|| Volume 10|| Issue 2|| 2025 || ISSN (Online) 2456-0774 INTERNATIONAL JOURNAL OF ADVANCE SCIENTIFIC RESEARCH AND ENGINEERING TRENDS

"Experimental Study on Mechanical Strength and Durability of Fiber-Reinforced Geopolymer Concrete with Mineral Admixtures"

[1]Ujjwal Vyas [2]Indrajeet Singh Chouhan [3]Nilesh Kadam

[1] *M.Tech Scholar, Department of Civil Engineering, Sushila Devi Bansal College of Engineering Indore*

[2,3]*Assistant Professor, Department of Civil Engineering, Sushila Devi Bansal College of Engineering Indore*

Abstract: All construction projects use concrete as a common building material. Building large, high-end, and sophisticated structures requires large amounts of cement. The demand for structural concrete depends on workability, strength, durability, in operation, portability, ease of working etc. Concrete technology has made many advances over the years. Significant advances in concrete technology include fiber-reinforced concrete (FRC), high-strength concrete, high-performance concrete, large-volume fly ash concrete, self- hardening concrete, self-compacting concrete, geopolymer concrete, etc., with consistent use of chemical and mineral admixtures The thesis begins with a blended design of GPC grade M-Forty. The mixture was modified using various amounts of ground granulated blast furnace slag (GGBS as replacements for fly ash.

Like ordinary concrete, GPC has a denser structure, making compression more robust. The current study tested four types of fibers, metallic (steel fibers) and non-metallic (glass, polypropylene, basalt), in GPC mixes. Steel fibers are used at an optimum ratio of one with a maximum aspect ratio of forty. Non-metallic fibers such as glass, polypropylene, and basalt have been found to contribute little to increased strength

Keywords: Fiber-reinforced concrete, high-strength concrete, high-performance concrete, large-volume fly ash concrete, self- hardening concrete

---

I. INTRODUCTION

Materials like concrete are most used for all infrastructural applications like skyscrapers, highways, culverts, industrial buildings, nuclear power plants, precast structures, etc. The key reason for this is the easy availability of materials, mouldability of concrete into any shape, and low price. Every day a massive amount of concrete is poured at sites that require a large amount of cement. We currently use various industrial by- products, such as fly ash, ground granulated blast furnace slag. etc., to replace cement, reducing pollution a tiny part. However, day by day, the production quantity of industrial waste by- products is also getting increased. At the same time, the full-fledged use of waste material in construction works is not taking place. If we do not utilise these industrial by-products to the maximum, it is also creating a hazardous environmental problem. The quantity of these waste materials will increase day by day, which will occupy a considerable amount of land, which in turn, will affect our cultivation system

Innovation of Geopolymer Concrete

In this scenario, concrete made with an alkaline solution is the best alternative developed in the late 1970s. The developed product is called Geopolymer Concrete (GPC). In GPC, silica and alumina-rich industrial waste by-products like fly ash and ground granulated blast furnace slag (GGBS) were used to replace cement completely. High silica and alumina levels in these waste by-products can be activated with an alkaline solution obtained by combining sodium hydroxide (NaOH) with sodium silicate (Na2Sio3). Helps in producing geopolymer bonds through the geopolymerization process.

Development of Geopolymer Concrete-

A French scientist named Davidovits developed geopolymer concrete in 1970. He showed that binders are rich in silica and alumina, which can be activated using the desired molarity of sodium hydroxide solution and sodium silicate to produce geopolymer concrete. During his study, it was observed that potassium-based alkaline solutions are more expensive compared to sodium-based alkaline solutions.

Binding Material for GPC-

In GPC's research, fly ash was mainly used as the main binder. However, researchers have also tried ground granulated blast furnace slag (GGBS) as a binder material in manufacturing GPC, and the results are encouraging. In the present thesis work, GGBS as a supplementary cementing materials are combined in various amounts. GPC mixes are prepared, and the properties are studied

Fly ash - It results from the pulverized coal being burned in power stations to make electricity. Mineral contaminants in coal melt during combustion, and in suspension, these contaminants float with the flue gases from the combustor. Electrostatic precipitators or bag filters remove this molten material from the flue gases after it rises and cools into spherical glass particles known as fly ash.

