A STUDY ON MECHANICAL PROPERTIES OF GEOPOLYMER CONCRETE REINFORCED WITH BASALT FIBER

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Abstract

Concrete is most used construction material. Construction industry uses most of the natural resources as it includes production of cement. It is the major contributing factor to the CO_2 emission, causing global warming. An alternate to the OPC has been found out known as Geopolymer concrete. It uses industrial waste material such as fly ash and ggbs instead of cement thereby decreasing impacts due to cement production. In this study both fly ash and GGBS are utilized in making Geopolymer concrete. Alkaline solution used is comprises of sodium silicate (103 kg/m^3) and Sodium hydroxide in the ratio of 2.5.sodium hydroxide of 10 molarity is used. Plain concrete is weaker in tension. Fibers are added to enhance the strength to the concrete to meet given serviceability requirements. Basalt fiber is considered a promising new material .it has good strength characteristics, resistance to chemical attack, sound insulation properties. It has wide range of applications like soil strengthening, construction of bridges, highways, industrial floors. In present study various proportions of basalt fibers added to the geopolymer concrete and compressive and split tensile strength of the different mixes were compared with the geopolymer concrete without basalt fibers. Fibers are added to the geopolymer concrete in the range of 0.5% to 2.5% at 0.5% increments. Compressive and tensile strength of different mixes compared with reference mix (0% fiber). From the results it is concluded that addition of basalt fibers at an optimum content to the geopolymer concrete can increase both compressive and tensile strength.

Keywords: *Basalt Fiber, Geopolymer concrete*

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1. INTRODUCTION

Concrete is the most utilized construction material around the world. It uses cement, fine aggregate and coarse aggregate as its constituents. Because of its extensive use the consumption of cement is increasing now days. Portland cement production is major contributing factor to the Carbon- die-oxide emissions, this causes global warming. So an alternate to the ordinary Portland cement has been developed and known as Geopolymer concrete. It uses waste material such as fly ash, blast furnace slag to produce concrete.

Plain Geopolymer concrete is weak in tension, because of concrete hold aggregates can crack, and cause concrete to break. Different type of fibers is added to the concrete to enhance the strength to the concrete. Fibers act as crack arrestors in concrete. The different types of fibers used in concrete are steel fibers, basalt fibers, glass fibers polypropylene fibers.

1.1 Geopolymer Concrete

Geopolymer concrete uses waste such as Fly ash, blast furnace slag instead of cement in a concrete. it is also known as “inorganic polymer”, it is emerged as greener concrete. In geopolymer concrete the binding action is produced by reaction of alkaline solution with the material that is rich in Silica (Si) and Alumina (Al).the alkaline solution is usually comprises of sodium silicate and sodium hydroxide solution. Geopolymerization process includes the reaction between alumina silicate oxides and alkali poly silicates by formation of Si-O-Al bonds. In Geopolymer concrete poly condensation of silica and alumina precursors and high alkali contents to attain structural strength.

1.2 Basalt Fibers

Basalt is a volcanic rock shaped by decompression softening of the world's mantle; Quarried basalt rock is pulverized, then washed and stacked into a receptacle, joined to feeders that move the material into dissolving showers in gas-warmed heaters. Liquid basalt streams from heater through a platinum-rhodium bushing with 200, 400, 800 or more gaps and the filaments can be drawn from the melt under hydrostatic weight. At that point an estimating is connected to the surface of the strands by a measuring tool. At long last, a winder permits understanding some extensive spools of consistent basalt fiber. New innovations in mechanical creation helps underway of basalt strands with costs equivalent or even not exactly the expense of glass fiber.

2. MATERIALS USED

Materials used in this study and their properties are given below.

2.1 Fly Ash

Fly ash is one of the waste products from the power plants. It is obtained in the process of burning of bituminous. It is rich in silica and alumina, this property of fly ash tends to use it in the preparation of geopolymer concrete. It is also a crucial ingredient in the creation of geopolymer concrete due to its role in the geopolymerization process. Fly ash is a powdery pozzolana. A pozzolana is a material that exhibits cemantacious properties when combined with calcium hydroxide. Fly ash separated from the combustion gases by dust collection system with the help of electrostatic precipitators.fly ash particles are finer, spherical diameter of the fly ash particles varies from 1µm to 150µm. Fly ash improves the quality of concrete. Fly ash improves workability, reduces water demand, and reduces segregation, bleeding and lowers heat of hydration. Over all it affects plastic properties of the concrete. Fly ash increases strength by reducing permeability (due to finer particles). The fly ash used in this study is Class F which is provided from Raichur Thermal Power Station (RTPS), Karnataka. The chemical composition is given in table 1.

