PERFORMANCE OF GEOPOLYMER CONCRETE USING POLYPROPYLENE FIBER

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Abstract - *Fly Ash is one of the major waste materials available from thermal power plants. Its treatment and disposal was a problem in the early stages. Here an experiment has been conducted to study the performance of concrete using fly ash as the major binding material without of cement. Alkaline liquid Sodium hydroxide and Sodium silicate solution are used in this project as binders. It is used in Geo polymerization process. Polypropylene is one of the cheapest and abundantly available polymers. To improve the mechanical properties of GPC, polypropylene fibers were added to GPC in various percentages in this study, Super plasticizer is added to improve the workability of GPC. The mechanical properties of geopolymer concrete were studied.*

Key words: Polypropylene fiber, Geopolymer concrete, sodium hydroxide, sodium silicate, fly ash, Super plasticizer.

1. INTRODUCTION

Concrete is the most often used construction material. The worldwide consumption of concrete was estimated to be about 8.8 billion tons per year. The production of Portland cement worldwide is increasing 10% annually. The production of every ton of Portland cement contributes about one ton of CO_2.So to overcome this problem, the concrete to be used should be Eco friendly. Geopolymer concrete is an innovative and eco-friendly construction material and replacement for Portland cement concrete. The term geopolymer was initially introduced by Davidovits. Geopolymer concrete (GPC) is a 'new' material that does not need the presence of Portland cement as a binder. Geopolymer concrete is emerging as a new environment friendly construction material for sustainable development, using Fly ash and alkali in place of OPC the binding agent. This results in two benefits i.e. Reducing CO_2 releases from production of OPC and effective utilization of industrial waste by products such as fly ash by decreasing the use of Ordinary Portland Cement.

1.1 Fly ash-based Geopolymer concrete

In this work, low-calcium (ASTM Class F) fly ash-based geopolymer is used as the binder, instead of Portland or other hydraulic cement paste to produce concrete. The fly ash based geopolymer paste binds the loose coarse aggregates, fine aggregate sand other un-reacted materials together to form the geopolymer concrete, with or without the presence of admixtures. The manufacture of geopolymer concrete is carried out using the usual concrete technology methods. As in the case of OPC concrete, the aggregates occupy about 75-80 % by mass, in geopolymer concrete. The silicon and the aluminum in the low-calcium (ASTM Class F) fly ash react with an alkaline liquid that is a combination of sodium silicate and sodium hydroxide solutions to form the geopolymer paste that binds the aggregates and other un-reacted materials.

1.2 Aim of the project

- To study the strength properties of geopolymer concrete by using polypropylene fiber.
- Recommendations for the use of Class F fly ash instead of cement in high volume.
- To utilize the waste material such as fly ash in concrete to minimize the global warming.
- To study the properties of geopolymer concrete under severe environment.
- To minimize the cost of concrete products.

2. LITERATURE REVIEW

2.1 General

This chapter presents an overview of literatures collected from various journals. The most worthy of them which are relevant to the current study are being reviewed.

2.2 Literatures

K.Naveen Kumar Reddy et al. Found that geopolymer concrete prepared from low lime based fly-ash and a mixed alkali activator of sodium hydroxide and sodium silicate solution are investigated. An increase in compressive strength of these concrete samples is observed with increased molarity of NaOH solution. The workability of concrete decreases when the molarity of NaOH solution is increased for the samples cured at 60°C.The workability of geopolymer concrete is reduced with higher concentrations of sodium hydroxide (in the range of 10 M to16 M) solution which results in a higher Compressive strength .There is a slight increase in the compressive strength with age of the concrete for a defined concentration of NaOH solution. The addition of high-range water reducing admixture with 1.5% of fly-ash(by mass) resulted no much impact on the compressive strength of the hardened concrete, but improved workability of fresh geopolymer concrete.

