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A Review of Alkali Activated Concrete Using Eco friendly Industrial Waste Materials.

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Abstract :– Geopolymerization is a sustainable way to make concrete by using industrial waste materials and alkaline activators. However, Geopolymer concrete often doesn't have the strength it needs, so adding nano materials can help. This review looks at how different amounts of nano materials affect the properties of geopolymer concrete. Adding nano-silica, aluminum oxide, titanium oxide, graphene, and carbon nanotubes has shown significant improvements in the concrete's strength, even when it's cured at normal temperatures. The addition of nano materials makes the concrete more dense, reducing its ability to absorb water and making it more durable against acidic conditions. Using recycled glass powder as a partial replacement in geopolymer production has also shown promising results. Adding nano-silica improves the compressive strength of geopolymer concrete, and a computer model can accurately predict the strength. The ratio of alkaline solution to binder, the concentration of the solution, and the curing temperature all affect the compressive strength of geopolymer concrete. Using waste materials in concrete production can help reduce environmental problems. Geopolymer technology can reduce greenhouse gas emissions and energy consumption, making it a promising solution for sustainable construction.

Keywords*: Geopolymer, Nano-silica, Waste glass powder, Sustainable construction, Compressive strength, Recycled materials, Alkali-activated, Microstructure, Durability, Environmental impact*

1. Introduction

The construction industry is facing big environmental problems due to its high energy use and greenhouse gas emissions. One of the main causes of these emissions is cement production, which needs to be addressed. To solve this issue, researchers are looking into alternative binding agents like geopolymers, which can be made from industrial waste materials. Although geopolymers have shown promise in reducing environmental impacts, they are still in the early stages of development.

To make geopolymers more widely used, it's essential to improve their mechanical properties. Researchers are studying the use of nano-silica and other nano-materials to increase their strength, flexibility, and durability. While these materials have shown potential, more research is needed to optimize their use in geopolymer production.

The development of geopolymers has the potential to significantly reduce the environmental impacts of cement production. However, more research is needed to fully understand their properties and behavior. This research aims to contribute to the development of geopolymers by examining the effects of nano-silica on their mechanical properties and exploring the use of other nano-materials to enhance their performance.

In summary, the construction industry is facing significant environmental challenges, and the development of geopolymers offers a promising solution. Further research is needed to optimize the use of nano-silica and other nano-materials in geopolymer production, and to gain a deeper understanding of their properties and behavior.

2. Litrature Review

Paruthi, S., Rahman, I., Husain, A., Khan, A. H., Mania-Saghin, A. M., & Sabi, E. (2023), The study explores the use of nanomaterials to improve geopolymer concrete (GPC), a more environmentally friendly alternative to traditional concrete that reduces CO2 emissions. However, GPC has a major drawback: its strength decreases when cured at normal temperatures. To address this, the researchers investigated the addition of nanomaterials like nano-silica, aluminum oxide, and carbon nanotubes to enhance GPC's properties. Interestingly, these nanomaterials successfully increased the strength of GPC, even when cured at ambient temperatures. The paper examines how these materials affect GPC's strength, durability, and resistance to acid and water absorption.(1)

Saini, G., & Vattipalli, U. (2020), The research paper "Assessing properties of alkali activated GGBS based self-compacting geopolymer concrete using nano-silica" investigates the development of self-compacting geopolymer concrete (SCGC) using Ground Granulated Blast Furnace Slag (GGBS) and nano-silica. The study involves six different mix designs, varying in alkaline solution molarity (10M, 12M, 16M) and binder content (450 kg/m³ and 500 kg/m³). The performance of these mixes is compared to a control mix without nano-silica, examining both fresh and hardened properties such as compressive strength, split tensile strength, and flexural strength over different curing periods (7, 28, 56, 90 days). The results show that the mix with a 16M concentration and 500 kg/m³ binder content, supplemented with 2% nano-silica, achieved the highest compressive strength (81.33 MPa), split tensile strength (6.398 MPa), and flexural strength (7.875 MPa) at 90 days. Additionally, the inclusion of nano-silica improved the concrete's permeability and sorptivity, resulting in a more compact microstructure. (2)