Table -1: Chemical composition of fly ash

Sl. No.	Element Code	Percentage
1	SiO_2	61.2
2	Al_2O_3	28.22
3	CaO	2.94
4	MgO	0.93
5	MnO_2	0.01
6	TiO_2	0.69
7	K_2O	0.01
8	Na_2O	1.34
9	Fe_2O_3	3.91

2.2 GGBS

Ground-granulated blast furnace slag is gotten during the time spent extinguishing liquid iron slag (a by-result of iron and steel-production) from an blast furnace in water or steam to create a smooth, granular item that is then dried and ground into a fine powder. Ground granulated impact blast furnace slag (GGBS) is a waste product from the iron commercial industries. blast furnaces are encouraged with controlled blend of coke, iron mineral and limestone, and worked at a high temperature of around 1,500°C. At the point when iron-mineral, coke and limestone melt in the impact heater, liquid iron and liquid slag were delivered. The liquid slag is lighter henceforth coasts on the top while liquid iron is kept at base. The liquid slag contains generally silicates and alumina from the first iron metal, consolidated with a few oxides from the limestone. The path toward pulverizing the slag incorporates cooling of fluid slag through high-weight water planes. This rapidly smothers the slag and structures granular particles all around not more noteworthy than 5 mm. The quick cooling keeps the course of action of greater jewels, and the consequent granular material includes around 95% non-crystalline calcium-alumino silicates. In this study the GGBS is taken from JSW steel commercial enterprises.

Table -2: Chemical composition of GGBS

Sl. No.	Parameter	Percentage
1	Cao	37.34
2	Al_2O_3	14.42
3	Fe_2O_3	1.11
4	SiO_2	37.73
5	MgO	8.71
6	MnO	0.02
7	Sulphide	0.39
8	LoI	1.41
9	Insoluble residue	1.59
10	Glass content	0.92

2.3 Basalt Fibers

Basalt is a volcanic rock and can be chopped into small particles then formed into continues or chopped fibers. Basalt fiber has a higher working temperature and has a good resistance to chemical attack, impact load, and fire with less poisonous fumes. These fibers are used in wide range of applications such as strengthening of soils,construction of highways,bridges and industrial floors,retrofitting activities etc.

Table -3: Properties of basalt fibers

Properties	Value
Density	2630 kg/m^3
Tensile Strength	3200 -3850 M Pa
Elastic Modulus	75-90 G Pa
Elongation at break	3.1 %
Softening point	1050 ^0C
Working temperature	-260 – 650 ^0C
Thermal conductivity	0.0030 – 0.0036 W/m-K

2.4 Alkaline Solution

Sodium Hydroxide (NaOH) is available in the local market in pellet form 10 Molar solution to be used. Since the molecular weight of Sodium Hydroxide is 40, and in order to prepare 10 molar solution 10 x 40= 400 grams of Sodium Hydroxide is to be dissolved in 1000 ml of water. Sodium Silicate (Na_2SiO_3) and sodium hydroxide solution with a ratio of SiO_2 to Na_2O is 2(approximately) is used. That is 34.80% SiO2, 16.51 % Na_2O and 48.69 % of water.

2.5 Super Plasticizer

MYK Remicrete PC 5 is the super plasticizer used which is high performance water reducing and super plasticizing admixture based on PCE base polymers and is supplied as a clear to light brownish liquid instantly dispersible in water.

2.6 Fine Aggregates

River sand is used as fine aggregates in this mix. Fine aggregates are tested for specific gravity, sieve analysis & moisture content. The properties of fine aggregates are given in below table.

Table -4: Properties of Fine Aggregates

Specific Gravity	2.63
Moisture content	0.65
Fineness Modulus	2.2
Grading(IS 383-1970)	Zone 4

2.7 Coarse Aggregates

Coarse aggregates of 20 mm down size are used in this experimental work. Properties of coarse aggregates are given below.MYK Remicrete PC 5 is the super plasticizer used.

Table -5: Properties of Coarse Aggregates

Specific Gravity	2.70
Moisture content	0.5
Fineness Modulus	6.7
Grading(IS 383-1970)	Zone 2

3. METHODOLOGY

Concrete specimens for compressive and split tensile strength are prepared as per IS standards. Cube compressive strength of 150 mm cube is calculated. Split tensile strength of cylinders of is calculated

3.1 Design of Geopolymer Concrete

Based on previous studies geopolymer concrete the geopolymer concrete was designed. Sodium hydroxide of 10 molarity is used. Alkaline solution used in the ratio of 2.5 was used. Common methods of manufacturing of Geopolymer concrete used.

