Experimental Investigation On Reinforced Geo-Polymer Concrete By Using Fly Ash, Ground Granulated Blast Furnace Slag And Steel Fibres

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Abstract **Natural resources are used in large quantities for the production of cement, which is also quite energy-intensive. However, there is already a massive global production of fly ash, much of which is dumped in landfills and is not adequately utilized. Both the above issues are addressed in this work. The mechanical properties of geopolymer composites containing 70% fly ash (FA), 30% GGBFS, alkaline liquids, and steel fibers are examined experimentally, and the results are provided in this work. The compressive strength, split tensile strength, and flexural strengths of FRGPC are just a few of the mechanical parameters that are examined in this study on the effects of steel fibers.**

Keywords —Fly ash ,GGBFS, Steel fibers ,alkaline liquid and mechanical properties.

I. Introduction

Concrete usage around the world is second only to water. Traditionally, ordinary Portland cement (OPC) is utilized as the primary binder in concrete production. The environmental impact of OPC manufacture is widely known. The amount of carbon dioxide released during OPC manufacturing due to limestone calcination and fossil fuel burning is approximately one ton for every ton of OPC produced. In addition, the extent of energy required to produce OPC is only next to steel and aluminium.

On the other hand, the widespread availability of fly ash around the world provides an opportunity to use this byproduct of coal combustion as a substitute for OPC in concrete manufacturing. When used as a partial replacement for OPC, fly ash combines with calcium hydroxide during the OPC hydration process to generate the calcium silicate hydrate (C-S-H) gel in the presence of water and at ambient temperatures. The creation and implementation of high volume fly ash concrete, which allowed for up to 60% mass substitution of OPC.

Davidovits proposed the term geopolymer in 1978. Aluminum and silicon are high in fly-ash and GGBS. This interacts with an alkaline solution to produce Al-Si gel, which binds aggregate to form geopolymer concrete.A hardened cementitious paste formed from fly ash and alkaline solution. Using waste products to create useful products.

II. LITERATURE REVIEW

Djwantoro Hardjito et al. (2004) examined the production of fly ash-based geopolymer concrete. It was concluded that in geopolymer concrete, a by-product material rich in silicon and aluminium, such as low-calcium (ASTM C 618 Class F) fly ash, can be chemically activated by a high-alkaline solution to form a paste that binds the loose, coarse and fine aggregates and other unreacted materials in the mixture. The test results demonstrated the impact of various parameters on the qualities of geopolymer concrete..

B. Vijay Rangan et al. (2008) provided a thorough synopsis of considerable research on fly ash-based geopolymer concrete. Test results were used to determine the effects of key parameters on the characteristics of geopolymer concrete in both fresh and hardened states. These results are utilized to propose a simple method for the design of geopolymer concrete mixtures. The test results for various short- and long-term properties of geopolymer concrete were then presented. The results of testing on large-scale reinforced geopolymer concrete members were detailed, and the use of geopolymer concrete in the construction industry was demonstrated. The economic benefits of geopolymer concrete were also discussed.

--Rajamane N.P et. al. (2012) conducted a comprehensive literature survey on various aspects of Geopolymer Concretes (GPCs) to understand the nature of GPCs from engineering applications point of view so that a rational technical plan for development of GPCs with given aluminosilicate sources (such as fly ash, blast furnace slag powder etc) can be formulated. According to the literature

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review, the term "geopolymer" (GP) is just one of several terms used to refer to the binder made of an alumina-silicate gel structure. Unlike Portland cement technology the science of GP has not yet advanced to the point where a person may create a GPC mix by just adding water. The on-site engineer must be knowledgeable about the chemical makeup of the GP binding action in question. On the other hand, there is enough qualitative data on mechanical strength to allow for the development of GPC mixtures that will yield the required strength for application in constructions.

G. S. Manjunath et al. (2011) used industrial byproducts and marginal materials to study the strength development of ambient cured geopolymer mortar for sustainable development. Ground Granulated Blast Furnace Slag (GGBFS), Quarry Dust, and Fly Ash were the ingredients that were taken into consideration. Instead of using any traditional cement, geo-polymer mortar was made. Casting geopolymer mortar cubes and measuring their compressive strength at various ages were the experimental program's tasks. Alkaline activator molarity, binder component proportion, binder to fine aggregate ratio, and alkaline fluid to binder ratio were among the several characteristics taken into consideration in the study. The findings showed that without using a traditional curing agent, the geopolymer mortar gains strength even at room temperature. The more GGBFS there are, the stronger they get.

