

Effect of Polypropylene fibers over GGBS based Geopolymer Concrete Under Ambient Curing

A. Chithambar Ganesh, M. Muthukannan

Abstract- Geopolymer is being widely used in the construction industry in the recent years. Ground Granulated Blast Furnace Slag (GGBS) based geopolymer concrete is the most suited for ambient curing conditions. It has been perceived that geopolymer concrete is brittle in nature. This brittleness could be reduced by the augmentation of fibers. The objective of this paper is to study the effect of incorporation of polypropylene fibers in Geopolymer Concrete. The various proportions of the ingredients of Geopolymer concrete were calculated from the B.V.Rangan mix design of Geopolymer Concrete. Based on the previous research works conducted by the author, optimum molarity of the sodium hydroxide solution to be used as a part of alkaline activator solution was taken as 13M. Polypropylene fibers were added to the matrix in the ratios from 0.1% to 0.6%. Cubical, Cylindrical and Prism Specimens were casted and subjected to ambient curing. Compaction factor test was performed to measure workability of fresh concrete and tests such as compressive strength test, split tensile strength test and flexural strength test were performed to assess the mechanical properties of hardened Fiber Reinforced Geopolymer Concrete. Tests were carried after curing period of 7 days & 28 days and the results were tabulated. Being a low modulus fiber, the fiber possesses a good post cracking behaviour and reduce the brittleness of the Geopolymer Concrete. The incorporation of polypropylene fibers increases the compressive strength and flexural strength initially and then decreases.

Keywords: Polypropylene fibers, GGBS based Geopolymer Concrete, Geopolymer Concrete, Ambient Curing

1. INTRODUCTION

Concrete plays a vital role in construction engineering industry. But the production of cement, an essential ingredient in concrete, involves the release of large amount of harmful gases into the environment [1]. 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]. Meritoriously this GGBS is a pozzalonic material and this could be utilized to manufacture Geopolymer concrete with the help of alkaline activator solution [3]. Geopolymer Concrete possess better engineering properties than ordinary concrete [4]. Fibers are usually used in concrete to increase ductility and to control plastic shrinkage cracking and drying shrinkage cracking [5-6]. Briefly, There are two types of fibers named low modulus and high modulus fiber. [7].

These fibers can be added in the concrete to alter its engineering properties. Low modulus fibers are found to increase the post cracking behaviour of the concrete [8].

It has been reported in many literatures that Geopolymer Concrete possess more brittleness than ordinary concrete [9-10]. This brittleness can be abridged by the addition of fibers [11]. They also lower the permeability of concrete and thus reduce bleeding of water [12]. Seyed et al., [13] investigated the performance of polypropylene fibers in geopolymer concrete made of rice husk ash. Results reported a significant increase in split tensile strength and flexural strength at the optimum percent of fiber addition with a small increase in compressive strength. Ziad and Jack [14] studied the fresh and hardened properties of concrete reinforced with 0.5 inch and 0.75 inch long polypropylene fiber. Workability decreased with fiber addition. Usage of 0.75 inch polypropylene increased post-peak resistance than 0.5 inch long polypropylene fiber. There was an increase in mechanical properties at the optimum fiber proportion. Leung and Balendran [15] experimentally studied the fresh properties of polypropylene fiber reinforced concrete. It was reported that incorporation of polypropylene fibers decreased the workability and setting time. Polypropylene fibers can be mixed with ease as they are hydrophobic in nature [12, 16]. Polypropylene short fibers are added in small fractions varying from 0.1 to 1 percentage of the concrete [17]. The addition of such fibers attenuates the shrinkage, micro cracks and augments the abrasion resistances by 25% [18]. The objective of this paper is to investigate the effect of incorporation of polypropylene fibers in the GGBS based Geopolymer concrete by studying its fresh and hardened properties. The study aims in enhancing the properties of geopolymer concrete with the use of low modulus fiber.

2. MATERIALS

The materials used to manufacture fiber reinforced geopolymer concrete specimens are Ground Granulated Blast Furnace Slag (GGBFS), Coarse aggregate (20mm), Fine aggregate (M-Sand), Alkaline activator solution (Sodium hydroxide solution and sodium silicate solution). The various materials were proportioned by using B.V. Rangan's proposed mix design which was relevant to IS 2062-2009. [3]

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2.1 GGBFS

Ground Granulated Blast furnace Slag (GGBS) is a by-product obtained from the blast furnace during the manufacture of iron. In this work GGBS obtained from salem steel plant, was used as the alumina silicate base material. The specific gravity of GGBS was calculated using pycnometer test as 2.9.

2.2 Alkaline Liquid

A concoction of sodium hydroxide solution and sodium silicate solution was chosen as alkaline activator solution [5]. Concentration of Sodium hydroxide was selected as 13Molarity from the previous research works conducted by the author. Sodium hydroxide of 13M concentration consists of $13 \times 40 = 520$ grams of sodium hydroxide pellets dissolved per liter of distilled water. Sodium silicate solution was in gel form. Both the solutions were mixed 24 hours prior to casting and stirred well. Specific gravity of Sodium hydroxide solution is 2.1 and that of Sodium silicate solution is 1.5.