Fly ash elements are spherical, and an excellent material; most particles are less than 1μm and 100μm in diameter. The fineness of fly ash particles is usually between 250 and 600 m2/kg.

Geopolymers- Geopolymers are aluminosilicate materials with amorphous three- dimensional microstructures. They can also be defined as covalently bonded non-crystalline Si-O-Al networks in which tetrahedral frameworks of Sio4 and Alo4 are linked and divided by oxygen to form a semi-crystalline or amorphous dense three-dimensional framework.

Geopolymerization- It converts aluminosilicate raw material into a 3D covalently bonded network composed of (-Si-O-Al-O-) n bonds. This integrated process for synthesizing geopolymers involves diffusion, reorientation, polymerization, and condensation.

Ambient Cured Geopolymers- This type of curing is used to eliminate the external application of heat during the synthesis of geopolymers. Thus, the cost can be reduced, and the manufacturing process can be simplified. For ambient temperature-cured samples, the rate of strength gain and microstructural development can be delayed by eliminating the external application of heat.

Heat Cured Geopolymers- Before placing the sample in the oven, a rest period is generally maintained, which has a pre-cure time to prevent water loss from sealed samples. After placing the samples in the furnace, heat curing at 600°C can be extended from 4 to 48 hours. The chemical reaction in the geopolymer paste is greatly aided by heat curing. A more extended curing phase improves the polymerisation process, resulting in higher compressive strength. Up to 24 hours, the rate of strength increase was rapid, and after 24 hours, the rate of strength increase was prolonged.Objective of the Present Study**-** The current study focuses on producing geopolymer concrete with various mineral admixtures, including fibers. Most of the present research is currently focused on developing fly ash-based geopolymers with the low calcium content. This research aims to produce a geopolymer concrete with various starting materials and to study the technical properties of GPC both in the fresh and hardened state, considering the parameters that affect the dosage of the mixture.

Objectives of the project

1. Manufacture of construction-grade geopolymer concrete using a variety of mineral admixtures and fibers cured at room temperature.

2. To determine short-term mechanical properties such as strength and modulus of elasticity.

3. To investigate the impact strength of geopolymer concrete.

4. To investigate the durability of geopolymer concrete by subjecting samples to acid attack.

II.LITERATURE REVIEW

Origin of Geopolymer Concrete

1. **Ramesh et al. (2022)** Found that the ratio of sodium silicate to sodium hydroxide or potassium silicate to potassium hydroxide (depending on the alkali used) and the ratio of alkali to binder are important considerations. Geopolymer concrete has sufficient compressive strength to be used in construction projects. On the other hand, fly ash is a by-product that is widely available and can be used in construction.

2. **Lazarescu et al. (2021)** The results of this study provided insight into the following observations that were made, and it was found that such an approach gives high-quality results of the fly ash alkaline solution geopolymer paste, especially the mechanical performance, which can only be improved through strict monitoring and testing. Accordingly, the compressive strength of the materials was significantly increased by increasing the proportion of water glass solution in the combinations. This phenomenon is believed to occur because the solution contains additional silicon (Si) species that play a key role in the geopolymerization process, resulting in a high- performance and densely packed material matrix.

3. **Van Jaarsveld et al. (2020)** Reported that the calcium content in fly ash played a significant role in strength development and ultimate compressive strength, as higher calcium content resulted in faster strength development and higher compressive strength. Particle size, calcium content, alkali metal content, amorphous content, and fly ash morphology and origin have also been found to affect the properties of geopolymers.