R.Anuradha et al. showed that experimental study was conducted to assess the Acid resistance of fly ash based geopolymer mortar specimens of size 50x50x50mm with a ratio of fly ash to sand as 1:3.The ratio between solution(Sodium hydroxide and Sodium silicate solution) to fly ash were 0.376,0.386,0.396 and 0.316. After casting the specimens were subjected to both ambient curing and heat curing. In heat curing the specimens were kept continuously at 60˚C for 23 hrs. Durability of specimens was assessed by immersing them in 5% of sulfuric acid and 5% hydrochloric acid for a period of 13 weeks. Evaluation of its resistance in terms of change in weight, compressive strength and visual appearance at regular intervals was carried out. After exposure in the acid solutions for 13 weeks, the samples showed very low weight loss. Results obtained from the present study indicate that geopolymers are highly resistance to sulfuric acid and hydrochloric acid.

Ilamvazhuthi et al. studied mainly on the effects of polypropylene (PP) and glass fiber on the mechanical properties of geopolymer concrete. PP fibers have gained popularity in recent years for use in concrete, mainly owing to their low price and excellent characteristics in improving tensile strength, flexural strength and crack resistance. Since the surface of PP fiber is hydrophobic, it will not be affected by wet geopolymer matrix and this helps to prevent chopped fibers from balling effect during mixing. Alkali resistant glass fiber reinforcement is relatively a new addition to the family of fibers and available in continuous or chopped lengths. They impart high tensile strength, high stiffness, high chemical resistance and considerable durability to fiber reinforced concrete.

Deshmukh & Kawade et al. Presented the data on the engineering properties of geopolymer concrete with varying molarity (11.5 to 13.5 M) & different percentage of polypropylene fibers & steel fiber (0.2%,0.3% ,0.6%,0.8%, 1%). Ratio of Na_2SiO_3 / NaOH is kept as 2 & Na_2O / SiO_2 is kept as 2.25.It was concluded that flexural strength and split tensile strength increases as the morality increases. Optimum results were obtained at 13M, thereafter, the strength of the geopolymer concrete decreases in this study. Steel fibers at 0.8% and Polypropylene fibers at 0.2% by mass of concrete obtained enhanced properties of geopolymer concrete.

Anil Ronad et al. Studied the mechanical properties of geopolymer concrete reinforced with polypropylene fiber, both fly ash and GGBS were utilized in making geopolymer concrete. Alkaline solution used was sodium silicate and sodium hydroxide in the ratio of 2.5. Fibers were added to the geopolymer concrete in the range of 0.5% to 2.5% at 0.5% increments. The compressive strength of the GPC was observed to be enhanced by 33.73 % on the addition of the fibers. The percentage increase in tensile strength of the GPC was found to be 37.5% with the incorporation of basalt fibers. Hence it was concluded that addition of polypropylene fibers at 2% to the geopolymer concrete can increase both compressive and tensile strength and also polypropylene fiber act as a crack arrestors and prevent sudden failure of the structure.

Patil et al. Had done an experimental program to determine mechanical properties of polypropylene fiber reinforced geopolymer concrete. The effects of inclusion of polypropylene fibers on compressive strength, split tensile strength and flexural strength of hardened geopolymer concrete composite were studied. Polypropylene fibers were added to the mix in two different lengths of 12mm and 20mm and also the hybridization of both polypropylene fibers was mixed in volume of concrete. Based on the test results, it was observed that the polypropylene fiber reinforced geopolymer concrete had relatively higher strength than GPC & OPC concrete.

3. MATERIALS

3.1 Fly ash

The fly ash is should be used having high fineness, low carbon content and good reactivity .The characteristics of fly ash such as specific gravity, grain size, compaction characteristics permeability coefficient, shear strength parameters and consolidation parameters are the same as those for natural soils .The procedure for determination of these parameter are also similar to those soils .the quality of fly ash was found to satisfy the requirement of fly ash.

Table- 1: Properties of fly ash

S.No	Property	Value
1.	Specific gravity	2.77
2.	Water absorption	0.75%
3.	Fineness modulus	5.91
4.	Uniformity coefficient	1.48
5.	Coefficient of curvature	1.21

3.2 Alkaline activators

A combination of sodium silicate solution and sodium hydroxide solution was chosen as the alkaline liquid. Sodium- based solution was chosen because they were cheaper than potassium- based solution. The sodium hydroxide solids were commercial grade in flakes form with 97% purity and sodium silicate solution was obtained from a local chemical supplier. In this investigation the sodium hydroxide pellets in 12 molar concentrations are used. The chemical composition of the sodium silicate solution was Na_2O=14.7%, SiO_2=29.4%, and water 55.9% by mass.