Si, R., Guo, S., Dai, Q., & Wang, J. (2020). Researchers explored the possibility of using recycled glass powder as a substitute in metakaolin-based geopolymer binders to create a more sustainable and high-performance material. The study found that adding glass powder improved the geopolymer binder's workability and setting time, leading to a more compact microstructure. Furthermore, the addition of glass powder enhanced the mechanical properties of the geopolymer binder, including its compressive strength and elastic modulus. However, the study revealed that the optimal replacement ratio of glass powder is approximately 10%, as exceeding this threshold resulted in a decline in mechanical properties.(3)

Ahmed, H. U., Mohammed, A. S., Faraj, R. H., Qaidi, S. M., & Mohammed, A. A. (2022), This research examines the effects of nano-silica (nS) incorporation on the compressive strength of geopolymer concrete (GPC), combining a thorough literature review with experimental validation. The results show that adding nS to GPC significantly enhances its compressive strength, with an optimal dosage of 3% nS. Furthermore, the study identifies several critical factors influencing compressive strength, including the alkaline solution-to-binder ratio, molarity, NaOH content, curing temperature, and age. The authors develop and compare five predictive models - Linear Regression, Nonlinear Regression, Multi-Logistic Regression, Artificial Neural Network, and M5P-tree - to forecast the compressive strength of nS-modified GPC using a dataset of 207 samples. The Artificial Neural Network (ANN) model emerges as the most accurate predictor of compressive strength, characterized by a high coefficient of determination (R2) and low error values. Ultimately, this study provides novel insights into the impact of nS on GPC's compressive strength and demonstrates the potential of machine learning models in predicting compressive strength. (4)

J. M., & Özakça, M. (2018), This research explores the creation of a novel concrete material, geopolymer concrete (GPC), using innovative components such as cold-bonded fly ash aggregate (CFA), minute silica particles (NS), and steel fibers (SF). The study examines the impact of these components on the concrete's permeability and mechanical properties. The findings reveal that substituting natural aggregate with CFA leads to a decline in GPC's mechanical strength, but the incorporation of NS and SF can counteract this effect. Notably, NS significantly enhances the concrete's resistance to water and reduces its air permeability. The addition of SF also improves water resistance and reduces air permeability, with a more pronounced effect when combined with NS. A strong correlation is observed between mechanical strength and transport properties, suggesting that higher mechanical strength is linked to lower transport properties. The study concludes that CFA can be a sustainable precursor for artificial aggregate production via the cold-bonded process. The integration of NS and SF can improve GPC's transport properties and mechanical strength, offsetting the negative effects of CFA. The developed GPC has the potential to be a sustainable and durable alternative to traditional concrete, with its properties tunable by adjusting the proportions of CFA, NS, and SF. (5)

Adak, D., Sarkar, M., & Mandal, S. (2014), This study investigates how adding tiny silica particles (nano-silica) affects the strength and durability of a special type of mortar made from fly ash. The results show that adding 6% nano-silica significantly improves the mortar's strength in compression, bending, and tension after 28 days of curing at normal temperatures. Additionally, the mortar absorbs less water and has lower electrical conductivity when 6% nano-silica is added. This improvement is due to the transformation of disordered compounds into crystalline structures. The analysis of X-ray diffraction and field emission scanning electron microscopy confirms the formation of new phases and a denser matrix with the addition of nano-silica. The study concludes that the optimal amount of nano-silica is 6% to achieve significant compressive strength under normal curing conditions. The results also demonstrate that adding nano-silica improves the mortar's durability. The study suggests that using nano-silica could eliminate the need for heat curing in geopolymer mortar, which has important implications for developing sustainable and durable construction materials. The findings provide new insights into how nano-silica affects the properties of geopolymer mortar.(6)

Deb, P. S., Sarker, P. K., & Barbhuiya, S. (2015), This research investigates how tiny silica particles (nano-silica) affect the strength of a special type of material called geopolymer when it's cured at room temperature. The geopolymer was made using fly ash, nano-silica, and either regular cement or a type of slag. The results show that adding nano-silica makes the geopolymer stronger, but only up to a certain point (2% nano-silica). After that, the strength starts to decrease. Looking at the material with a special microscope (SEM) reveals that adding nano-silica makes the material more compact. Another test (EDX) shows that new compounds are formed, such as calcium silicate hydrate and others. The study finds that the best amount of nano-silica to add is 2%, which results in a strong material with a compressive strength of 72 MPa. The study also finds that the ratio of silicon to aluminum and sodium to aluminum in the material affects its strength, with optimal ratios of 1.33-1.40 and 3.27, respectively.(7)