4. **Gourley et al. (2020)** It has also been found that the presence of significant amounts of calcium in fly ash interferes with the setting rate of the polymerisation and alters the microstructure. As a result, fly ash containing low calcium appears to be preferable to high calcium fly ash for the manufacturing of geopolymers. Fly ash should be low in calcium and have other qualities such as unburned material below 5%, Fe2O3 content, not more than 10%, 40-50% reactive silica content, 80- 90% particles less than 45 µm in size and high glass phase content to achieve the best bonding properties of the material.

5. **Fernndez-Jimnez & Palomo et al. (2019)** Conducted extensive research on geopolymer concrete made with fly ash and stated that the use of dry, low-calcium ASTM Class F fly ash from a power plant with calcium content in the fly ash of about 2% by mass helped to increase the compressive strength and concluded that fly ash based geopolymer concrete has good compressive strength and is suitable for structural applications

.MATERIALS USED IN THE EXPERIMENTATION

A mineral admixture such as fly ash and other industrial waste by- products such as GGBS were used in the present experiment to replace cement. It is intended to develop a grade M40 geopolymer concrete containing a solution of 8 M NaOH and sodium silicate. In general, geopolymerization occurs in materials rich in silica and alumina

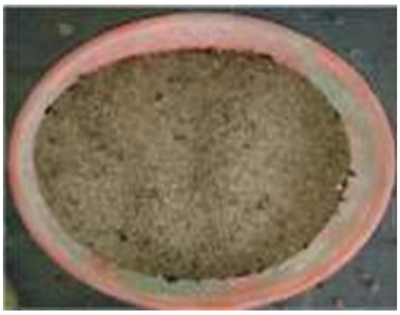
Coarse aggregate Crushed coarse aggregate with a maximum size of 20 mm is used in this study. This is obtained from the local crushing plant. It is free from dust, clay particles, organic matter, etc. Grading, specific gravity and bulk density of coarse aggregates are measured; according to IS 2386-2016 Tables 3.1 to 3.2 show the specifics of the physical properties

.

Coarse Aggregate

Fine Aggregate

In this study, local river sand was used as a fine aggregate. The sand contains no clay, silt or organic impurities. The classification, specific gravity and bulk density of fine aggregates are all assessed according to IS 2386-2016[79], IS 383-2016[78] and Zone II sand used



Fine Aggregate

Mineral Admixtures

Fly ash- A common by-product of coal-fired power plants is fly ash, formed when finely ground coal used for fuel is burned to generate electricity. The dust collection mechanism removes the fly ash. This releases small particles from combustion gases into the atmosphere. Fly ash particles are spherical and composed of silica, alumina, and iron.

TEST RESULTS

1.1 GPC Composites with Mineral Admixtures

1.2 A total of two different GPC composites were tested to determine the impact of mineral additives used as a partial fly ash replacement. A maximum total replacement of 100% was assumed.