Table-2: Physical properties of sodium hydroxide

S.No	Property	Value
1.	Specific gravity	2.13
2.	PH	14
3.	Colour	White
4.	Appearance	Solid(Pellets or flakes)

Table -3: Physical properties of sodium silicate

S.No	Property	Value
1.	Specific gravity	1.6
2.	Molecular weight	184.04
3.	Boiling Point	102˚C for 40% aqueous solution
4.	Appearance	Liquid (Gel)
5.	Colour	white (gel)

3.3 Fine aggregate

Fine aggregate shall consist of natural sand or manufactured sand or a combination. Fine aggregate used in this investigation is clean river sand passing through 4.75mm sieve. The fine aggregates were tested, as per Indian specifications IS383-1970.

3.4 Coarse aggregate

Coarse aggregate are used for making concrete. They may be in the form of irregular broken stone or naturally-occurring rounded gravel. Material which are large to be retained on 4.7mm sieve size (say 5 mm for convenience) are called coarse aggregates. A maximum size of 20mm is usually selected as coarse aggregates used in concrete. Aggregates should be strong and free of internal flaws or fractures. Aggregates of high intrinsic strength are generally preferred.

Table-4: Physical properties of coarse aggregate

S.NO	Property	Value
1.	Specific gravity	2.77
2.	Water absorption	0.75%
3.	Fineness modulus	5.91
4.	Uniformity coefficient	1.48
5.	Coefficient of curvature	1.21

3.5 Water

Water for masonry must be clean and free of harmful amounts of acid, alkalis and organic materials.

3.6 Polypropylene fiber

Polypropylene fibers, the most popular of the synthetics, are chemically inert, Hydrophobic, and lightweight. They are produced as continuous cylindrical monofilaments that can be chopped to specified lengths or cut as films and tapes and formed into fine fibrils of rectangular cross section. The presence of Polypropylene fibers in concrete may reduce settlement of aggregate particles, thus reducing capillary bleed channels. Polypropylene fibers can help reduce the spalling of high strength, low-permeability concrete exposed to fire in a moist condition. Some of the other advantages are excellent abrasion resistance, chemical resistance, corrosion resistance, heat resistance. Hence it is concluded that the polypropylene fibers at 0.1% to 0.3% can be used as a promising additive to the geopolymer concrete to enhance the properties of geopolymer concrete.

Table -5: Physical properties of polypropylene fiber

S.No	Property	Value
1.	Polymer	100% virgin polypropylene homo polymer
2.	Length	6mm
3.	Specific gravity	0.91
4.	Melting range	162-164°C
5.	Strength	500-550 MPa
6.	Diameter	0.02mm

3.7 Super plasticizer

To achieve workability of fresh Geopolymer Concrete, Sulphonated Naphthalene polymer based super plasticizer Conplast SP 430 in the form of a brown liquid instantly dispersible in water, was used in all the mixtures.

4. EXPERIMENTAL PROGRAM

The experimental work consists of casting of Geopolymer concrete specimens with 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 7,14 and 28 days.

4.1 Mix proportion of M_{30} grade Geopolymer concrete

- The Ratio of sodium silicate solution to sodium hydroxide solution, by mass of 0.4 to 2.5.
- This ratio was fixed at 2.5 for most of the mixtures because the sodium silicate solution is considerably cheaper than the sodium hydroxide solution.
- Molarities of sodium hydroxide (NaOH) solution in the range of 12M.
- Ratio of activator solution fly ash, by mass, in the range of 0.35
- Coarse and fine aggregate of approximately 75 to 80% of the entire mixture by mass.
- Extra water (if necessary).
- Polypropylene fibers were used in various proportions from 0.1% to 0.3% of the mass of Fly ash.