Table -6: Mix Design

Constituents weight(kg/m^3)	0% Fiber Mix
Fly ash	245
GGBS	163
Basalt fibers	0
F A	554
C A	1294
Sodium silicate	103
Sodium hydroxide	41
Super plasticizer	6

Basalt Fibers are added at 0.5%,1%,1.5%,2%,2.5% by the weight of cemantacious material (fly ash + GGBS) for the different Mixes. Results were noted and compared with reference mix.

3.2 Compressive Strength Test

It gives an idea about characteristics of a concrete. It is the resistance against failure under compressive load. Compressive strength of the GPC depends on many factors like water/geopolymer solids ratio, concentration of NaOH (in terms of molarity), curing.

The compressive strength test is conducted on the cube specimens (as per IS-516 1959).The specimens are of 150 mm were prepared. Compressive strength of cubes were calculated Specimen is placed centrally in the compression testing machine and uniform load of 140 kg/cm^2 applied continuously. The load for which specimen fails is recorded.the compressive strength of the each specimen was calculated and mean compressive strength was calculated.the procedure is shown in below fig.1.

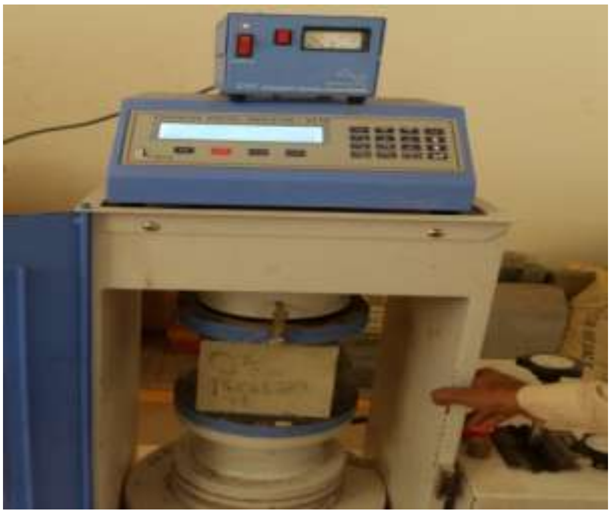

Fig-1: Compressive Test of GPC

3.3 Split Tensile Strength Test

Fig-2: Split Tensile Strength of Cylinders

The tensile strength on cylinders is conducted according to the following procedure. lines are drawn on diametrical end of the cylindrical specimen so that load applied at diametrical ends. Average diameter may be calculated by measuring diameter at different diametrical ends.then specimen is placed in compressive testing machine and load is applied along diametrical ends.load is increased continuously until the specimen fails.note down the reading for which specimen fails and split tensile strength of the specimens were calculated.Record the maximum load applied to specimen as shown in Fig. 3

4. RESULTS AND DISCUSSIONS

Compressive Strength of 150mmX150mmX150 mm is calculated at 7 and 28 days for different mixes. Split tensile strength of cylinders is also calculated according to IS516-1959.

4.1 Compressive Strength

Compressive strength of the cubes at 7 and 28 days (according to IS516-1959).cubes were tested to find the compressive strength of GPC with various percentage of geopolymer concrete. Compressive strength of the GPC is given in table 6.

Table -6: Compressive strength results

Basalt Fiber	Compressive Strength (N/mm^2)	
%	At 7 days	At 28 days
0	30.82	43.35
0.5	33.89	47.87
1	35.8	50.84
1.5	38.9	54.31
2	40.11	58.41
2.5	39.35	55.45

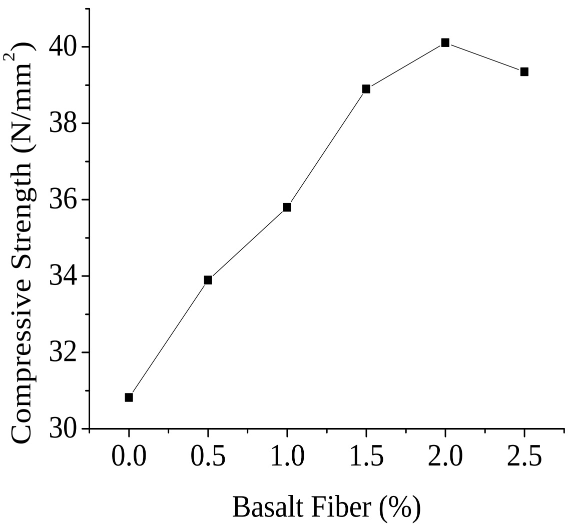

Chart-1: Variation of Compressive Strength at 7 days.

