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Compressive Strength Assessment of Concrete Containing Metakaolin Powder and Glass Powder

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ABSTRACT: This study explores the partial replacement of cement with metakaolin powder and waste glass powder in concrete production to enhance sustainability and performance. Metakaolin, a highly reactive pozzolanic material, and finely ground glass powder, rich in silica, were used as supplementary cementitious materials. The objective was to evaluate their effects on the Compressive Strength of concrete. Results showed that replacing cement with these materials improved compressive strength. The findings support the use of metakaolin and glass powder as eco-friendly alternatives that reduce cement consumption and environmental impact. The combined use of ground glass powder and metakaolin in concrete is allowable at replacement of up to 20% of the cement, in order to promote microstructural improvements and increase in properties related to durability and compressive strength at 28 days.

KEYWORDS: Metakaolin powder, glass powder, pozzolanic material, cementitious, microstructural

I. INTRODUCTION

The combination of metakaolin powder and glass powder as partial replacements for cement in concrete presents a synergistic approach to enhancing both sustainability and performance. Metakaolin, with its high pozzolanic reactivity, contributes significantly to early-age strength and micro structural refinement, while finely ground glass powder, rich in amorphous silica, supports long-term strength development and durability. When used together, these materials complement each other by improving the hydration process and increasing the formation of secondary calcium silicate hydrate (C-S-H), resulting in a denser and more durable concrete matrix. Additionally, this blend reduces the overall cement content, thereby lowering the carbon footprint of concrete production without compromising structural integrity. The improved packing density and pore structure achieved by combining these powders help in minimizing water absorption and permeability, making the concrete more resistant to environmental deterioration.

Using both metakaolin and glass powder also has economic and environmental advantages. The partial substitution of cement with these materials not only reduces reliance on energy-intensive Portland cement but also promotes the recycling of industrial by products such as waste glass. This dual replacement strategy can significantly reduce greenhouse gas emissions and conserve natural resources.

II. LITERATURE SURVEY

Malla Chandra sekhar et al. (2023) This study explores the use of metakaolin (MK) and glass powder (GP) as sustainable alternatives to cement and sand in concrete, aiming to enhance its mechanical properties while addressing environmental concerns. MK, with its pozzolanic nature, improves the microstructure and strength of concrete, while GP, rich in silica, serves as an effective fine aggregate replacement. The research tested various mix proportions of MK

and GP in M40 grade concrete and found that a combination of 12% MK and 10% GP significantly improved compressive, flexural, and tensile strengths compared to conventional concrete. The work fills a research gap by examining their combined effect—particularly with GP used as a sand substitute—and supports the broader goal of developing durable, eco-friendly construction materials.

Juvas Klaus et al. (2009) Metakaolin (MK), derived from the calcination of kaolinitic clay, has emerged as a highly effective supplementary cementing material in modern concrete technology. With its fine particle size and high pozzolanic reactivity, MK significantly enhances both the mechanical and durability properties of concrete and mortar. Its incorporation improves compressive and flexural strength, reduces permeability, and increases resistance to chemical attack and alkali-silica reactivity. Widely applied in high-performance and lightweight concrete, precast components, and fiber-reinforced composites, MK contributes to denser microstructures and improved workability. This review highlights MK's versatility and positive impact when used as a partial cement replacement, supporting the development of more durable, sustainable, and high-quality concrete products.

Bhupendra Singh et al. (2014) The increasing challenges of waste disposal and environmental sustainability have led researchers to explore the reuse of industrial and municipal waste materials in concrete production. Among these, waste glass powder has shown promising results as a partial replacement for cement, offering both environmental and technical benefits. Various studies indicate that incorporating finely ground glass powder into concrete can enhance workability and improve mechanical properties such as compressive, flexural, and tensile strengths, particularly at replacement levels up to 20–30%. These improvements are often attributed to the pozzolanic nature of glass powder and its fine particle size, which contribute to better particle packing and reduced porosity. Additionally, durability characteristics like reduced water absorption and lower sorptivity have been observed, enhancing the concrete's resistance to moisture and chemical attack. While early concerns about alkali-silica reaction (ASR) had limited glass use, recent advances have mitigated these risks, making glass powder a viable and sustainable supplementary cementitious material. Overall, the literature supports the beneficial use of waste glass in concrete, providing a sustainable solution to both concrete production and glass waste management.