P. Chindaprasirt et al. (2011) investigated the use of fine high-calcium fly ash in the manufacture of high-strength geopolymer. Investigations were conducted into the effects of fly ash fineness on the drying shrinkage, workability, strength development, and setting time of geopolymer paste in geopolymer mortars formed from high-calcium fly ash that is categorized as fine. For their investigation, Mae Moh Power Station air-classified fly ash in three distinct fineness levels—coarse original fly ash (CFA), medium-fineness fly ash (MFA), and fine fly ash (FFA)—was utilized. NaOH and sodium silicate were used to activate the heat-cured geopolymers. To make it workable, a tiny bit of water was added. The findings showed that when fly-ash fineness increases, paste setting time lowers. Using fine fly ash enhanced the properties of mortars, including flow, strength, and drying-shrinkage. It was possible to create geopolymer mortars with a high 28-day compressive strength of 86.0 MPa.

III. MATERIALS

In this experiment, the constituents used in the GPC mixtures are different from the conventional concrete mixtures, which include

- Fly ash
- GGBFS
- Aggregates
- Alkaline Solution
- Super plasticizer
- Water

Fly ash

Fly ash is a finely divided residue produced by the combustion of powered coal, carried by flue gases, and collected by an electrostatic precipitator. Fly Ash is the most often used pozzalonic substance across the world. Class C and Class F are the two classifications based on the type of coal burned and its CaO level. Because the presence of calcium in significant amounts can interfere with the polymerization process and affect the microstructure, Class F grade fly ash is employed rather than Class C. The current investigation uses Class C fly ash source materials.

Table: 1 Chemical composition of fly ash

Characteristics	Fly ash (% wt.)
Silica	55 – 65
Iron Oxide	5 – 7
Aluminium Oxide	22 – 25
Calcium Oxide	5 – 7
Magnesium Oxide	<1
Titanium Oxide	<1
Phosphorous	<1
Sulphates	0.1
Alkali Oxide	<1
Loss of ignition	1 – 1.5

Ground granulated blast furnace slag (GGBFS).

Ground granulated blast furnace slag is a nonmetallic substance made up primarily of calcium silicates and aluminates that is a byproduct of the iron industry. The molten slag is swiftly chilled by quenching in water, forming a glassy sand-like granular substance.

Aggregates

It makes up 75-80% of the bulk of GPC. The coarse aggregates used in this experiment were 12mm in down size. The aggregates were immersed in water until saturated, then saturated surface dry conditioned aggregates were employed to cast the specimens. This experiment used fine particles that passed through a 4.75mm sieve.

Alkaline solution

Alkaline solutions serve a significant role in geopolymer synthesis for the dissolving of silica and alumina, as well as the catalysis of the polymerization reaction. Reactions occur at a faster rate when the alkaline liquid contains soluble silicate, either sodium or potassium silicate, as opposed to using simply alkaline hydroxides. The most common alkaline liquid used in geopolymerisation is a solution of sodium hydroxide (NaOH) or potassium hydroxide (KOH) with sodium silicate or potassium

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silicate.In the present work, the sodium hydroxide solution and the sodium silicate solution are used as alkaline activators.

Sodium Hydroxide Solution (NaOH)

In the present study, sodium hydroxide solution NaOH (97% purity, in the form of pellets Figure 3.2) was dissolved in water to form 14M solution , The sodium hydroxide (NaOH) solution was prepared by dissolving either the flakes or the pellets in water

Figure:1

Sodium Silicate Solution (Na2SiO3)

Table : 2 Chemical component Percentage by mass

Chemical component	Percentage by mass
Na2O	14.70%
SiO2	29.40%
Water	55.90%

Superplasticizer

The use of fly ash and GGBFS in GPC reduces the workability of concrete; to increase this property in GPC, superplasticizer is utilized. In this investigation, the super plasticizer named conplast-SP430 was used.

Water

Water in geopolymer concrete is classified into two types: water in an alkaline solution and extra water. Because water is present in very small quantities in alkaline solutions, geopolymer concrete mixes are typically very stiff. To improve workability and make geopolymer mixes more homogeneous, additional water is added to the mix, but this water is the main parameter that directly affects the strength of geopolymer concrete.

Steel fibre

Several studies have been undertaken to investigate the strength of reinforced concrete (RC) elements using fibre reinforced composite fabrics. Recently, high strength fibre-reinforced polymer (FRP) technologies have gained acceptance as structural reinforcement for concrete. This composite material has small discontinuous fibres that are randomly distributed throughout the concrete mass. This composite material's behavioral efficiency far outperforms that of plain concrete and many other construction materials of the same cost.

