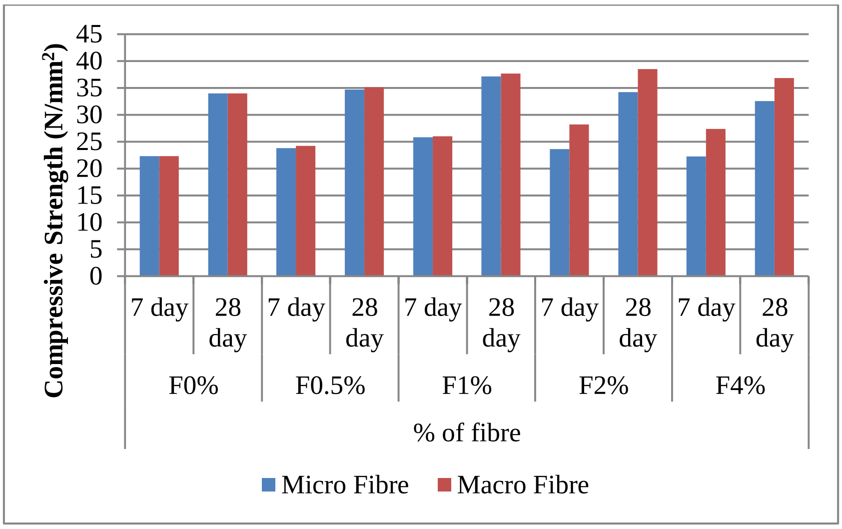

Fig. 4 Test results of 7 and 28 days compressive strength of fibre reinforced concrete

From the above results it is observed that out of 0% to 4% micro-polypropylene fibre, 1% fibre has higher compressive strength for 7 days and 28 days. It is also observed that 2% macro-polypropylene has higher compressive strength out of 0% to 6% for 7 days and 28 days. The long fibre acts as an anchor in between the cement paste, fine and coarse aggregate and shows higher compressive strength than micro fibres. Microfibers fail to dissolve homogeneously inside concrete, resulting reduction in strength.

B. Tests on concrete mix with GGBFS content

GGBFS were added in constant dosage of fibre concrete with varying percentage such as 0%, 30%, 40%, 50% and 60% by weight of cement.

- **Fresh concrete properties**

The fresh concrete properties were observed using slump test. The workability was found to decreasing as the GGBFS content increased. Fig. 5 shows the slump value of varying percentage of GGBFS in constant dosage of fibre.

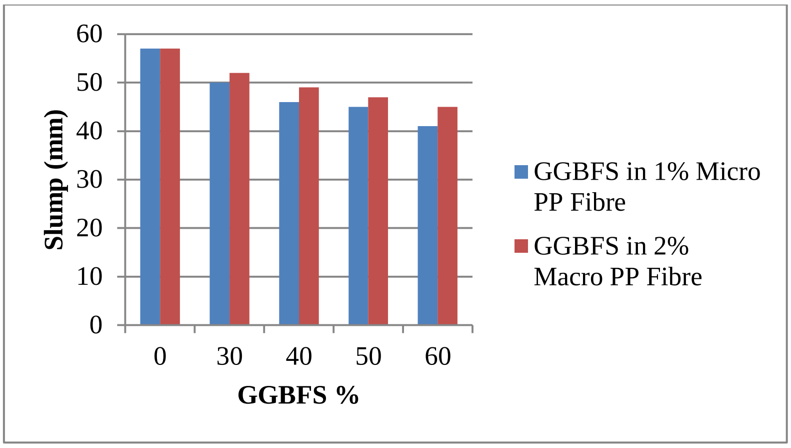

Fig. 5Slump value for varying percentage of GGBFS in fibre reinforced concrete

It has been observed that slump decreases by increasing GGBFS content in fibre concrete. When the GGBFS content increases water/binder ratio decreases workability also decreases.

- **Cube Compressive Strength**

The cube compressive strength of the mixes was observed for 7 and 28days. The tests were according to the I.S Specifications. Fig 6 shows the variation as the GGBFS dosage increases with age.

GGBFS used as a partial cement replacement of 30% to 60% in the fibrous concrete. It was observed that cement replaced with 40% GGBFS shows higher strength in 7 and 28 days. Compressive strength of GGBFS fibre concrete was increased due to the filler effects of GGBFS. The compressive strength increased up to 40% and excess amount of GGBFS decrease the strength. The low quantity of cement combined with high replacement levels of GGBFS reduced the formation of calcium silicate hydrate (CSH) gel due to the hydration of OPC, resulting in lower compressive strength.