Shilpa Raju et al. (2014) Recent studies have focused on the use of waste glass powder as a partial replacement for cement in concrete, aiming to reduce environmental impacts associated with cement production, which contributes significantly to global CO₂ emissions. Finely ground waste glass, due to its high silica content and pozzolanic properties, offers potential as a sustainable binder. In the referenced research, concrete mixes were prepared by replacing cement with glass powder in varying proportions (5% to 40%), and tested for compressive and flexural strength at 7, 28, and 90 days. The results indicated that a 20% replacement level yielded the highest strength improvements compared to conventional concrete, with compressive and flexural strengths increasing by approximately 24% and 20% respectively at 28 days. However, workability decreased with higher glass content due to reduced cementitious paste, while alkalinity tests revealed pH levels above 12 across all mixes, indicating sufficient resistance to corrosion. Overall, the study supports the feasibility of using glass powder in concrete for enhanced strength and environmental benefits, particularly at optimized replacement levels.

Ahmed Tafraoui et al. (2016) Ultra-High Performance Concrete (UHPC) incorporating metakaolin has been demonstrated to exhibit outstanding durability characteristics, making it a viable alternative to traditional UHPC that relies heavily on silica fume. This study evaluates the resistance of such concrete to various forms of degradation, including permeability to oxygen, chloride ion penetration, water absorption, carbonation, and chemical leaching. The results show that metakaolin-based UHPC maintains high mechanical strength, with compressive strengths reaching 250 MPa and notable tensile capacities, while offering similar or improved durability performance compared to silica fume-based mixes. Given the rising cost and limited availability of silica fume, metakaolin proves to be a technically and economically advantageous substitute, contributing to dense microstructures with low porosity and high resistance to aggressive agents. Microstructural analyses using X-ray diffraction and SEM confirm the effective participation of metakaolin in pozzolanic reactions, supporting its role in enhancing the long-term durability of UHPC.



MATERIALS:

1. Metakaolin powder

Metakaolin is a pozzolanic material created by calcining kaolin clay, a mineral commonly used in ceramics

2. Glass powder:

Glass powder is a granular or fine powder produced by milling or crushing glass into very small particles,

MIX PROPORTIONS:

1. Cement-100%

2. Cement-90%, Metakaolin powder-5%, Glass powder-5%

3. Cement-84%, Metakaolin powder-8%, Glass powder-8%

4. Cement-78%, Metakaolin powder-11%, Glass powder-11%

5. Cement-76%, Metakaolin powder-12%, Glass powder-12%

6. Cement-72%, Metakaolin powder-14%, Glass powder-14%

TESTS DONE ON COARSE AGGREGATE AND FINE AGGREGATE:

1. Specific gravity of coarse aggregate & Fine aggregate:

The specific gravity test for coarse aggregate determines the ratio of the mass of a given volume of the aggregate to the mass of an equal volume of water.

2. Water absorption of coarse aggregate & Fine aggregate

The water absorption test for coarse aggregates assesses how much water a material can absorb into its pores,

3. Sieve analysis of coarse aggregate & fine aggregate:

Sieve analysis determines the particle size distribution of both coarse and fine aggregates by separating particles using sieves with decreasing mesh sizes

III. RESULTS

Compression test values of combination of metakaolin powder and glass powder for 28 days of curing

S.NO	% Percentages	Cube-1	Cube-2	Cube-3	Average
1	Cement (100%)	93 N/mm ²	76 N/mm ²	85 N/mm ²	84.6 N/mm ²
2	5%	80 N/mm ²	79 N/mm ²	85 N/mm ²	81.3 N/mm ²
3	8%	63 N/mm ²	68 N/mm ²	69 N/mm ²	66.6 N/mm ²
4	11%	81 N/mm ²	78 N/mm ²	74 N/mm ²	77.6 N/mm ²
5	12%	91 N/mm ²	90 N/mm ²	84 N/mm ²	88.3 N/mm ²
6	14%	61 N/mm ²	76 N/mm ²	70 N/mm ²	69 N/mm ²

IV. RESULT AND CONCLUSION

The compressive strength results of concrete with varying percentages of cement replacement reveal a fluctuating trend. The control mix with 100% cement achieved an average strength of **84.6 N/mm²**, serving as the baseline. A 5% replacement resulted in a slight reduction to **81.3 N/mm²**, indicating limited impact on strength. At 8%, a significant drop to **66.6 N/mm²** was observed, showing that higher replacement levels can weaken the concrete. However, strength slightly improved at 11% with **77.6 N/mm²**, and peaked at **12%** with **88.3 N/mm²**, surpassing the control mix and suggesting an optimal replacement level. Beyond this, at 14%, the strength declined again to **69 N/mm²**, confirming that excessive replacement negatively affects performance. To regain or enhance strength at higher replacement levels, supplementary strategies can be adopted, such as incorporating **pozzolanic materials like silica fume or fly ash**, improving **curing conditions**, using **super plasticizers for better compaction**, and optimizing **water-to-cement ratios** to improve the concrete's microstructure and bonding.

