

ENHANCE THE TENSILE STRENGTH PROPERTIES OF ACTIVATING SOLUTION CONCRETE

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ABSTRACT

Study highlights the potential of steel slag as a sustainable alternative to natural coarse aggregates in geopolymer concrete (GPC) with low-calcium fly ash and zero cement content. By evaluating its mechanical properties—including compressive, tensile, flexural strength, rebound hammer, and ultrasonic pulse velocity tests—you demonstrated that steel slag performs comparably to natural aggregates. The use of steel slag promotes waste utilization and reduces dependency on natural resources, aligning with sustainable construction practices. Comparable performance in strength and durability tests suggests that steel slag can effectively replace natural aggregates without compromising structural integrity.

Keywords: Natural coarse aggregates, geopolymer concrete (GPC), compressive, tensile, flexural strength, steel slag.

1. INTRODUCTION

Geo-polymer concrete, made from industrial waste like fly ash, slag, or silica fume, uses alkali activation instead of Portland cement. Adding iron powder slag can. The zero-cement GPC further contributes to lowering the carbon footprint, making it environmentally friendly. Assess resistance to sulfate attack, acid attack, and freeze-thaw cycles to establish long-term performance. The urgent need for sustainable practices in concrete production, particularly by adopting geopolymer concrete to address environmental challenges. Geopolymer concrete utilizes silica- and alumina-rich pozzolanic materials, such as fly ash, GGBS (Ground Granulated Blast Furnace Slag), and metakaolin, which are activated by alkaline solutions like sodium hydroxide (NaOH) and sodium silicate. This reduces carbon emissions significantly compared to the traditional Ordinary Portland Cement (OPC) process, which contributes to 8–10% of global CO₂ emissions. Incorporating these waste materials into geopolymer concrete **provides a dual benefit by addressing** waste disposal issues **and** conserving resources.

Enhance Strength: Iron slag acts as a pozzolanic or reactive material, improving the compressive and flexural strength of GPC.

Reduce Environmental Impact: Both GPC and iron powder slag are industrial by-products, minimizing the carbon footprint compared to traditional concrete.

Improve Durability: Iron slag can refine pore structure and increase resistance to chemical attack.

Utilize Industrial Waste: Reduces landfilling and promotes a circular economy.

Shaofeng Zhang et al (2023) this study aims to improve the mechanical properties of cement-iron slag mortar by the addition of alkaline activators (NaOH, Na₂CO₃/NaOH and water glass) to promote the optimal utilization of iron slag. In this paper, the setting time, flexural and compressive strength, early-age hydration kinetics and microstructure are investigated to explore how the alkaline activators influence the hydration of cement-iron slag system. The results indicate that the incorporation alkaline activators shortens the setting time and enhances the mechanical strength of cement-iron slag composite binder, which are ranked from large to small in the order of water glass > Na₂CO₃/NaOH > NaOH. Moreover, the hydration exothermic action of cement-iron slag activated by alkaline activators is significantly accelerated in comparison to cement-iron slag. Furthermore, the incorporation of alkaline activators promotes the formation of amorphous gel products, such as gel, of cement-iron slag system, which can fill the capillary pores and convert them into gel pores with a smaller pore size, leading to a denser microstructure. Based on the outcome of different analytical techniques, it is observed that alkaline activators can facilitate disintegration of iron slag's vitreous structure and can be applied to enhance the reactivity of iron slag in the cement-iron slag system to develop a sustainable composite cement.

Zhengyi Ren et al (2023) Iron slag is a solid waste produced in crude iron smelting, and a typical management option is stockpiling in slag disposal yards. Over the years, the massive production of iron slags and the continuous use of residue yards have led to vast occupation of land resources and caused severe environmental concerns. Iron slag particles can potentially be used as aggregates in concrete production. However, the volume stability of iron slag is poor, and the direct use of untreated iron slag aggregate (SSA) may cause cracking and spalling of concrete. The

present research summarizes, analyzes, and compares the chemical, physical, and mechanical properties of iron slags. The mechanism and treatment methods of volume expansion are introduced, and the advantages, disadvantages, and applicable targets of these methods are discussed. Then, the latest research progress of iron slag aggregate concrete (SSAC) is reviewed. Using SSA leads to an increase in the density of concrete and a decrease in workability, but the mechanical properties and durability of SSAC are superior to natural aggregate concrete (NAC). Finally, future research in this field is proposed to motivate further studies and guide decision-making.

