Effect of steel fiber and poly propylene fiber on the strength properties of fly ash based Geopolymer concrete

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Abstract – *In order to improve the tensile strength and durability properties of Geopolymer concrete addition of fibre particles play a vital role in the field of modern concrete technology. In this research, combined effects of steel fibre and polypropylene fibre were studied with different aspect ratios. The crimped steel fiber with aspect ratio 60 and polymeric synthetic fibers of aspect ratio 240 were used. Alkaline liquids (Sodium Hydroxide and Sodium, Silicate solution) together mixed with proper ratio (Ratio of Na2SiO3 to NaOH is 2.50). Sodium hydroxide solution was made by dissolving NaOH solid in water. Sodium hydroxide solutions were prepared for 12 molar mass of solid depends on the concentration of solution. For 12 molar solution 480gm of NaOH pellet were mixed in 1000 ml of water.*

Key Words: Steel fiber, poly propylene fiber, geopolymer concrete, fly ash, alkaline liquid.

1. INTRODUCTION

Concrete is the second highest consumable material in the world next to water. As construction increases demand of concrete increases so the demand of Portland cement also increases. Around 65% of global warming is contributed by carbon dioxide among all greenhouse gasses due to the production of cement. The cement industries is also one of the responsible for the emission of carbon dioxide that is one tone of carbon dioxide is emitted in production of one tone Portland cement to the atmosphere The utilization of the other cementing materials such as fly ash, silica fume, granulated blast furnace slag, rice husk etc. are developed as the alternative binders to the Portland cement. In the meantime the Geopolymer technology was introduced. These new binders which are alternative materials to blended cement and concrete are obtained by the alkaline activation or geopolymerization of different industrial products. To improve the mechanical performance of Geopolymer concrete the efficient method is to add the fibers in concrete. Adding of these fibers will arrest the crack, also it is well known for the increase in facture toughness provided by fiber bridging on the main crack plane prior to crack extension. The steel fiber and polypropylene fibers are used in this experiment and study the mechanical properties and behavior of Geopolymer concrete.

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1.1 Scope of the work

- The experimental work was conducted to obtain the strength of fly ash based GPC at temperature of 60ºC.
- In this experimental work only one source of dry low calcium fly ash (class F) from the Raichur Thermal Power Station (RTPS) was used.
- Sodium silicate solution and Sodium hydroxide pellets were procured commercially from local vender.
- Fiber admixture like steel fiber and polypropylene fiber are introduced in the concrete.
- To prepare the concrete that exhibits environmental friendly and minimize the global warming.
- Manufacture and test of compressive strength, split tensile strength and flexural strength of geopolymer concrete beams with fiber reinforced and without fiber reinforced by changing the volume fraction of the fiber.

2. MATERIALS & METHODS

2.1 Fly ash

Fly ash used in this study was low calcium (class F) dry fly ash from Raichur Termal Power Station, Shakthinagar, Karntaka. Fly ash is the alumino silicate source material used for the synthesis of geo polymeric binder.

- Specific gravity : 2.36

- Fineness (air permeability apparatus) : 426.038 cm^2/gm

Fig -1: Low calcium fly ash

2.2 Aggregates

Locally available aggregates were used comprising of 20mm, 12mm and 6mm and fine aggregate passing through 4.75 mm all aggregates were in saturated surface dry condition. The course aggregates were crushed granite type and the fine aggregate used in this study was manufactured sand.