2.3 Coarse Aggregate

Coarse aggregate of 20mm size were used for the research work. Fineness modulus of Coarse Aggregate was found to be 6.10. Bulk density and Specific gravity of Coarse aggregate was found to be 1456 kg/m³ and 2.7.

2.4 Fine Aggregate

Manufactured sand which was obtained as the by-product of crushing process in quarries was used as Fine aggregate. It comes under zone- III having fineness modulus of 2.36, bulk density of 1702 kg/m³ and specific gravity of 2.8.

2.5 Polypropylene fiber

Polypropylene is one of the cheapest & abundantly available polymers with high chemical resistance. It has high boiling point about 1650C making it suitable to be used under any condition. The fiber length is of 6mm and diameter is of 0.1mm was used. Aspect ratio = Length of fiber/ diameter of fiber = $6/0.1 = 60$

3. EXPERIMENTAL PROGRAM

The experimental work consists of casting of specimens with and without polypropylene fibers in the form of cubes, cylinders and prisms to determine the mechanical properties of the fiber reinforced geopolymer concrete at the end of 7 and 28 days.

3.1 Mixing and casting of specimens:

The concrete mix proportion was based on B.V Rangan and is shown in table 1. Initially GGBS and M-Sand were mixed in pan mixer and is followed by the addition of coarse aggregate. Then the alkaline solution was added to the mix and polypropylene fibers were dispersed randomly into the mix and mixed for about 5minutes. The addition of fibers were found to reduce the workability.

TABLE 1 CONCRETE MIX

Materials	Mass (kg/m ³)
GGBFS	550
M-Sand	587
Coarse aggregate	907
Sodium silicate	239.64
Sodium hydroxide	95.86
Water	16.5

3.2 Specimen details:

The cubical specimens of size 100X100X100mm, cylindrical specimens of size 100X200mm and prism specimens of size 500X100X100mm were casted. The total number of specimens casted was tabulated in table 2.

TABLE 2 DETAILS OF SPECIMEN

Percentage of fibers (%)	Number of Specimens		
	Cubes	Cylinders	Prisms
0.1	6	6	3
0.2	6	6	3
0.3	6	6	3
0.4	6	6	3
0.5	6	6	3
0.6	6	6	3
Total	36	36	18

4. TEST RESULTS AND DISCUSSION:

The compaction factor test was carried out to assess the fresh property of fiber reinforced Geopolymer concrete. The various hardened test such as compression test, split tensile test and flexural test were carried out to determine the mechanical properties of polypropylene fiber reinforced geopolymer concrete.

4.1 Compaction factor test:

The compaction factor test was carried out for various percentages of polypropylene fibers and the readings were tabulated in table 3.

TABLE 3 COMPACTION FACTOR

Percentage of fibers (%)	Compaction factor
0%	0.88
0.1	0.86
0.2	0.84
0.3	0.83
0.4	0.83
0.5	0.82
0.6	0.80

The decrease in the compaction factor values are shown in the Figure1. The decrease in compaction factor values indicates the decrease in workability.

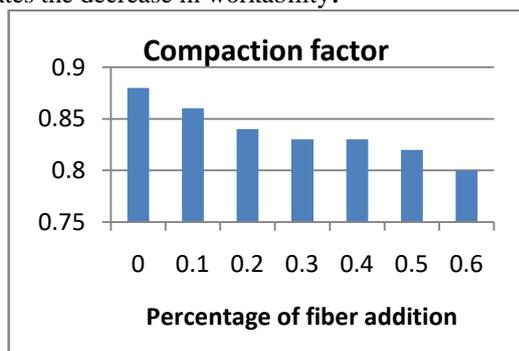


FIGURE 1 COMPACTION FACTOR

4.2 Compression test

The compression test was carried out for the addition of various percentage of polypropylene fibers and tested in two regimes for 7 days and 28 days. The readings were tabulated in table 4 respectively.

TABLE 4 COMPRESSIVE STRENGTH FOR 7DAYS AND 28DAYS

Percentage of fibers (%)	Compressive strength (Mpa)	
	7 days	28 days
0	19.60	48
0.1	21.54	49.65
0.2	22.35	50.40
0.3	22.90	52.35
0.4	24.60	54.6
0.5	24.90	56.3
0.6	24.5	55.7

The values are plotted in graph and shown in Figure2 for the better interpretation of the comparison of 7 days and 28 days strength gain.

