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Performance of Fibre Reinforced Geopolymer Concrete: A Review

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Abstract: This review comprehensively investigates the performance characteristics of FRGPC, with emphasis on the mechanical behavior, durability performance imparted by fibre addition. The role of different fibre types, shapes, aspect ratios, and volume fractions is discussed in detail, considering their influence on fresh properties like workability and setting time, and hardened properties including compressive strength, split tensile strength, flexural strength. The review highlights that steel fibres are most effective in enhancing mechanical strength, while polypropylene fibres contribute significantly to improving fire and chemical resistance, reducing permeability, and controlling shrinkage cracks. Furthermore, this paper examines the influence of fibre reinforcement on durability aspects such as resistance to acid and sulphate attack. The synergy between geopolymer chemistry and fibre-matrix interaction is explored through the lens of current experimental findings, with a focus on improving the material's resistance to aggressive environmental conditions.
Keywords: Geopolymer Concrete, Fibers, Compressive Strength, Flexural Strength, Tensile Strength

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I.INTRODUCTION:

The development of Geopolymer Concrete offers promising signs for a change in the way of producing concrete. However, to seriously consider Geopolymer binders as an alternative to Ordinary Portland Cement (OPC), various strength related factors of this new material should be evaluated in any comparative analysis format. Till date, very less published literature dealing with the mechanical, durability properties and application of Indian fly ash with Polypropylene Fibre in the development of Geopolymer Concrete. Every year millions of tons of fly ash are generated worldwide by coal-fired power plants satisfying the large demand for industrial and domestic energy. The management of this by-product is always a matter of concern. Only about 20-30% of the generated fly ash is used, mainly as additive in cement and concrete, filling material and the rest is disposed of. Therefore, strategies are required to deal with this waste safely. Special attention should be paid not only to prevent environmental pollution, but also to treat fly ash as a valuable resource material. In this regard, the synthesis of Geopolymer is foreseen as an interesting approach. The most important operation in the manufacture of Geopolymer Concrete is curing. Unlike OPC concrete which needs water for curing, Geopolymer Concrete requires heat or temperature to activate the chemical reaction that takes place in Geopolymer matrix. Steam curing, dry curing and curing at ambient temperature are the types of curing that could be employed to cure the Geopolymer Concrete. The steam curing and dry curing are collectively called Heat-curing. In India, the possibility of curing at ambient temperature is high. But, in India only in summer temperature is between 26°C to 40°C. The main drawbacks in adopting ambient temperature curing are found to be the longer time it consumes to cure the concrete to get required compressive strength and the non-availability of required temperature in winter. On the other hand, the advantage of heat-curing is attainment of required compressive strength within several hours and even during all seasons. The requirement of boiler and fire wood to generate steam or electrical energy to produce heat makes it a little expensive.

II.OBJECTIVE OF THE PRESENT STUDY

1. To assess fresh properties (workability) of GPC with and without fibres.
2. To investigate mechanical performance: compressive, tensile, and flexural strength.
3. To evaluate durability through water absorption, and acid resistance tests.
4. To identify the optimum dosage of polypropylene fibre for maximum performance.

III.REVIEW OF LITERATURE

1. **Mayank Kumar "Geopolymer Concrete: Leading the World Towards a Sustainable Future" International Journal of Engineering Research & Technology (IJERT) Vol. 4 Issue 09, September-2015.:** Evaluated test results obtained on large number of Geopolymer concrete units by various researchers around the world and illustrates methods adopted for preparation, mixing, curing of eco- concrete, mechanical properties of GPC, and other useful properties like shrinkage, creep, fire and chemical resistance. Basic Properties of Geopolymer Concrete and OPC concrete based on test results are being compared. Economic benefits, recent developments and applications of geopolymer concrete are also discussed.
2. **Prabir Kumar Sarker a, Simon Mcbeath b "Fire endurance of steel reinforced fly ash geopolymer concrete elements" Construction and Building Materials Volume 90, 15 August 2015,** studied a new alternative to OPC; investigation into the fire endurance of Geopolymer Concrete is of utmost importance in order to ensure safety. Geopolymer and OPC Concrete panels of 125–175 mm thickness

containing a layer of steel mesh were exposed to fire for 2 h. Test results show higher heat transfer rate and less cracking and spalling in the Geopolymer Concrete specimens. The residual load capacity was between 61% and 71% for the Geopolymer and between 50% and 53% for the OPC concrete panels. Thus, the reinforced Geopolymer Concrete elements demonstrated superior fire endurance than the OPC counterparts.