Table -1: Physical characteristics of course aggregate

Sl. No.	Specific gravity	Fineness modulus	Flakiness index	Density kg/m^3	
				loose	Rodded
1	2.63	7.04	28.4%	1228	1504

Fig -2: Coarse aggregate

Fig -3: Fine aggregate

Table -2: Physical characteristics of fine aggregate

Sl. No.	Specific gravity	Fineness modulus	Density kg/m^3	
			loose	Rodded
1	2.56	2.506	1350	1617

2.3 Alkali Activator

In the alkaline activator substances of Silica are dissolved in strong alkaline conditions with high P^H. During the dissolution of the silica and aluminum the alkaline solution is active and plays a main role in the condensation process (Lindgård et al. 2012). Sodium hydroxide, potassium hydroxide, sodium silicate and potassium silicate are the common activators used for geopolymer. Alkaline liquid was framed by mixing sodium hydroxide (NaOH) solution and sodium silicate (Na2SiO3) solution. Sodium hydroxide solution was made by dissolving NaOH solid in water. Sodium hydroxide solutions were prepared for 12 molar mass of solid depends on the concentration of solution. For 12 molar solution 480gm of NaOH pellet were mixed in 1000 ml of water. Where 1M = 40gm of solid in 1000 ml water, during the process of mixing lot of heat get liberated when dissolving NaOH pellet in water. Therefore solution is kept for cool for 24 hour; this duration is required for polymerization process of alkaline liquids.

2.3.1 Sodium Hydroxide (NaOH)

Caustic soda is the other name to Sodium hydroxide, which is manufactured by the electrolysis of sodium chloride brine in a membrane or diaphragm electrolytic cell (Occidental Chemical Corporation 2000). Paper industry and manufacturers that need an alkaline based material are the largest users and buyers of caustic soda. Sodium hydroxide (NaOH) is accessible in four varieties: beads, flakes, compounders and solid castings. All the forms have the same chemical composition.

Fig.4. Sodium Hydroxide flakes

2.3.2 Sodium Silicate Solution (Na2SiO3)

Alkali silicates Solutions are also termed as "water glass". Na_2SiO_3Solution can be produced in two ways one by dissolving alkali silicate pellets in hot water or second way is hydrothermally dissolving a reactive silica source, mainly silica sand, into the respective alkali hydroxide solution (PQ Europe 2004).

Fig.5. Sodium Silicate Solution

2.4 Super plasticizer

To improve the workability of fresh concrete super plasticizer are added which are high range water reducing naphthalene based super plasticizer Conplast SP 430.

- Conplast SP-430 is based on sulphonated naphthalene polymer.
- It is brown in color and instantly disperses in water.
- Conplast SP-430 has a minimum 12 month of durability when stored in normal temperature.

Fig.6. Conplast SP-430

2.5 Steel fibers

Steel fibers were used to increase the tensile strength of the Geopolymer concrete. It also act has a crack arresting material in concrete. The crimped steel fiber with aspect ratio 60 is used.

- Effective diameter : 0.5 mm
- Length: 30 mm
- Specific gravity more than: 7.86
- Melting point : 11210 C
- Aspect ratio : 60
- Density of steel fiber : 7850 Kg/m^3

Fig.7. Steel fibers

2.6 Poly propylene fiber

The fibers are polymeric synthetic fibers used to increase the tensile strength and to arrest the crack.

- Effective diameter : 0.05 mm
- Length: 12 mm
- Specific gravity more than: 1.0
- Melting point : 160o C
- Aspect ratio : 240
- Density of polypropylene fiber : 900 to 920 Kg/m3

Fig.8. Polypropylene fiber

2.7 Ratio of Steel fiber to polypropylene fiber

As the density of steel fiber is higher than the density of poly propylene fiber, (i.e. 1 part of polypropylene fiber equal to 8.72 times of steel fiber). The amount addition of fiber in this study is combination of steel and polypropylene fiber of 0.3%, 0.6% and 0.90%. So add 88.50% of steel fiber and 11.5% of poly propylene fiber to the amount of cementitious material (Fly ash). Following Table.3 gives the details of amount of fiber (steel fiber and poly propylene fiber separately) to be added to the geopolymer concrete at the time of preparation.