Figure: 2

Table: 3 Specification of steel fibre

Aspect ratio	77
Length	35mm
Diameter	0.45mm
Density	7860kg/m3
Tensile strength	>1100 MPa
Deformation	Continuously deformed
Appearance	Bright and clean wire

IV. RESULTS

Compressive Strength

Testing for compressive strength was done on FRGPC in the M40 grade. 150 × 150 x 150 mm cube specimens were constructed for every batch of geopolymer concrete used in this investigation. At least three of these cubes were tested for compressive strength in a 200-ton compression testing machine at 3, 7, and 28 days after casting. The uniform rate of loading was set at 140 kg/cm2/min, and the compressive strength was computed using IS:516-1959.

An increase in compressive strength was observed in the FRGPC mix when 30% of the fly ash was substituted with GGBFS.

The compressive strength of different mixes at 3,7 and 28 days are represented below. An increase in compressive strength was observed in the FRGPC mix when 30% of the fly ash was substituted with GGBFS. Compressive strength rises for all mixes of concrete as it ages from three to twenty-eight days. The test results indicate that the average compressive strengths of the steel-fiber-containing Geopolymer Concrete Composites were higher than those of the composites without steel-fibers. Comparing the unreinforced goepolymer mix, there is a gain in compressive strength of 4.1%, 11.62%, and 20.93% as the

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volume fraction rises from 0.5 to 1%.

Table: 4 The compression testing results of M40 FRGPC

Steel fiber (%)	Alkali Flyash	Na2SiO3 NaOH	Molarity (M)	Compressive Strength N/mm^2		
				3Days	7Days	28Days
0	0.4	2.5	14	26	34	43
0.5	0.4	2.5	14	27.2	36	44.8
0.75	0.4	2.5	14	28.3	39	48
1	0.4	2.5	14	32	43	52

Split tensile Strength

The split tensile strength of the various blends after 3, 7, and 28 days is shown below. As the age of concrete increases from 7 days to 28 days, split tensile strength also increases for all the mixes. The test results indicate that the average tensile strengths of the steel-fiber-containing Geopolymer Concrete Composites were higher than those of the composites without steel fibers. In comparison to the control mix, split tensile strength increases as the volume fraction rises from 0.5 to 1%. Regarding M40 FRGPC, the increase in tensile strength compared to unreinforced GPC was approximately 12.72 percent, 31.27%, and 56.3% for fiber percentages of 0.5, 0.75, and 1%, respectively.

Table:5 The split tensile strength testing results for M40

Steel fiber (%)	Alkali Fly ash	Na2SiO3 NaOH		Split tensile Strength N/mm^2		
			Molarity (M)	3Days	7Days	28Days
0	0.4	2.5	14	2.14	2.44	2.75
0.5	0.4	2.5	14	2.4	2.8	3.1
0.75	0.4	2.5	14	2.84	3.24	3.61
1	0.4	2.5	14	3.42	3.9	4.3

Flexural Strength

The Modulus of rupture of different mixes at 7, 14 and 28 days are represented below. As the age of concrete increases from 7 days to 28 days, flexural strength also increases for all the mixes. From the test results it can be seen that, average flexural strengths of Geopolymer Concrete Composites containing steel fibres were higher than those of Geopolymer concrete composites without steel fibres. As the volume fraction increases from 0.5 to 1%, flexural strength increases with respect to the control mix.

Table:6 The Flexural strength testing results for M40

Steel fiber (%)	Alkali Flyash	Na2SiO3 NaOH		Flexural Strength N/mm^2		
			Molarity (M)	3Days	7Days	28Days
0	0.4	2.5	14	1.93	4.1	5.3
0.5	0.4	2.5	14	2.3	4.3	5.9
0.75	0.4	2.5	14	2.9	4.9	6.3
1	0.4	2.5	14	3.1	5.7	6.9

V. CONCLUSION

1. The two drawbacks of GPC, namely the longer setting time and the need for heat curing to increase strength, were removed by adding 30% more GGBFS to the GPC mix in place of fly ash.

2. Compressive strengths of up to 40 MPa can be achieved by curing steel fiber reinforced geopolymer concrete mixtures at room temperature.

3. The compressive strength increases by 4.1%, 11.62%, and 20.93% in comparison to the unreinforced goepolymer mix with a percentage volume fraction increase from 0.5 to 1%.

4. At 28 days of curing, the M40 FRGPC's split tensile strength increased by 12.72%, 31.27%, and 56.3%, respectively, with the addition of 0.5%, 0.75%, and 1% volume fraction of steel fibers.

5.The modulus of rupture of the samples studied, added with 0.5%, 0.75% and 1% volume fraction of fibers exhibited a substantial improvement of 11.2%,18.8% and 30.1% of load capacity.

VI. FUTURE SCOPE

•The durability study can be analyzed with organic acids because severs mostly contain more organic acids.

• The elastic properties like Poisson's ratio and modulus of elasticity can be studied beyond elastic limit.

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