2. METHODOLOGY

Steel slag is an industrial by-product generated during steel production, making its reuse a waste management solution that reduces. Iron powder slag can be effectively integrated into geo polymer concrete to produce high-strength, durable, and eco-friendly materials. Its application supports waste valorization and sustainability goals, particularly in infrastructure and industrial construction. Further research can focus on long-term durability tests and **cost** optimization to expand its practical use. Steel slag possesses high density and angular particle shapes, which enhance strength and interlocking properties in geopolymer concrete. Exhibits excellent abrasion resistance and impact strength, improving the concrete's durability. Rich in calcium, silica, and iron oxides, similar to natural aggregates, ensuring good bonding properties with geopolymer binders. Its alkaline nature complements geopolymerization reactions, enhancing the strength development. Utilizes industrial by-products **such** as fly ash, GGBS, or metakaolin as binders, eliminating the need for Ordinary Portland Cement (OPC). Provides improved compressive strength and flexural strength compared to traditional mixes. This study investigates the material properties and performance of geopolymer concrete composed of fly ash, fine aggregate, coarse aggregate, alkaline solution, and steel slag. The focus is to assess the compressive strength of cast specimens under different curing conditions and varying proportions of steel slag and fly ash. Clarify the curing type (water curing, oven curing, or ambient curing) and specify temperature ranges, especially since geopolymer concrete can have varying curing requirements.

Materials Used

Fly Ash - A by-product of coal combustion in thermal power plants, utilized as a source of aluminosilicate for geopolymerization.

Fine Aggregate - Clean, well-graded sand with appropriate fineness modulus for achieving workability.

Coarse Aggregate - Crushed stone or gravel providing strength and bulk to the concrete mix.

Alkaline Solution - A combination of sodium hydroxide (NaOH) and sodium silicate (Na₂SiO₃) as an activator to promote polymerization.

Steel Slag - An industrial by-product from steel manufacturing, used as a partial replacement for coarse or fine aggregate to improve strength and durability.

Experimental Setup

Mix Proportions

- ❖ Various proportions of fly ash and steel slag were used in the geopolymer concrete mix.
- ❖ Water-to-binder ratio and alkaline-to-binder ratio were kept consistent across samples.

Specimen Preparation

- ❖ Standard cube molds (150mm x 150mm x 150mm) were used for casting.
- ❖ Mixing was carried out using a mechanical mixer to ensure uniformity.

Curing Conditions

- ❖ **Ambient Curing:** Specimens were left to cure at room temperature for 28 days.
- ❖ **Sunshine Curing:** Specimens were exposed to direct sunlight during the daytime and ambient conditions at night.

Testing Methodology

- ❖ Conducted on cured specimens using a compression testing machine at specified intervals (7, 14, and 28 days).