Table -3: Quantity of fiber required to the GPC mix

Material	Mass, kg/m^3		
	0.3%	0.6%	0.9%
Steel fiber (88.50%)	1.046	2.092	3.138
Poly propylene fiber (11.50%)	0.135	0.270	0.405

3. GEOPOLYMER CONCRETE MIX PROPORTION

3.1 Mixing

Fly ash and aggregates were first mixed together dry in 80 liters capacity pan mixer for around 2 to 3 minutes. Aggregates used in this mix are saturated surface dry condition. Get ready with alkaline liquid and super plasticizer, and the extra water if required to be added depends upon the workability or ease of the concrete. The liquid component alkaline liquid slowly added to the pan with continuous mix with the dry material, this mixing should be again continued up to 2 minutes. Then the steel fibers and poly propylene fibers were added after the addition of liquid in the pan mixer and mixed for 1 to 2 more minutes the same procedure were repeated for different volume fraction of fibers 0.3%, 0.6% and 0.9%. Then the prepared fresh concrete is poured in the workability mould and check the consistency of the concrete. If the Geopolymer concrete doesn't achieve required slump (80 to 100), discard the sample and prepare the fresh mix once again by repeating the same procedure with different mix proportions, then pour the concrete to the moulds prepared which are already oiled or greased and tamped as same as the conventional concrete.

Table -4: Quantity of materials as per the Mix design

Materials	Mass, kg/m^3		
Coarse aggregate	15%	20mm	277
	20%	12mm	370
	35%	6mm	647
Fine aggregate (30%)	554		
Fly ash	394.28		
Na_2Sio_3	112.66		
NaOH	45.06		
Super plasticizer	2.0 %		
Extra water	5 %		

Fig.9. Fresh Geopolymer Concrete mix

3.2 Curing of geopolymer concrete

After the preparation of fresh concrete the concrete is filled in the moulds and leave them 24 hours in the room temperature and then it is demoulded and kept in oven for curing at the temperature of 600 C for 24 hours. The curing temperature will also influence the strength of concrete. The chemical reaction occurs in the geopolymer concrete and the polymerization process takes place in the curing processes. The specimens were then allowed to ambient curing. Some researches noticed that even curing these specimens in oven for extended duration with constant temperature may increase the strength properties of the geopolymer concrete.

Fig.10. Oven curing of Geopolymer Concrete specimens

4. TEST RESULTS AND DISCUSSIONS

4.1 Compressive Strength on GPC

Concrete is used mostly for structural purposes such as foundations, columns, beams and floors and therefore must be capable in taking the loads that will be applied. One of the methods of checking its fit for purpose is to carry out a concrete cube test which measures the compressible cube strength of the concrete and relates directly to the required design strength specified. Compressive strength is in turn related with durability, higher compressive strength better is the durability.

Relevant Indian Standards: **As per IS: 516-1959**

Compressive strength = [P/A] N/mm^2

Cross sectional area of cube = 0.0225m^2 ,

Pace ratio = 5.2

Table -5: Compressive strength test results

Compressive strength (MPa)				
% of fibre	7 Days		28 Days	
	Steel Fibre	Poly-propylene	Steel Fibre	Poly-propylene
0	54.45	54.45	57.30	57.30

0.3	60.01	56.80	60.85	60.96
0.6	54.75	52.90	56.05	56.86
0.9	52.85	50.85	53.50	54.15