3. **B. Singh, Ishwarya G., M. Gupta, S.K. Bhattacharyya "Geopolymer concrete: A review of some recent developments" Construction and Building Materials Volume 85, 15 June 2015**, presented along with opportunities for their use in building construction. The properties of mortars/concrete made from Geopolymeric binders are discussed with respect to fresh and hardened states, interfacial transition zone between aggregate and Geopolymer, bond with steel reinforcing bars and resistance to elevated temperature. The durability of Geopolymer pastes and concrete is highlighted in terms of their deterioration in various aggressive environments. R&D works carried out on heat and ambient cured Geopolymer at CSIR-CBRI are briefly outlined along with the product developments. Research findings revealed that Geopolymer Concrete exhibited comparative properties to that of OPC concrete which has potential to be used in Civil Engineering applications.

4. **Ampol Wongsa a, Yuwadee Zaetang b, Vanchai Sata a, P rinya Chindaprasirt a "Properties of lightweight fly ash geopolymer concrete containing bottom ash as aggregates" Construction and Building Materials Volume 111, 15 May 2016**, evaluated the utilization of waste from coal combustion thermal power plant, the properties of Lightweight Geopolymer Concrete (LWGC) containing fly ash as Geopolymer binder and bottom ash as aggregates were studied. Sodium silicate solution (NS) and 10 M sodium hydroxide (NH) were used as alkali activators. The NS/NH ratios of 0.5, 1.0, and 1.5 with liquid/ash (L/A) ratios of 0.70, 0.75, and 0.80 were used. The compressive strength, splitting tensile strength, surface abrasion resistance, density, thermal conductivity, and ultrasonic pulse velocity (UPV) of concrete were tested. The results indicated that fly ash and bottom ash could be used to produce LWGC with compressive strengths of 14.3–18.1 MPa, splitting tensile strengths of 1.2 to 2.0 MPa, and densities of 1661–1688 kg/m3 . Theirs thermal conductivity coefficients of 0.43–0.47 W/m K were lower than those of the Geopolymer Concrete containing natural aggregate. LWGC can be used for moderate strength concrete and thermal insulation concrete.

5. **Sudipta Naskar a, Arun Kumar Chakraborty b "Effect of nano materials in geopolymer concrete" Perspectives in Science Volume 8, September 2016** reported low calcium fly-ash based Geopolymer Concrete is an alternate option for cement based concrete, nano materials may also have some influence on it. An experimental program has been taken up on low calcium fly-ash based M25 grade Geopolymer Concrete having 16 (M) concentration of activator liquid. Different percentage of nano materials viz. nano silica, carbon nano tube, titanium di-oxide were also used to investigate the effect of nano materials on Geopolymer Concrete. Geopolymer Concrete with 1% Titanium di-oxide shows appreciable improvement in compressive strength although pH remains almost same in all cases.

6. **M. Albitar, M.S. Mohamed Ali, P. Visintin " Experimental study on fly ash and lead smelter slag-based geopolymer concrete columns" Construction and Building Materials Volume 141, 15 June 2017** addressed the application of Geopolymer Concrete at a member level through an experimental investigation on the behaviour of fly ash/Granulated Lead Smelter Slag (GLSS)-based Geopolymer Concrete columns and beams tested under concentric and eccentric loading. Slenderness effect of the Geopolymer Concrete columns are investigated and axial load-moment interaction envelopes are generated experimentally. The analytical interaction diagrams are compared to those calculated using classical methods for normal reinforced concrete beams and columns. The results of the comparison show that the analytical interaction diagrams overestimated the test results due to variation in material properties. Nevertheless, the results reveal that fly ash/GLSS-based Geopolymer Concrete exhibits similar structural behaviour to OPC concrete. The results also highlight potential issues with the scaling of ambient-cured Geopolymer Concrete to the structural level.

7. **Kolli. Ramujee [a], M. PothaRaju [b] "Mechanical Properties of Geopolymer Concrete Composites" Materials Today Proceeding Volume 4, Issue 2, Part A, 2017** investigated the mechanical properties of flyash based Geopolymer Concrete (GPC). Experimentally measured values of the Compressive Strength and Split Tensile Strength of GPC specimens made from low, medium and higher grades compared with reference to the control mixes (OPC).The regression model analysis was carried out to study the relationship between the Compressive strength and Split Tensile strength and it was found that the mechanical behaviour of GPC is similar to that of ordinary Portland cement (OPC) concrete.

8. **R. Pouhet, M. Cyr "Formulation and performance of flash metakaolin geopolymer concretes" Construction and Building Materials Volume 120, 1 September 2016**, evaluated flash metakaolin Geopolymer as an effective binder to replace Portland cement in concrete. A study conducted on the workability of fresh Geopolymer Concretes has revealed that several applications can be targeted, from fluid to dry concretes: reinforced beam or masonry units directly manufactured in industrial precast plant. Compressive strength of Geopolymer Concretes showed that these materials could have better mechanical properties than

Portland Cement Concretes, despite a larger porosity. The amount of aggregates (in the range 71–83%) seemed to have a negligible effect on the performance of Geopolymer Concrete, probably due to the absence of ITZ at the binder-aggregate interface.