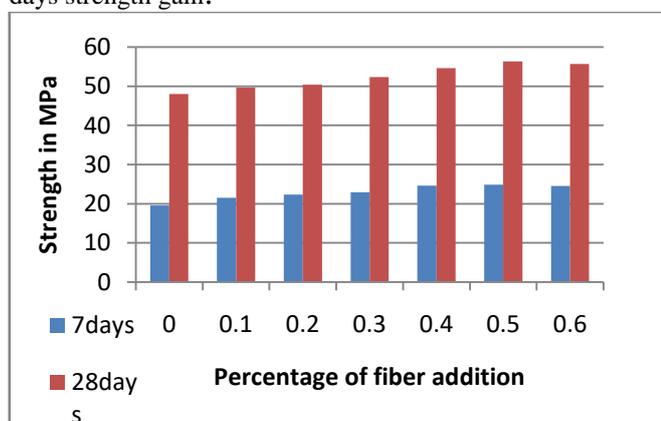


FIGURE 2 COMPRESSIVE STRENGTH AT 7DAYS AND 28DAYS

4.3 Split tensile test

The split tensile strength was calculated for the addition

of different percentages of polypropylene fibers and tested for both 7 days and 28 days. The readings were tabulated in table 4 respectively.

TABLE 5 SPLIT TENSILE STRENGTH FOR 7DAYS AND 28DAYS

Percentage of fibers (%)	Split tensile strength (MPa)	
	7 days	28 days
0	1.2	3.5
0.1	1.22	3.64
0.2	1.26	3.72
0.3	1.3	3.9
0.4	1.45	4.1
0.5	1.7	4.3
0.6	1.55	4.1

The values are plotted in graph and shown in Figure2 for the better interpretation of the comparison of 7 days and 28 days strength gain.

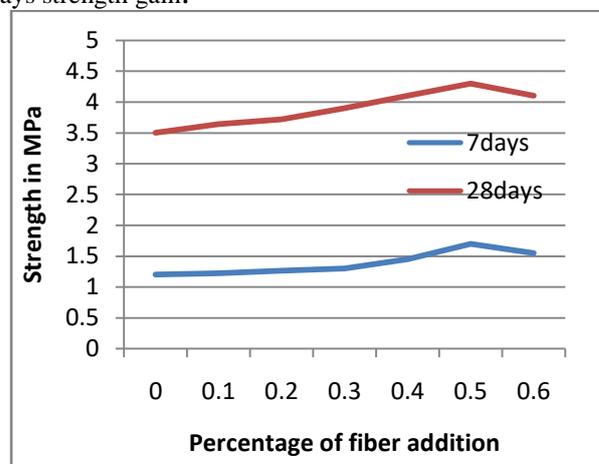


FIGURE 3 SPLIT TENSILE STRENGTH

4.4 Flexural strength test

Flexural strength of the fiber reinforced geopolymer concrete was calculated by casting and testing the prism specimens after 28days. The average values are plotted in the graph for better interpretation. The graph is shown in the Figure4.

TABLE 6 FLEXURAL STRENGTH FOR 7DAYS AND 28DAYS

Percentage of fibers (%)	28 days strength
0	5.45
0.1	5.51
0.2	5.55

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0.3	5.62
0.4	5.68
0.5	5.7
0.6	5.65

The above values are plotted in graphical form in Figure 4 for better understanding of the effect of addition of fibers over the flexural property of the fiber reinforced geopolymer concrete specimen.

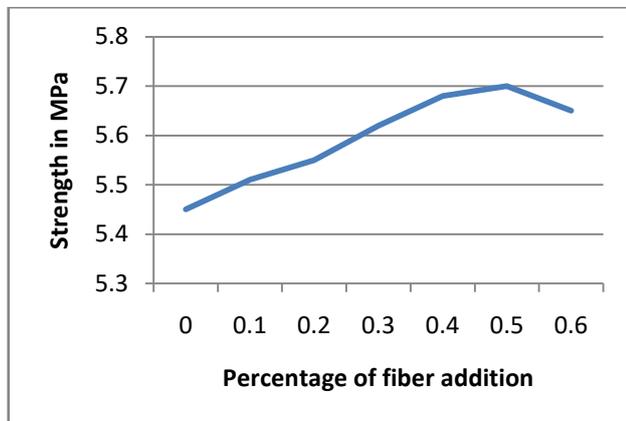


FIGURE 4 FLEXURAL STRENGTH AT 28 DAYS

5. CONCLUSION:

Based upon the above discussions, the following conclusions could be drawn,

The geopolymer has low workability and it further decreases with the increase in the addition of polypropylene fibers.

The incorporation of fibers increases the compressive strength and split tensile strength in small proportions till 0.5% and then it decreases. This fall in the characteristic strength could be due to the more complex matrix due to the presence of fibers. The presence of fibers add more air voids inside the matrix that results in the decrease of the mechanical properties after optimum percent of utilization.

There is a significant increase in the flexural strength of the polypropylene fiber reinforced geopolymer concrete with the increase in the addition of polypropylene fibers till 0.5%.

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