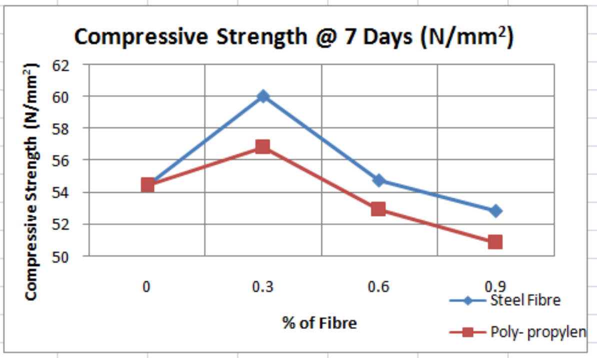

Chart -1: Compressive strength v/s % of fiber @ 7 days

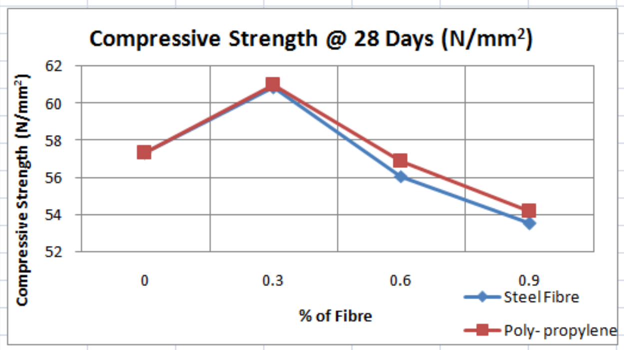

Chart -2: Compressive strength v/s % of fiber @ 28 days

4.2 Split Tensile Strength on GPC

Tensile strength is one of the basic and important properties of concrete. The concrete is not usually expected to resist the direct tension because of its low tensile strength and brittle nature. However determination of tensile strength of concrete is necessary to determine the load at which the concrete may crack. The crack is a form of tension or flexure failure.

cross sectional area of cylinder = [(2xP) / (πxdxL)] N/mm^2

Pace ratio = 4.8

Table -6: Split Tensile strength test results

Split Tensile strength (MPa)				
% of fibre	7 Days		28 Days	
	Steel Fibre	Poly propylene	Steel Fibre	Poly propylene
0	2.61	2.61	3	3.00
0.3	3.72	3.28	3.82	3.52
0.6	4.39	3.25	5.33	3.34
0.9	3.52	2.76	3.69	2.81

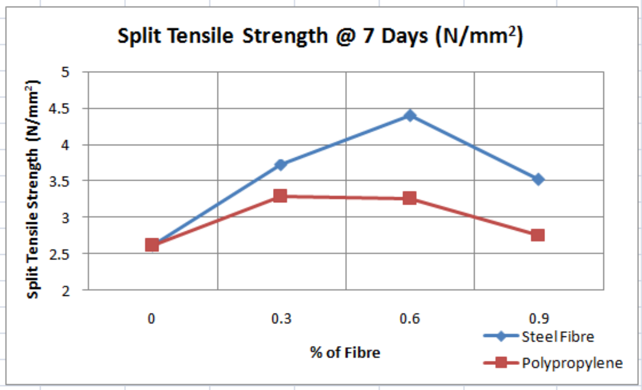

Chart -3: Split tensile strength v/s % of fiber @ 7 days

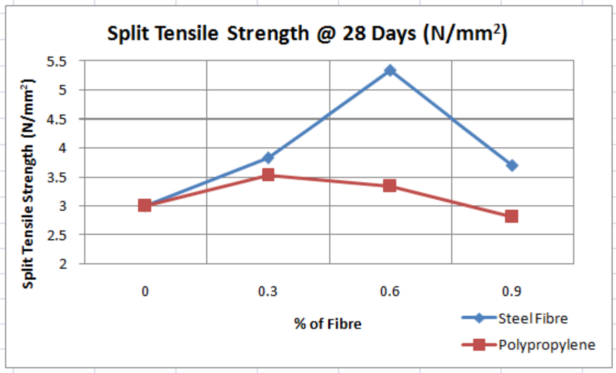

Chart -4: Split tensile strength v/s % of fiber @ 28 days

4.3 Flexural Strength on GPC

The flexural strength is expressed as "Modulus of Rupture" (MR). Flexural MR is about 12% to 20% of compressive strength. However, the best correlation for specific materials is obtained by laboratory tests. Flexural tests are extremely sensitive to specimen preparation, handling, and curing procedure. A short period of drying can produce a sharp drop in flexural strength. The beam is of a rectangular cross section of 100 mm x 100 mm and length of 500 mm. The size of test specimen was selected to suit the capacity of the testing machine in the laboratory. All beams were simply supported over a span of 500 mm. Fig. 4.19, 4.20 and 4.21 show the loading configuration and a typical test set-up for each test specimen. Flexural strength is the ability of a beam or slab to resist failure in bending.