9. **P. Visintin, M.S. Mohamed Ali, M. Albitar, W. Lucas "Shear behaviour of geopolymer concrete beams without stirrups" Construction and Building Materials Volume 148, 1 September 2017**, studied a recently developed mechanics based segmental approach for predicting the shear capacity of reinforced concrete (RC) beams is extended and applied to reinforced Geopolymer Concrete Beams without stirrups. The results of eight reinforced Geopolymer Concrete Beam tests without stirrups are presented along with the results of four direct shear tests with low levels of confinement. Significantly, the results of the direct shear tests show that the shear-friction properties for the Geopolymer Concrete utilised in the experimental investigation fall within the range of shear-friction properties of established OPC concrete. Moreover, it is shown that the segmental approach proposed can predict the shear capacity of Geopolymer Concrete beams with good accuracy and hence can be used as a tool to aid in the development of new design guidelines for Geopolymer Concrete.

10. **Selvakumar T1 "Impact and Compressive Strength Performance of Fibre Reinforced Geopolymer Concrete" International Research Journal of Engineering and Technology (IRJET) Volume: 05 Issue: 08 Aug 2018** investigated experimental study on the impact and compressive strength performance of fibre reinforced Geopolymer concrete, prepared using Ground Granulated Blast Furnace Slag (GGBFS) and Black Rice Husk Ash (BRHA). The Fibre reinforced Geopolymer concrete was prepared with GGBFS as the primary binder instead of BRHA and cement was replaced with GGBS at various proportions such as 10%, 20% and 30%. The compressive strength of Geopolymer concrete for various replacement of BRHA was studied in addition to the impact study. The test results showed that the strength of Geopolymer concrete with 10% replacement of BRHA was high compared to 20% and 30% replacement levels. The Addition of crimped fibers in the geopolymer concrete was used for studying the impact strength of concrete. Crimped fiber was added at 0.5%,0.75% and 1% by volume of concrete. Energy absorption of geopolymer concrete with 0.5% addition of crimped fibers is found in the higher compared to other percentages of fibers.

11. **S. Deepa Raj1, Ajith Ramachandran1 "Performance of hybrid fbre reinforced geopolymer concrete beams" SN Applied Sciences (2019)** investigation was carried out to study the efect steel fbres and hybrid fbres (steel and polypropylene) on the performance of low calcium fy ash based geopolymer concrete beams under shear. The main variable considered are the volume fraction of steel fbres (0.5% and 1%) and volume fraction of hybrid fbres (0.25% steel fbres and 0.25% polypropylene fbres, 0.25% steel fbres and 0.75% polypropylene fbres and 0.5% steel fbres and 0.5% polypropylene fbres). Test results revealed that the split tensile strength, fexural strength and modulus of elasticity of hybrid fbre reinforced concrete are more than that of steel fbre reinforced concrete. For studying the performance of fbre reinforced and hybrid fbre reinforced beams under shear, shear defcient beams of size 1200 mm ×100 mm×150 mm size were prepared with varying volume fractions of fbres. The beams were tested under two point loading after 28 days of casting. Experimental results indicated that the hybrid fbre reinforced geopolymer concrete beams are having better shear strength and superior behaviour than steel fbre reinforced beams.

12. **A Chithambar Ganesh1 , K Rajesh Kumar2,7 ,M Vinod Kumar3 , Vyshnavi 8 , RVandhiyan4 , N Gurumoorthy5 and S Sivakumar6 "Durability Studies on the Hybrid Fiber reinforced Geopolymer concrete made of M-sand under ambient curing" IOP Conf. Series: Materials Science and Engineering 981 (2020)** studied on high elasticity modulus and low elasticity modulus fibers were inserted into geopolymer concrete made of M-sand. As ambient curing is favored in this study, geopolymer concrete is GGBS dependent.

    As an alkali solution, a mixture of sodium hydroxide solution and sodium silicate solution is used.Durability properties such as water absorption, sorptivity, rapid chloride penetration test, resistance to HCL attack, resistance to H2SO4attack,resistance to sulphate and marine attack are determined in this study.

    Significant observance has been made with respect to different proportions of glass fiber and polypropylene fiber. Glass fibers yielded fairer results compared to the polypropylene fibers. This study reviews the scope of the use of hybrid fibers made of M-sand in Geopolymer concrete.