Bilondi, M. P., Toufigh, M. M., & Toufigh, V. (2018), This research investigates the use of a special type of cement made from recycled glass powder to improve the strength of clay soils. The results show that adding this cement to the soil significantly increases its ability to withstand compression and deformation. Specifically, the soil's compressive strength increased by 4.8 times when 15% of the recycled glass powder cement was added, compared to the soil without any cement. The study also found that the amount of a certain chemical (NaOH) used in the cement is crucial for it to work effectively. If too much or too little of this chemical is used, the soil's strength decreases. The cement also helped the soil to withstand more deformation and strain before failing. Additionally, increasing the temperature during the cement's creation process from 25°C to 70°C made the soil even stronger. Images from a special microscope (SEM) and analysis of the soil's composition (EDX) confirmed that the cement had formed a strong bond with the soil. Overall, the study shows that using recycled glass powder cement is a great way to stabilize clay soils in an environmentally friendly way. (8)

Alvee, A. R., Malinda, R., Akbar, A. M., Ashar, R. D., Rahmawati, C., Alomayri, T., ... & Shaikh, F. U. A. (2022), This study looks at how adding tiny particles of silica (called nano-silica) and special additives (called crystalline admixtures) affects the strength and structure of a type of cement called geopolymer paste. The nano-silica was made from rice husk ash using a special method. The results show that adding nano-silica and crystalline admixtures makes the geopolymer paste denser and stronger. Specifically, the compressive strength and flexural strength of the paste increased when nano-silica and crystalline admixtures were added, with the biggest increase happening when 5% of these additives were used. The additives also made the paste more resistant to cracking. Analysis of the paste's structure showed that it contained special compounds that can help heal cracks, making the paste more durable. The study found that the nano-silica and crystalline admixtures worked together to create strong bonds in the paste, making it stronger and more resistant to damage.(9)

Dadsetan, S., Siad, H., Lachemi, M., & Sahmaran, M. (2021), This study looks at how adding glass powder (GP) affects the properties of a special type of cement called metakaolin-based (MK) geopolymer binders. The researchers used a specific method to mix the ingredients to achieve certain chemical ratios. They found that adding GP doesn't change the way the cement mixture flows, but it does make the silica in the mixture more soluble. The study shows that using up to 25% GP can produce cement with the same strength as cement made with 100% MK. The results also indicate that changing the chemical ratios of the mixture affects its flow and strength. Specifically, increasing the GP content makes the cement less thick and more flowable. Images from a special microscope (SEM) show that the cement has a well-distributed, polymeric structure when the chemical ratios are optimal. Analysis of the cement's composition (EDS) confirms the presence of reactive silicon and aluminum at higher sodium concentrations. The differences in compressive strength are consistent with the formation of a specific type of polymer, where the number of polymeric chains decreases when GP is used. (10)

Shoaei, P., Ameri, F., Musaeei, H. R., Ghasemi, T., & Cheah, C. B. (2020), This study explores the use of glass powder as a partial ingredient in two types of cement-based mortars: Portland cement (OPC) and alkali-activated slag (AAS). The results show that adding glass powder to the mortars makes them easier to work with, thanks to the smooth surface of the glass particles. However, the addition of glass powder has different effects on the strength of the two types of mortars. In OPC mortars, the strength is generally lower with the addition of glass powder, except when 20% glass powder is used, which actually increases the strength. In contrast, AAS mortars become stronger with the addition of glass powder, with the highest strength achieved when 30% glass powder is used. The study also found that the flexural strength of OPC mortars is higher than that of AAS mortars, likely due to the higher degree of micro-cracking in AAS mortars. Additionally, the water absorption of both types of mortars increases with the addition of glass powder, due to the instability of the sodium silicate gel. The study also looked at the environmental impact of using glass powder in these mortars and found that AAS mortars have a lower carbon footprint and energy demand than OPC mortars. Furthermore, using glass powder as a partial ingredient reduces the environmental impact of both types of mortars.(11)