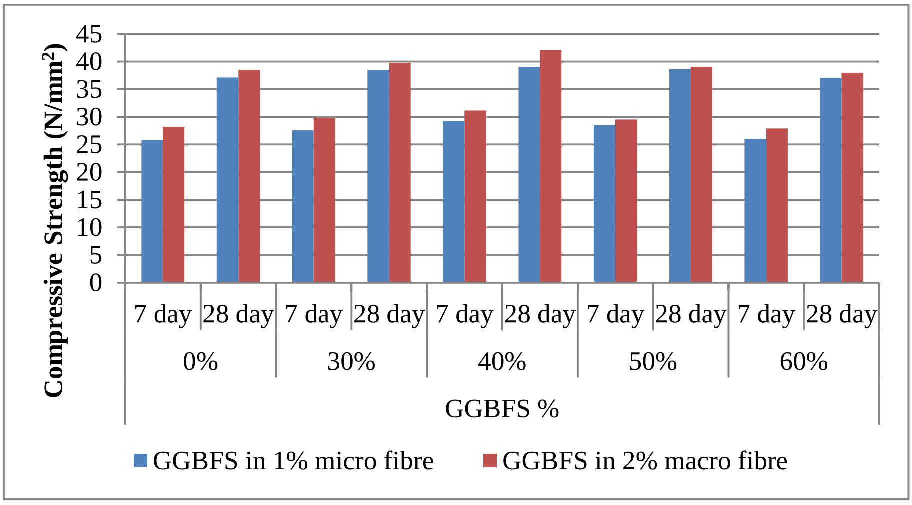

Fig. 6 Compressive strength of varying percentage of GGBFS in fibre reinforced concrete

- **Flexural strength**

The flexural strength of normal concrete, GGBFS micro pp fibre concrete and GGBFS macro pp fibre concrete were determined by conducting flexure test as per IS 516 – 1959 on beam specimens of size 100×100×500 mm. The results obtained are given in Table 3.

Table 3 Flexural Strength at 7 days and 28days

Mix Designation	Strength at 7 days	Strength at 28 days
Control mix	4.28	5.56
GGBFS + micro pp	5.67	7.4
GGBFS + macro pp	6.17	8.02

The results showed that there was increase in flexural strength for GGBFS macro pp fibre concrete than GGBFS micro pp fibre concrete and normal concrete. The flexural strength of beam was increased due to the bridging effect of macro fibre and filler effect of GGBFS. Macro fibre acts as effective crack arrester than micro fibres.

- **Split tensile strength**

For split tensile strength test, cylinder specimens of dimension 150 mm diameter and 300 mm length were casted. The results obtained are shown in Table 4.

Table 4 Split Tensile Strength at 7 days and 28days

Mix Designation	Strength at 7 days	Strength at 28 days
Control mix	2.64	3.43
GGBFS + micro pp	3.14	4.15
GGBFS + macro pp	4.28	5.6

The split tensile strength of the mixes was showing an increasing trend when compared to that of without fibre content. The increase in split tensile strength shows that the added fibre in the matrix act as crack arresting mechanisms and improve tensile strength of concrete. From the above results it was observed that GGBFS macro pp fibre reinforced concrete shows high tensile strength than GGBFS micro pp fibre reinforced concrete.

- **Pullout test**

Pullout was used for determining the bond strength of hardened concrete in test specimen. The testspecimens consist of concrete cubes of size 100 x 100x 100 mm with a single reinforcing bar embedded vertically along a central axis in each specimen. The test specimen shall be mounted in a suitable testing machine in such a manner that the bar is pulled axially from the cube. Bond strength of various mixes was calculated by using equation 1 and Table 5 shows steel bond strength and failure type of various mixes.

$$\text{Bond strength} = \frac{w \times 1000}{2\pi RL} \quad (1)$$

Where, w is theload taken by the bar, tonnes

R is the radius of bar, cm

L is the Length of embedded bar, cm

Table 5 Steel bond strength and failure type of various mixes

Mix Designation	Bond strength (Kg f/cm^2)	Failure type
Control mix	7.21	Split failure
GGBFS + micro pp	7.79	Steel break off
GGBFS + macro pp	8.53	Steel break off

From the above results it was observed that split failure for control mix and steel break off for fiber reinforced concrete specimen. In case of fiber reinforced specimens, fibers are capable of imparting toughness to the concrete specimen and arrest the formation of cracks. They are also capable of imparting higher bond strength in concrete by bridging the matrix together.

4. CONCLUSIONS

- The optimum dosage of micro pp fibre and macro pp fibre was found to be 1% and 2 % respectively.
- Macro pp fibre concrete was found to be more tensile and workable than micro pp fibre concrete.
- Micro and macro pp fibre addition in GGBFS concrete, compressive strength was increased up to 40% replacement level due to the filler effects of pozzolan.
- Flexural strength and split tensile strength of macro pp fibre concrete higher values than micro pp fibre and control mix. The strength of beam was increased due to the bridging effect of macro fibre and filler effect of GGBFS.
- From the pullout results, split failure was observed in the case of control mix and steel break off was observed in case of fiber reinforced concrete specimen.
- The use of GGBFS as the cement replacement reduces cement content in the concrete and also reduces the cost of construction.
- Macro pp fibre with GGBFS shows good mechanical properties than micro pp fibre with GGBFS.
- Fibre increases both compressive strength and tensile strength. As the GGBFS is an industrial waste, used in this type of concrete makes more ecofriendly and will give more life to concrete.

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