4.2 Mixing, Casting and Curing

The solids constituents of the fly ash-based geopolymer concrete, i.e. the aggregate, sand, fly ash were dry mixed about three minutes. The liquid part of the mixture, i.e., the sodium silicate solution, the sodium hydroxide solution, added water (if any).The fresh fly ash-based geopolymer concrete was dark in color and shiny in appearance. The workability of the fresh concrete was measured by means of the conventional slump test .Compaction of fresh concrete in the cylinder steel moulds was achieved by applying twenty five manual strokes per layer in three equal layers.

5. RESULTS AND DISCUSSION

The various strength test are to be done listed below.

5.1 Compressive Strength Test

These specimens are tested by compression testing machine after 7 days curing or 14 days or 28 days curing. Load should be applied gradually till the Specimens fails. Load at the failure divided by area of specimen gives the compressive strength of concrete.

Table -6: Result of compressive strength

Proportions	7 days in N/mm^2	14days in N/mm^2	28 days in N/mm^2
CC	19.57	29.15	34.48
GPC	23.47	36.17	45.85
GPC P0.1	23.83	36.53	46.31
GPCP0.2	24.63	37.26	47.82
GPCP0.3	23.16	36.06	46.07

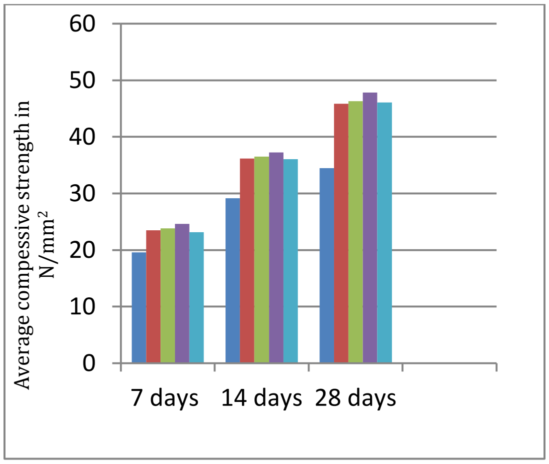

Chart -1: comparison of compression strength

5.2 Split Tensile Strength Test

Split tensile strength of concrete is usually found by testing cylinder. The tensile strength of concrete is one of the basic and important properties. The size of the mould used is 150mm diameter and 300mm height. The specimen were tested for its strength as per IS: 516-1959 using a calibrated compression testing machine of 2000 KN capacity.

Table -7: Result of split tensile strength

Proportion	7 days in N/mm^2	14 days in N/mm^2	28 days in N/mm^2
CC	1.96	2.69	3.40
GPC	2.69	3.92	4.67
GPCP0.1	2.83	4.18	4.94
GPCP0.2	3.24	4.86	5.59
GPCP0.3	3.91	5.25	5.98

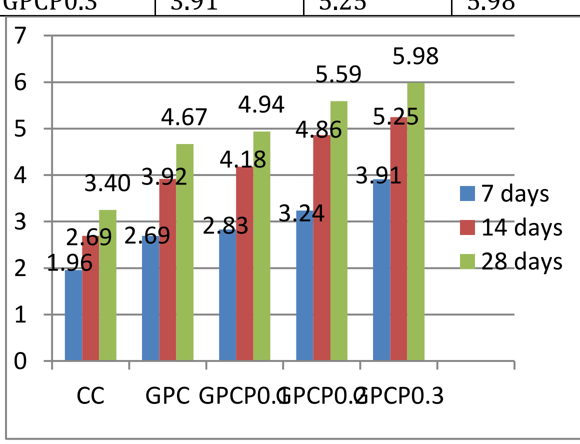

Chart -2: Comparison of split tensile strength

5.3 Flexural strength of beams

Flexural strength is one measure of the tensile strength of concrete.it is a measure of an unreinforced concrete beam or slab to resist failure in bending. Concrete beams of size 500mm×100mm×100mm are found to be dependable to measure flexural strength property of concrete. The systems of loading used in finding out flexural strength are two points loading at L/3 distance. The testing was carried out in the loading frame and the load was measured using proving ring, of 600kN capacities. The deflections were noted at L/2 and L/3 distance from supports. By using the test values load Vs deflection cure was drawn. Deflection cure was drawn.