Vafaei, M., & Allahverdi, A. (2017), This study explores the possibility of using waste glass powder as a main ingredient in making geopolymer binders. However, waste glass powder lacks a key component called reactive alumina, which is necessary for the geopolymerization process to work. To solve this problem, the researchers added a type of cement called calcium aluminate cement (CAC) to the mixture. They tested three different types of CACs (Fondu, Secar 71, and Secar 80) to see how they affected the chemical composition of the geopolymer mixture. The results show that adding CACs significantly improves the strength of the geopolymer mortars. The researchers found that the optimal amount of a certain chemical (Na2O) and the ideal replacement level of CACs are 10% and 24%, respectively. Notably, the geopolymer mortar with Secar 71 showed the highest strength of 87 MPa. Adding CACs also reduces the likelihood of a problem called efflorescence formation. Analysis using a technique called Fourier transform infrared (FTIR) revealed that the addition of CACs creates a more extensive network of geopolymer bonds. The study shows that waste glass powder can be a suitable main ingredient in making geopolymer binders.(12)

Luo, Z., Li, W., Li, P., Wang, K., & Shah, S. P. (2021), This study looks at how dispersing tiny particles of silica (called nanosilica) affects the properties and structure of a type of cement called fly ash-based geopolymer composite. The researchers found that using a special machine called a sonicator to mix the particles is more effective than manual stirring. When the particles are well-mixed, the geopolymer becomes stronger. The tiny particles also help the reaction happen faster, especially when they are dispersed evenly. The study shows that good dispersion of the particles makes the gel-like substance in the geopolymer stronger and more uniform. The researchers also found that using the sonicator for 2 hours is enough to get good dispersion of the particles. As a result, the compressive strength of the geopolymer increases, and the micro modulus of the gel also improves. (13)

Si, R., Dai, Q., Guo, S., & Wang, J. (2020), This study explores how adding waste glass powder to a type of cement called metakaolin-based geopolymer mixtures affects their strength, structure, and ability to resist shrinkage. The researchers found that adding a small amount of glass powder (less than 10%) makes the geopolymer mortars stronger. However, adding too much glass powder (20%) has a negative effect on the strength. The study also showed that the addition of glass powder improves the geopolymer's ability to resist creep (a type of deformation) and creates a denser, more stable structure. The pores in the geopolymer binder become smaller and more refined as the amount of glass powder increases. However, high-temperature curing can make the pores larger. The study also found that adding glass powder reduces the amount of shrinkage in the mixture, making it more stable. This is because the glass powder fills in the pores, reducing the rate of moisture loss and making the mixture more resistant to shrinkage. Additionally, the unreacted glass powder acts as tiny aggregates, improving the mixture's stability at early ages. The study suggests that partially replacing metakaolin with glass powder in geopolymer mortar could be a way to reduce shrinkage. High-temperature curing can also help reduce shrinkage. The best mixture design is considered to be the metakaolin geopolymer with 10% glass powder replacement, which shows improved resistance to shrinkage.(14)

Tahwia, A. M., Heniegal, A. M., Abdellatief, M., Tayeh, B. A., & Abd Elrahman, M. (2022), This study examines the characteristics of a special type of concrete called ultra-high performance geopolymer concrete (UHPGC) that incorporates recycled waste glass. The researchers discovered that adding waste glass makes the concrete more workable, meaning it's easier to mix and pour. However, as the amount of waste glass increases, the concrete's strength decreases slightly, although it remains strong and durable. The study also investigated how well the concrete resists damage from sulfate and acid. The results show that the concrete is resistant to sulfate damage, but its resistance to acid damage is lower. Notably, the addition of waste glass improves the concrete's resistance to acid damage. The researchers used advanced tools, such as scanning electron microscopy (SEM) and energy-dispersive spectroscopy (EDS), to examine the concrete's internal structure. They found that adding waste glass improves the concrete's microstructure. Overall, the study suggests that using recycled waste glass in UHPGC is a sustainable and durable way to build structures.(15)