IV.CONCLUSION

Based on the investigations, the following conclusions were drawn

- The presence of fibres tends to reduce the workability of fresh geopolymer concrete.
- Fibre Reinforced Geopolymer Concrete (FRGPC) provides a viable and eco-friendly substitute for conventional Portland cement concrete.
- The incorporation of fibres significantly improves mechanical properties like tensile strength, flexural strength, and impact resistance.
- FRGPC demonstrates strong resistance to chemical attacks (acids, sulphates).

V.REFERENCE

1. Albitar.M, Ali M.S., Visintin P. "Experimental study on fly ash and lead smelter slag-based geopolymer concrete columns" Construction and Building Materials Volume 141, 15 June 2017.
2. Baskar.P , Annadurai.S , Sekar.K, Prabakaran.M, "A Review on Fresh, Hardened, and Microstructural Properties of Fibre-Reinforced Geopolymer Concrete" Polymers (Basel) 2023 Mar 16;15(6):1484
3. Chithambar A, Kumar K , Kumar M , Vandhiyan R , Gurumoorthy N and Sivakumar S "Durability Studies on the Hybrid Fiber reinforced Geopolymer concrete made of M-sand under ambient curing" IOP Conf. Series: Materials Science and Engineering 981 (2020).
4. Farhan.K*, Johari.M, Demirboğa.R, Shihata.A "Performance of Polypropylene Fiber Reinforced GGBFS-based Alkali Activated Composite under Elevated Temperatures" Journal of Advanced Concrete Technology Vol. 21, July 2023
5. Kadarkarai A, Arunachalam S Chithambar G, Loganathan V. "Optimization of hybrid fibre reinforced geopolymer concrete using hardened and durability properties" Res. Eng. Struct. Mat. Vol. 9 Iss. 1 (2023).
6. Kumar.N, Rahul S.M And Manuvijay "Sustainable Development And Performance Evaluation Of Geopolymer Concrete (GPC): A Comprehensive Study" IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), Volume 21, Issue 6 Ser. 2 (Nov. – Dec. 2024)
7. Kumar. M "Geopolymer Concrete: Leading the World Towards a Sustainable Future" International Journal of Engineering Research & Technology (IJERT) Vol. 4 Issue 09, September-2015
8. Kolli. R , PothaRaju. M. "Mechanical Properties of Geopolymer Concrete Composites" Materials Today Proceeding Volume 4, Issue 2, Part A, 2017.
9. Lingling Q, Jiahao Y, Mengya Z , et al. Mechanical properties and durability of fiber reinforced geopolymer composites: A review on recent progressd. Advance. September 15, 2022
10. Li .W, Shiying.T , Wang.Z , Zerfu.K "Eco-friendly fibre reinforced geopolymer concrete: A critical review on the microstructure and long-term durability properties" Case Studies in Construction Materials Volume 16, June 2022)
11. Nair.D, Meena.T, Nair.P S, Farsana.F, Preethymol. P , Balakrishnan.K "Hybrid fibre reinforced geopolymer concrete: An ecofriendly construction material" International Journal of Engineering Research and Applications, Vol. 14, Issue 4, April, 2024
12. Naskar. S, Chakraborty. A "Effect of nano materials in geopolymer concrete" Perspectives in Science Volume 8, September 2016.
13. Pouhet R., Cyr.M "Formulation and performance of flash metakaolin geopolymer concretes" Construction and Building Materials Volume 120, 1 September 2016.
14. Porpadham. T, Thirugnanasambandam S. "Mechanical and Durability Performance of Fiber-Reinforced Geopolymer Concrete," SSRG International Journal of Civil Engineering, vol. 11, no. 11, , 2024
15. Ramachandran A. "Performance of hybrid fbre reinforced geopolymer concrete beams" SN Applied Sciences (2019).
16. Sarker.P, Mcbeath.S "Fire endurance of steel reinforced fly ash geopolymer concrete elements" Construction and Building Materials Volume 90, 15 August 2015.
17. Selvakumar. T "Impact and Compressive Strength Performance of Fibre Reinforced Geopolymer Concrete" International Research Journal of Engineering and Technology (IRJET) Volume: 05 Issue: 08 Aug 2018.
18. Singh B. Ishwarya G., Gupta M., Bhattacharyya S.K. "Geopolymer concrete: A review of some recent developments" Construction and Building Materials Volume 85, 15 June 2015.
19. Visintin.P, Ali M.S., Albitar.M, Lucas.W "Shear behaviour of geopolymer concrete beams without stirrups" Construction and Building Materials Volume 148, 1 September 2017.
20. Wongsa A, Zaetang Y , Sata V, Chindaprasirt P "Properties of lightweight fly ash geopolymer concrete containing bottom ash as aggregates" Construction and Building Materials Volume 111, 15 May 2016