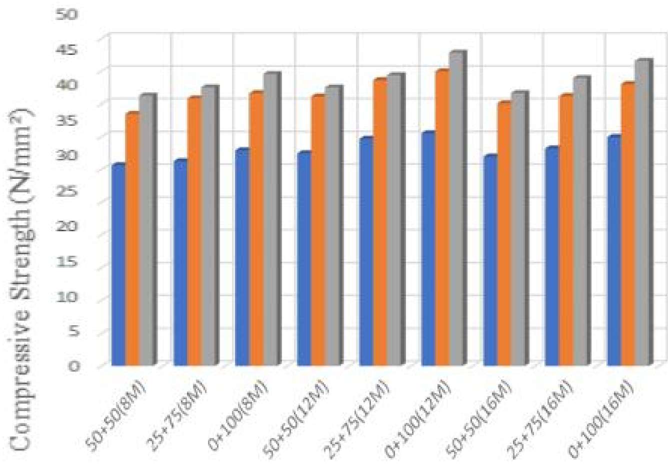
1.3 The mixes include,

1.4 With 50%, 75% and 100% GGBS

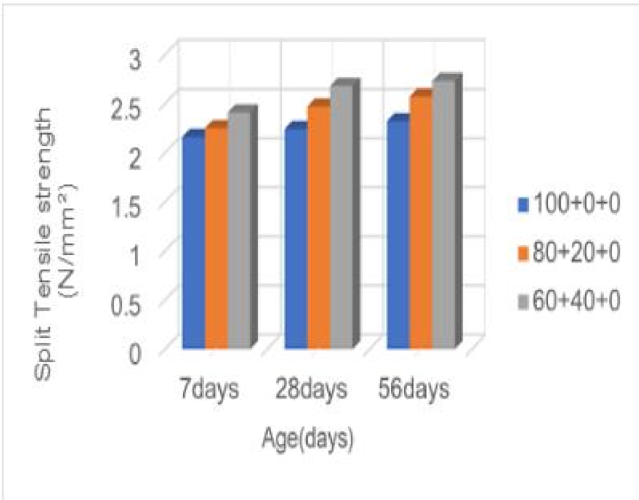
1.5 Base mix along with 0%, 20% and 40% GGBS with different percentages of glass fiber

Base mix with 0% to 100% GGBS with steel and glass fibers

Table1: Compressive strength Results of geopolymer concrete (Fly Ash 50%+ GGBS 50%) through Ambient Curing with different molarities



Graph 1 Variation of compressive strength with different concentrations of Sodium Hydroxide Solution Graph 2 Compressive strength variation for different mixes



Graph 3 Split Tensile strength variation in different mixes with 0% glass fiber

S. No	Mix	Mineral Admixtures		without fiber (0%)	Steel (0.5%) fiber	Glass (0.5%) fibre	Poly propylene (0.5%) fibe	Basat (0.5%) fiber
		Fly asl	GGBS					

		%	%					
1	M	100	0	43.5	45.55	44.35	43.7	43.6
2	M	80	20	49.5	51.5	46.35	46.15	46
3	M	60	40	52.5	53.3	53	52.8	52.6
4	M	50	50	53	54.3	53.65	53.3	53.1
5	M	40	60	54.3	56	55	54.75	54.5
6	M	30	70	59.85	61.8	60.4	60.15	60
7	M	20	80	58.5	60.45	59.25	58.85	58.7
8	M	10	90	48.8	50.75	50.5	50	49.7
9	M	0	100	48.3	50.1	49	48.85	48.6
10	M0	0	100	47	48.25	48.6	48.2	48

OVERALL DISCUSSION OF THE RESULTS

Mix design of Geopolymer Concrete (GPC)

When designing geopolymer concrete mixes, The comprise 70% of the total aggregate and 30% of the binder consisting of binder as fly ash together with fine, coarse aggregate and caustic solution and a small amount of additional water. In addition to using chemical admixtures to improve the flowability of concrete, optimal dosages of super-plasticizer and an additional amount of water were determined by trials to maintain workability.

Workability of GPC

Freshly prepared geopolymer concrete mixes were tested for workability using the standard expanding cone technique. Due to the sodium silicate's presence, all combinations were generally cohesive and glossy. All combinations were shown workability with slump values over 100mm. Geopolymer concrete becomes less workable with an increased NaOH concentration in the alkaline activator solution. This may be because adding more NaOH increases the overall solid content of the combination and reduces the amount of water present

Variation in compressive, split tensile and flexural strength geopolymer concrete composites with steel and glass fiber

It has been discovered that adding 0.5%, 0.75%, or 1.00% steel fibres to fly ash and GGBS -based geopolymer concrete boosts the compressive strength by 3.25, 9.4 or 12% for the blend of 40% fly ash and 60% GGBS. The proportional improvements in split tensile strength for the same mixture are 5%, 30.6%, and 69.4%. Flexural strength increased by 7.2%, 13%, and 17.60%, respectively. The use of glass fibres has boosted the variable strengths of geopolymer concrete mixtures. Comparatively, different glass fibre combinations are less substantial than steel fibre combinations. It was discovered that the cracks in the glass fiber-reinforced GPC samples were spread more smoothly than those in the unreinforced samples.

II.CONCLUSIONS:

Based on the research studies conducted, the following conclusions are drawn.