Table-8: Flexural strength test result

Proportion	Specimen	7 days N/mm^2	14 days N/mm^2	28 days N/mm^2
CC	Beam	2.52	3.78	4.21
GPC	Beam	3.37	5.05	5.62
GPCP0.1	Beam	3.46	5.20	5.78
GPCP0.2	Beam	3.57	5.36	5.96
GPCP0.3	Beam	3.67	5.64	6.13

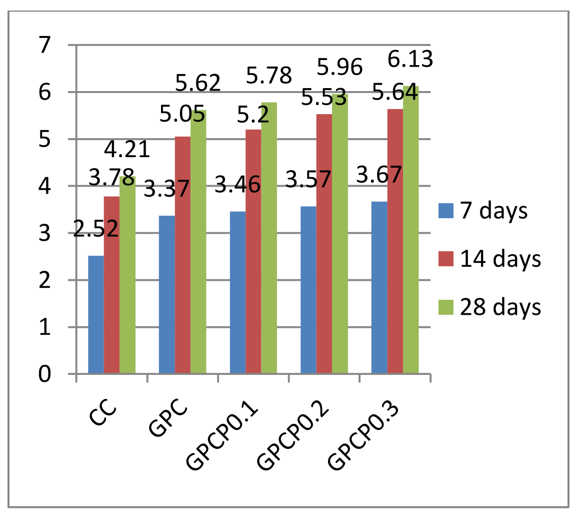

Chart -3: comparison of flexural strength

5.4 Durability test

Durability is claimed to be one of the strongest advantages of geopolymer concrete over the OPC one because this binder system does not rely on calcium compounds and is free from C3A and CaO which are very vulnerable in acidic and sulfate attack. Lots of experimental results from the past proved that geopolymer concrete has lower permeability, higher resistance against aggressive environments, such as acidic and sulphate, water as well as very less or nil corrosion in reinforcing steel under marine environments.

5.4.1 Acid Resistance test (H_2SO_4)

Acid resistance property of geopolymer concrete mixes has been studied by exposing the concrete specimens in 5% of sulfuric acid for 60 days. To perform the acid attack in the present investigation immersion techniques is adopted. After casting and curing, cubes immersed in H_2SO_4 solution as shown in fig, if the concentration of H_2SO_4 acid solution is 5%. The pH value of water is 6.17 and it is dropped to 5.45.The evaluation is conducted after 60 days from the date of immersion. The solution is kept at room temperature and the solution is stirred regularly. The solution is replaced at regular intervals to maintain concentration of solution throughout the test period. The weight of geopolymer concrete decreases, when the acid concentration increases and the same effect is reflected after 60 days immersion in acid. The weight of GPC specimen before and after immersion is shown in Table. Various parameter evaluated are visual appearance, change in mass and change in compressive strength after the exposure period of both type of concrete.

Fig 1 Geopolymer concrete dipped in sulphuric acid

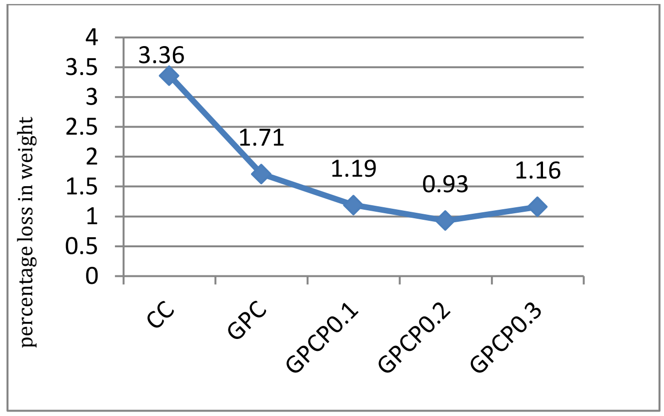

Chart -5: Percentage loss in weight after acid attack

Table-9: Result of compressive strength after acid exposure

Type of concrete	Compressive strength in N/mm²		Percentage loss in compressive strength
	Initial strength	after 60 days acid attack	
CC	34.48	24.16	29.9
GPC	45.85	39.98	12.8
GPC P0.1	46.31	41.67	10.01
GPC P0.2	47.82	43.35	9.34
GPC P0.3	46.07	41.46	10