Flexural strength= [(PxL) / (BxD²)] N/mm^2

Where,

P: Failure load ; L: Length of the beam

B: Breadth of the beam ; D: Depth of the beam

Table -7: Flexural strength test results

Flexural strength (MPa)				
% of fibre	7 Days		28 Days	
	Steel Fibre	Poly propylene	Steel Fibre	Poly propylene
0	6.62	6.62	6.87	6.88
0.3	9.75	9.88	10.375	10.125
0.6	10.75	7.62	11.25	7.75
0.9	10.37	6	10.625	6.25

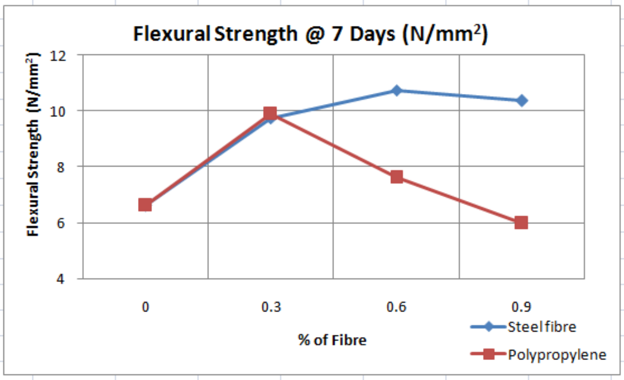

Chart -5: Flexural strength v/s % of fiber @ 7 days

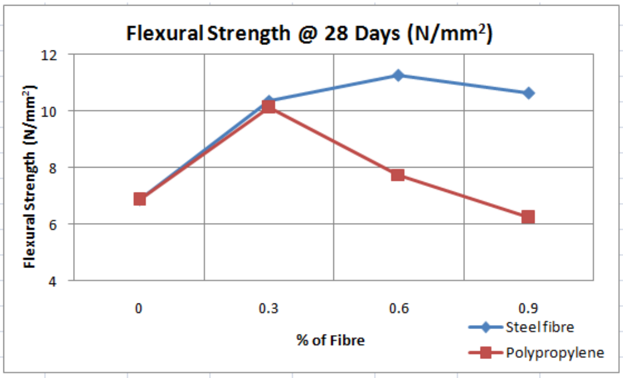

Chart -6: Flexural strength v/s % of fiber @ 28 days

5.0 CONCLUSION

- The geopolymer concrete is having good compressive strength as the % of steel fibres and polypropolyne fibre increased up to volume fraction of 0.3% and the strength decreases hence the optimum dosage of fibre is 0.3%.
- The geopolymer concrete with steel fibre increase the split tensile strength up to 0.6% of volume fraction and decreases as the fibre increased from 0.6% to 0.9% therefore the optimum dosage of steel fibre admixture was 0.6%.
- The geopolymer concrete with steel fibre increase the flexural strength up to 0.6% of volume fraction and decreases as the fibre increased from 0.6% to 0.9% therefore the optimum dosage of steel fibre admixture was 0.6%.
- The geopolymer concrete with polypropylene fibres increase the split tensile strength up to 0.3% of volume fraction and decreases as the fibre increased from 0.3% to 0.9% therefore the optimum dosage of steel fibre admixture was 0.3%.
- The geopolymer concrete with polypropylene fibre increase the flexural strength up to 0.3% of volume fraction and decreases as the fibre increased from 0.3% to 0.9% therefore the optimum dosage of steel fibre admixture was 0.3%.

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