REFERENCES

1. Sekhar, M. C., Kumar, M. H., Raju, S. L., & Saikrishnamacharyulu, I. (2023). Influence of metakaolin and glass powder on mechanical behaviour of concrete. Materials Today: Proceedings. Advance online publication. <https://doi.org/10.1016/j.matpr.2023.03.713>
2. Siddique, R., & Klaus, J. (2009). Influence of metakaolin on the properties of mortar and concrete: A review. Applied Clay Science, 43(3–4), 392–400. <https://doi.org/10.1016/j.clay.2008.11.007>
3. Shekhawat, B. S., & Aggarwal, V. (2014). Investigation of strength and durability parameters of glass powder based concrete. International Journal of Engineering Research & Technology (IJERT), 3(7). <https://www.ijert.org/investigation-of-strength-and-durability-parameters-of-glass-powder-based-concrete>
4. Raju, S., & Kumar, P. R. (2014). Effect of using glass powder in concrete. International Journal of Innovative Research in Science, Engineering and Technology, 3(5), 123–127. Retrieved from https://www.ijirset.com/upload/2014/special/iciaset/57_internationalseminar.pdf
5. Tafroui, A., Escadeillas, G., & Vidal, T. (2016). Durability of the ultra high performances concrete containing metakaolin. Construction and Building Materials, 112, 980–987. <https://doi.org/10.1016/j.conbuildmat.2016.02.169>
6. Chandak, M. A., & Pawade, P. Y. (2018). Influence of metakaolin in concrete mixture: A review. The International Journal of Engineering and Science (IJES), 7(4), 37–41. Retrieved from <https://theijes.com/1801-RICCE-Volume-1.html>
7. Abellán-García, J., Santofimio-Vargas, M. A., & Torres-Castellanos, N. (2020). Analysis of metakaolin as partial substitution of ordinary Portland cement in reactive powder concrete. Advances in Civil Engineering Materials, 9(1), 368–386. <https://doi.org/10.1520/ACEM20190224>
8. Aiswarya, S., Arulraj, P. G., & Dilip, C. (2013). A review on use of metakaolin in concrete. Engineering Science and Technology: An International Journal, 3(3), 592–597. Retrieved from https://www.academia.edu/35162353/A_REVIEW_ON_USE_OF_METAKAOLIN_IN_CONCRETE
9. Malagavelli, V., Angadi, S., & Prasad, J. S. R. (2018). Influence of metakaolin in concrete as partial replacement of cement. International Journal of Civil Engineering and Technology, 9(7), 105–111. Retrieved from <https://www.iaeme.com/ijciat/issues.asp?JType=IJCIET&VType=9&IType=7>

10. Badogiannis, E. G., Sfikas, I. P., Voukia, D. V., Trezos, K. G., & Tsivilis, S. G. (2015). Durability of metakaolin Self-Compacting Concrete. *Construction and Building Materials*, 86, 122–131. <https://doi.org/10.1016/j.conbuildmat.2015.03.116>
11. Muhd Norhasri, M. S., Hamidah, M. S., Mohd Fadzil, A., & Megawati, O. (2016). Inclusion of nano metakaolin as additive in ultra high performance concrete (UHPC). *Construction and Building Materials*, 127, 167–175. <https://doi.org/10.1016/j.conbuildmat.2016.09.127>
12. Dinakar, P., & Manu, S. N. (2014). Concrete mix design for high strength self-compacting concrete using metakaolin. *Materials & Design*, 60, 661–668. <https://doi.org/10.1016/j.matdes.2014.04.025>
13. Zidol, A., Tognonvi, M. T., & Tagnit-Hamou, A. (2017). Effect of glass powder on concrete sustainability. *New Journal of Glass and Ceramics*, 7(2), 34–47. <https://doi.org/10.4236/njgc.2017.72004>
14. Singh, H., & Siddique, R. (2023). Long term durability assessment of self-compacting concrete made with crushed recycle glass and metakaolin. *Construction and Building Materials*, 373, 130872. <https://doi.org/10.1016/j.conbuildmat.2023.130872>
15. Matos, A. M., & Sousa-Coutinho, J. (2012). Durability of mortar using waste glass powder as cement replacement. *Construction and Building Materials*, 36, 205–215. <https://doi.org/10.1016/j.conbuildmat.2012.04.027>



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