In the case of fly ash-based geopolymer concrete (GPC), almost 70% of the combined aggregate with 40% fly ash and the eight-molar alkaline solution gives the required design strength equivalent to M40. Higher strength can be obtained with higher molarity.

1. The workability of GPC can be maintained by adjusting a suitable amount of superplasticizer along with a limited quantity of extra water depending on the molarity of the sodium hydroxide (NaOH) solution. Adding supplementary cementing materials like fly ash and GGBS etc., at specific percentages affects the workability of GPC.

2. By curing at ambient temperature (at room temperature) after a rest period of 2 days, the design strength can be reached after 28 days. In the case of ambient curing, unlike the case of oven curing (elevated temperatures), there is a significant increase in strength from 7 to 28 days. However, over longer curing times of 28 to 56 days, there is only a marginal increase in strength.

3. As the concentration (molarity) of the NaOH solution increases, the compressive strength of the geopolymer concrete also increases. For example, in the present designed GPC mixture of 8 molarity, the strength increased when the molarity was increased to 12 molarity. However, it was found that there was a slight decrease in strength as the molarity was further increased to 16.

4. The mineral additive GGBS has proven to be an adequate replacement for fly ash in the GPC blend. As the percentage replacement by GGBS increases, the strength of GPC increases to an optimal replacement level of 70%. Beyond 70% replacement, there is a slight reduction in strength. Using glass fiber reinforcement at a certain percentage in the mix has improved the splitting strength.

5. The highest mechanical strengths of GPC were achieved with the optimum mixture of 40% fly ash and 60% GGBS. The

increases are 37.58%, 24.74% and 30.76%, in the compressive, split tensile and flexural strengths of GPC, respectively.

6. Using a further 1% steel fiber reinforcement in the GPC with an optimal combination, the mechanical strengths increased further by 12.6%, 53.49% and 16.8%. 1% steel fiber may be optimal due to balling and other issues as the percentage is further increased beyond 1%.

III.REFERENCES

1. Abdul M. Aleem, Arumairaj. P.D., “Geopolymer Concrete – A Review” International Journal of Engineering Sciences & Emerging Technologies, Volume.01, Issue 2, Feb 2012, pp.118-122.

2. Abdul Rahman, Mohammed Omer Farooq, Mohammed Abubakar, Touseeq Anwar Wasif, “Study on Performance of Concrete Incorporated with Mineral Admixtures”, International Research Journal of Engineering and Technology, Volume 08, Issue 04, April 2021, pp.1359-1364.

3. Abdullah Tahir. M.M.A. B, Tahir. M.F.M, Tajudin. M.A.F.M. A, Ekaput., Bayuaji., and Khatim. N.A.M., “Study on the Geopolymer Concrete Propete Reinforced with Hooked Steel Fiber”

4. I.O.P. Conf. Series: Materials Science and Engineering 267(2017)01201, pp.1-8.

5. Abhilash.P, Sashidhar.C, Ramana Reddy.I. V, “Strength Properties of Fly Ash and G.G.B.S. based Geopolymer Concrete”, International Journal of Chemical Tech Research, Volume.9, No.03,2016, pp: 350-356.

6. Abhishek Kumar Singh, Anshul Jain, Sanjay Jain, “Rapid Chloride Permeability Test of Polypropylene and Glass fiber Reinforced Concrete” International Journal of Engineering Research & Technology (I.J.E.R.T.) Volume. 2, Issue 5, May – 2013, pp.534-543.

7. Abhishek C. Ayachit, Pranav B. Nikam, Siddharth N. Pise, Akash D. Shaah, Vinayak. B, “Mix Design of Fly-Ash Based Geopolymer Concrete” International Journal of Scientific and Research Publications, Volume.6, Issue 2, February 2016, pp: 381-385.z

8. Adanagouda, Murthy. B, “Strength and Durability Properties of Geopolymer Concrete Made With G.G.B.S.” International Journal of Creative Research Thoughts (I.J.C.R.T.), Volume 5, Issue 4