Liang, G., Li, H., Zhu, H., Liu, T., Chen, Q., & Guo, H. (2021), This study looks at the possibility of reusing waste glass powder as a key ingredient in making a type of building material called alkali-activated metakaolin/fly ash pastes. The researchers found that adding waste glass powder makes the pastes easier to mix and improves their strength and density. The best amount of waste glass powder to add is 20% of the total mixture. Adding waste glass powder speeds up the chemical reaction and creates more binding agents. This makes the material's internal structure denser and more stable, with fewer unwanted pores. The study shows that using waste glass powder as a key ingredient is a viable way to make building materials, which can help reduce waste and conserve natural resources. The findings are useful for the construction industry.(16)

Çelik, A. İ., Tunç, U., Bahrami, A., Karalar, M., Mydin, M. A. O., Alomayri, T., & Özkılıç, Y. O. (2023), This study explores the possibility of using waste glass powder (WGP) to make a type of concrete called geopolymer concrete (GPC). The researchers looked at how WGP affects the concrete's mixability, how long it takes to set, and its strength. They found that adding WGP makes the concrete harder to mix, but the time it takes to set depends on the amount of sodium hydroxide (NaOH) used, not the amount of WGP. The strength of the concrete decreases as more WGP is added. The study suggests that using 10% WGP and a certain amount of

NaOH achieves the best balance of mixability, setting time, and strength. The researchers also found that WGP forms a strong bond with another ingredient called fly ash in the concrete. The study concludes that WGP can be a sustainable alternative to traditional cement in making GPC, with an optimal amount of 10% WGP.(17)

Novais, R. M., Ascensão, G., Seabra, M. P., & Labrincha, J. A. (2016), This study looks at the possibility of using waste glass from old fluorescent lamps as a raw material to make a type of building material called geopolymer. The researchers investigated how adding waste glass, changing the amount of sodium hydroxide (NaOH), and altering the curing conditions affect the material's internal structure, physical properties, and strength. They found that the curing conditions have a significant impact on the geopolymer's characteristics, while the amount of NaOH has a smaller effect. Notably, geopolymers containing 37.5% waste glass have a compressive strength of 14 MPa after 28 days of curing, making them suitable for non-structural uses. The study also shows that it's possible to create porous geopolymers from waste materials for new applications. Geopolymers offer a more environmentally friendly alternative to traditional cement, with much lower carbon dioxide emissions (six times lower). While recycling waste glass for pavement construction and using it as a silicate source for geopolymer production have been explored before, more research is needed to fully utilize this waste material. The study also highlights the need for innovative ways to recycle electronic waste, such as old fluorescent lamps, which are highly contaminated.(18)

Thapa, S., Debnath, S., Kulkarni, S., Solanki, H., & Nath, S. (2024). This study looks at creating environmentally friendly concrete called geopolymer concrete (GPC) by using additional materials like fly ash, ground granulated blast furnace slag (GGBS), metakaolin, and silica fume. The researchers tested different mixtures and curing conditions to see how they affect the concrete's strength. They found that using a 16 M NaOH solution and curing the concrete at 100°C resulted in the strongest concrete. They also discovered that adding more GGBS to the mixture made the concrete even stronger. The study shows that GPC has the potential to reduce carbon emissions in the construction industry and offers a sustainable alternative to traditional cement.(19)

3. Conclusion

This collection of research papers highlights the benefits of using nanomaterials, recycled glass powder, and waste glass to improve the properties of geopolymer concrete. Adding tiny materials like nanosilica, aluminum oxide, and carbon nanotubes to geopolymer concrete makes it stronger, more durable, and more resilient. Using recycled glass powder as a substitute in geopolymer binders improves the concrete's workability, setting time, and mechanical properties. Waste glass powder, when used as a precursor in alkali-activated metakaolin/fly ash pastes, enhances workability, mechanical properties, and microstructure. Geopolymer concrete that incorporates waste glass powder has better flowability, durability, and resistance to acid attack. The optimal amount of nanosilica, recycled glass powder, and waste glass powder depends on the specific application and desired properties. The studies show that using waste materials in geopolymer production is feasible and can contribute to a more sustainable and environmentally friendly construction industry. By incorporating nanomaterials and waste materials, we can reduce the negative environmental impacts associated with traditional concrete production. Overall, the research provides valuable insights into the development of sustainable and high-performance geopolymer materials.

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