The above figure shows the variation of compressive strength for different percentages of the basalt fibers. The compressive strength of the reference mix at 7 days is 31 M Pa. there is sudden increase in the compressive strength of about 10% for 0.5% addition of fiber, after that addition of fiber increases the compressive strength in gradually small values, it reaches maximum value of 40 M pa for fiber content of 2%.after that value addition of fibers un alters the compressive strength. so 2% is fiber to be added for increase the compressive strength of GPC.

Chart 2 shows the compressive strength of geopolymer concrete reinforced by basalt fibers at 28 days.

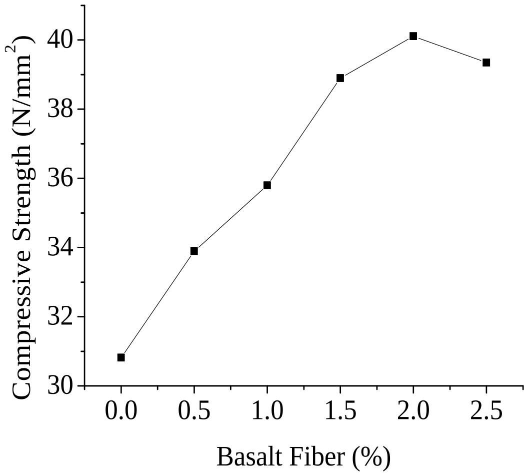

Chart-2: Variation of Compressive Strength at 28 days.

Compressive strength of the reference mix is found to be 43 M pa, there is a sudden increase in compressive strength of about 10% for an addition of 0.5%.for 1%,1.5%,2% there is a increase in compressive strength of 17%,25%,34% respectively. After that addition of basalt fiber will not affect the compressive strength of GPC. So 2% is the optimum value for the geopolymer concrete.

4.2 Split Tensile Strength

Split tensile strength of the cylinders at 7 and 28 days (according to IS516-1959). Cylinders were tested to find the split tensile strength of GPC with various percentage of geopolymer concrete. Split tensile strength of the GPC is given in Table 7.

Table-7: Split tensile strength results

Basalt Fiber	Tensile Strength (N/mm2)	
%	7 days	28 days
0	2.18	2.42
0.5	2.4	2.68
1	2.7	2.95
1.5	2.91	3.23
2	3.2	3.57
2.5	2.96	3.29

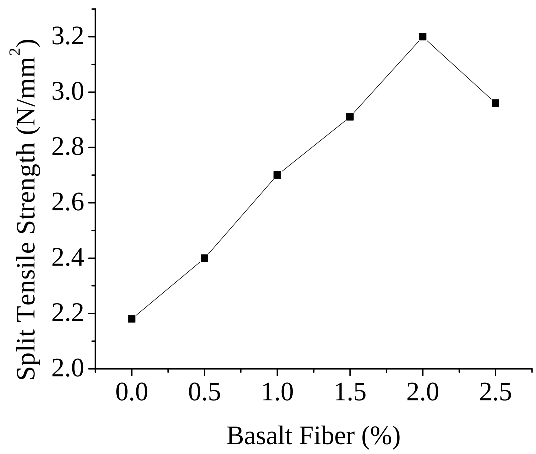

Chart-3: Variation of Tensile Strength at 7 days.

The above figure shows the variation of tensile strength for different percentages of the basalt fibers. There is a increase in the compressive strength with the increased basalt content was observed.

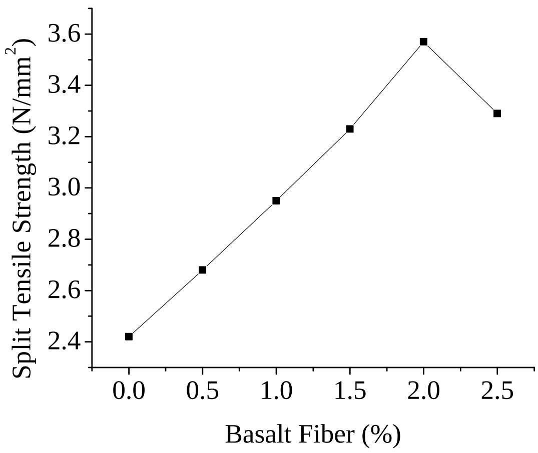

Chart -4: Variation of Tensile Strength at 28 days

5. CONCLUSION

From the above test results the following conclusions may be drawn.

Addition of basalt fibers to Geopolymer concrete Increase in the basalt fiber improves the mechanical properties. The compressive strength of the GPC is observed to be enhanced by 34.74 % on the addition of the fibers. The percentage increase in tensile strength of the GPC is found to be 47.5% with the incorporation of basalt fibers. hence it can be concluded that basalt fiber act as a crack arrestors &prevent sudden failure of the structure.

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