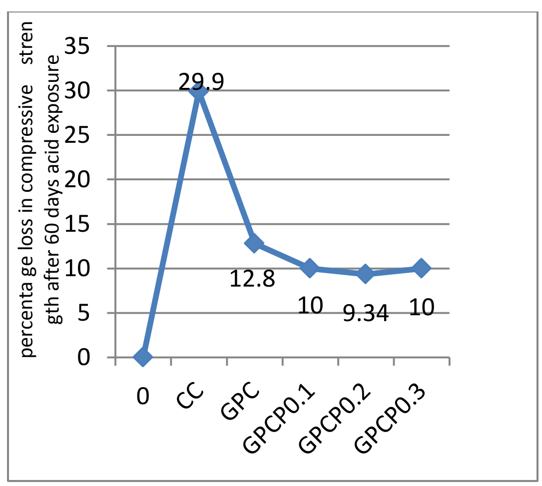

Chart -4: Percentage loss in compressive strength after acid attack

5.4.2 Water absorption test

The water absorption test has been carried out according to ASTM C 642-82, to study the relative porosity or permeability characteristics of geopolymer concrete with addition of polypropylene fiber (PFRGPCC) specimens. The specimens used for this test were 100 mm cubes. The values of saturated water absorption of the specimen at 28 days were found out and tabulated in the Table. From the test results, it can be seen that the water absorption values at 30 minutes for the PFRGPCC specimens for all the volume fractions of fibers were lower than the limit of 3% specified for good concretes. The water absorption capacity of PFRGPCC specimens having 0.1% and 0.2% volume fraction of fibers were less when compared with control GPCC specimens, whereas the specimens having 0.3% of fibers have higher water absorption capacity as compared to control GPCC specimens. Within the fibrous specimens, specimens containing 0.2% of polypropylene fibers performs better by showing lower value for water absorption as shown in graph.

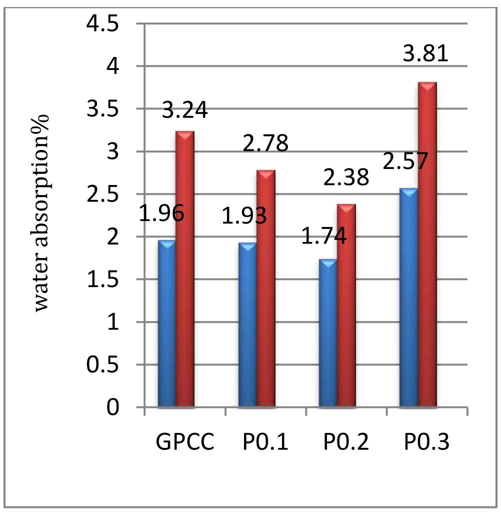

Chart -6: Water absorption at 30 minutes and 24 hours

6. CONCLUSIONS

In the present work an attempt was made to study the strength and durability properties of geopolymer concrete incorporated with polypropylene fiber.

The compressive strength of geopolymer concrete is 24.79% more than conventional concrete. In addition of polypropylene fiber, the fiber reinforced geopolymer concrete attain 4.1% more strength than geopolymer concrete till 0.2% mix only after, it compressive strength gradually decreases.

But the split tensile and flexural strength of geopolymer concrete increases with increasing polypropylene fiber up to 0.3%.

The split tensile strength of geopolymer concrete is 27.19% more than the conventional concrete and the flexural strength of geopolymer concrete is 25% more than conventional concrete.

The compressive strength loss for the specimens exposed in sulphuric acid is in the range of 29.9% in CC, where as it was about 12% in GPC and 9-10% in GPC with polypropylene fiber.

Fiber reinforced Geopolymer concrete are more resistance to acid attack than conventional concrete.

Fly ash is the industrial waste by-product for producing the binding material in concrete, so it can be considered as eco-friendly material.

Due to geopolymer concrete the consumption of cement, emission of carbon di -oxide and greenhouse effect are reduced.

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