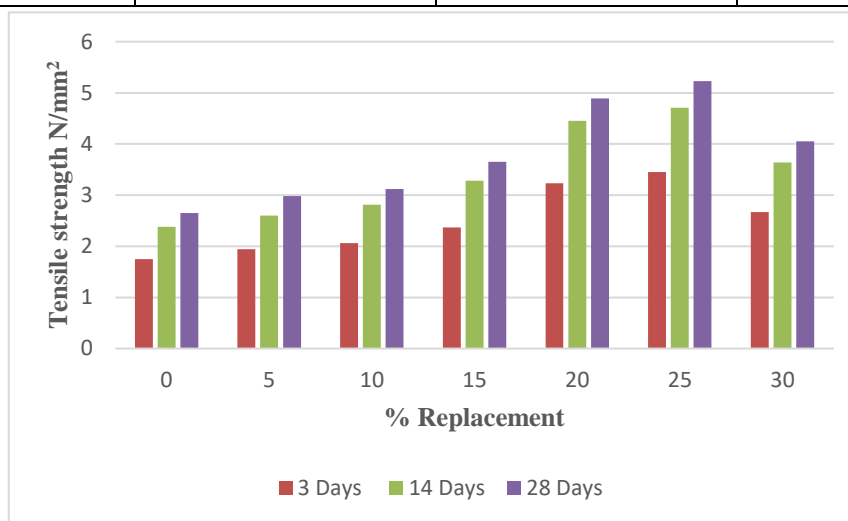
3. RESULTS AND DISCUSSION

- Specimens with higher steel slag content showed improved compressive strength compared to control specimens without steel slag.
- Fly ash content positively influenced strength development over time.
- Accelerated strength gain was observed due to increased temperature exposure.
- Early strength development was significantly higher than under ambient curing.
- Sunshine curing yielded better early-age strength, while ambient curing provided more gradual and stable strength development.

- Optimal performance was achieved with a balanced mix of fly ash and steel slag, combined with sunshine curing.

Table 1 Tensile strength N/mm²

% Replacement	3 Days	14 Days	28 Days
0	1.75	2.38	2.65
5	1.94	2.60	2.98
10	2.06	2.81	3.12
15	2.37	3.28	3.65
20	3.23	4.45	4.89
25	3.45	4.71	5.23
30	2.67	3.64	4.05



4. CONCLUSION

This study demonstrates that geopolymer concrete with fly ash and steel slag exhibits promising compressive strength characteristics. Sunshine curing enhances early strength, making it suitable for projects requiring rapid strength gain. The use of industrial by-products supports sustainable and eco-friendly construction practices. A versatile solution for modern construction needs. Its integration into structural applications can significantly reduce environmental impact, improve performance, and provide innovative building solutions.

5. REFERENCES

- [1] Shaofeng Zhang , Ditao Niu “Hydration and mechanical properties of cement-iron slag system incorporating different activators” Construction and Building Materials Volume 363, 11 January 2023, 129981.
- [2] Mr.T.Vijayashankar1 , V.Naveen2 , S.Vineeth “An Experimental Study on Geopolymer Concrete with Steel Slag as fine Aggregate” International Journal of Advances in Engineering and Management (IJAEM) Volume 5, Issue 4 April 2023, pp: 1325-1330 www.ijaem.net ISSN: 2395-5252.
- [3] D.Dutta, “Influence of Siliceous and Calcareous Materials. As an Additive on The Performance Of Fly Ash Based And Mortar” M.Sc. Department Of Civil Engineering Faculty Of Engineering And Technology Jadavpur University, Kolkata, May 2010, to be published.
- [4] B.Vijaya Ragan(2008), Studies On Fly Ash Based Geo Polymer Concrete , Article June 2008, Research Gate DOI 10.1201/9781420007657.Ch26.C hinaraju , Ramkumar (2013), Study On Concrete Using Steel Slag As Coarse Aggregate Replacement.
- [5] Mohammed Nadeem, Arun Pofale (2012), Experimental Investigation Of Using Slag As An Alternative To Normal Aggregates (Coarse And Fine) In Concrete.
- [6] N A Lloyd and B V Rangan (2010) , Geopolymer Concrete with Fly Ash, Second International Conference on Sustainable Construction materials.
- [7] B. Vijaya Rangan (2008), Studies on Fly Ash based Geopolymer Concrete, Article June 2008, Research Gate DOI 10.1201/9781420007657.ch26.Chinnaraju 1, Ramkumar(2013), Study On Concrete Using Steel Slag As Coarse Aggregate Replacement And Eco sand As Fine Aggregate Replacement, International Journal of Research in Engineering & Advanced Technology, Volume 1, Issue 3.

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- [8] Vinothini.P, Kumaravel. S and Girija. P(2015), Effect of Ambient Curing in Geopolymer Concrete, International Journal of Applied Engineering Research,ISSN 0973-4562 Vol.10 No.51(2015)
- [9] Nath, P., & Sarker, P. K. (2014). Effect of GGBFS on setting, workability and early strength properties of fly ash geopolymer concrete cured in ambient condition. *Construction and Building Materials*, 66, 163–171.
- [10] Ryu, G. S., Lee, Y. B., Koh, K. T., & Chung, Y. S. (2013). The mechanical properties of fly ash-based geopolymer concrete with alkaline activators. *Construction and Building Materials*, 47(2013), 409–418