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Research Article

Baseline Development and Characterization of Expanded-Perlite-Filled Waste Tile/Glass Geopolymer Composites

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Keywords

Alkali activation,
Expanded perlite,
Lightweight composites,
Waste based geopolymers,
Waste tile and glass powder.

Abstract

This study establishes the baseline physical and mechanical behavior of expanded-perlite-filled waste tile/glass geopolymer composites without fiber reinforcement. This study aims to develop sustainable lightweight geopolymer composites obtained from 100% waste materials. Waste tile dust and waste glass dust were used as alumina silicate sources. These were activated with varying sodium concentrations. To ensure lightness, expanded perlite was added as a filler at 2% and 4% weight of the binder. Experiments on the produced specimens evaluated the physical and mechanical performance of these lightweight composites. The results showed that the addition of 4% EP reduced the unit weight by up to 28.4% (in the range of 1275-1362 kg/m³), thus obtaining a lightweight building material. Increased internal porosity led to an increase in water absorption rate (up to 196%) and capillarity coefficients. When mechanical tests were evaluated, the addition of EP caused a decrease in strength. Here, a 6% Na concentration was determined as the activator dosage that showed better mechanical performance compared to other Na levels. At this concentration, a compressive strength of approximately 6.51 MPa was obtained in specimens containing 4% EP. Based on these results, it has been shown that these waste-based binders, which can be used instead of cement, are applicable for the production of lightweight insulation composite blocks together with expanded perlite. Thus, in addition to obtaining an environmentally friendly product, a contribution has been made to reducing the carbon footprint. The findings provide reference data for future studies involving reinforcement, durability enhancement, or thermal-performance optimization.

1. Introduction

Rapid urbanization has intensified housing demand, leading to increased construction activity and associated environmental impacts. Increased concrete construction creates environmental sustainability problems. Cement is the binder of concrete, which is the most consumed material after water. Due to the high calcination temperature and high energy consumption in the cement production process, it is responsible for 8% of total carbon dioxide emissions [1]. This has driven the development of alternative binders with lower carbon footprints. Geopolymer technology enables the conversion of industrial wastes into value-added binder systems [2]. Geopolimers obtained as a result of the reaction of aluminium silicates with alkali activators can reduce carbon dioxide emissions from cement by 90%. In addition, they can provide the desired strength and durability [3].

The reuse of construction and demolition wastes aligns with circular economy principles and remains a priority for sustainable material development [4]. Waste ceramic powders obtained from fired clay minerals form reactive silica and alumina nuclei when dissolved in an alkaline environment. Glass powders with high amorphous silica content form the main carrier component of the polymeric structure [5]. The performance of these systems is strongly influenced by the chemical composition of the alkali activator [6]. The sodium concentration in activators such as sodium hydroxide affects the dissolution rate, geopolymerization kinetics, and the formation of the three-dimensional zeolitic structure. Therefore, optimizing the Na dosage is important in terms of mechanical performance as well as reducing economic and environmental costs [7].

The use of lightweight building materials is becoming increasingly common because it reduces building weight and provides thermal insulation [8]. It is used in the production of lightweight geopolymers due to its porous structure and low density [9]. The use of expanded perlite in composite materials can increase the water absorption rate and reduce mechanical performance. There are extensive studies in the literature on the production of geopolymers with industrial wastes such as fly ash or blast furnace slag [10, 11]. This study addresses the previously insufficient investigation of the interaction between geopolymers produced from globally available glass and tile wastes, and expanded perlite used as a filler for lighter weight.

The present manuscript is limited to the development and characterization of unreinforced expanded-perlite-filled waste-based geopolymer composites. No fiber, mesh, or secondary reinforcement system was incorporated in this phase. Therefore, the results should be interpreted as baseline reference data for evaluating the effects of expanded perlite dosage and sodium concentration. The novelty of this study lies in defining the baseline physical, water-transport, and mechanical performance of lightweight geopolymer composites produced from waste tile and waste glass powders using expanded perlite as the lightweight filler. This research aims to fill this gap and comprehensively examines the development and characterization of waste-based geopolymer composites containing expanded perlite. The primary objective is to evaluate the effects of different sodium (Na) concentrations and expanded perlite ratios on the physical and mechanical properties of the composites.

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Through a comprehensive experimental program including unit weight, ultrasonic pulse velocity, water absorption, and capillarity tests, as well as flexural, compressive, and splitting tensile strength tests, the performance limits of lightweight and waste-based geopolymer systems are revealed. Demonstrating the technical feasibility of a binder system composed entirely of recycled raw materials, this study offers a unique contribution to the literature on sustainable building materials and energy-efficient building components.

2. Testing process

2.1. Test specimens and properties

No fiber reinforcement was used in any mixture in this study. The experimental design was intentionally restricted to sodium concentration and expanded perlite dosage in order to isolate their effects on the waste-based geopolymer matrix. In this study, geopolymer composites were obtained using alumina-rich waste tile dust and silica-rich waste glass dust. Both waste powders were ground to <45 μm particle size. The chemical compositions of these waste dusts, determined by X-ray fluorescence (XRF) analysis, are given in Table 1. Considering the high amorphous silica content of the waste glass dust, sodium hydroxide (NaOH) was chosen as the sole alkali activator to maintain the silicate/aluminate ratio without the need for additional sodium silicate.

Table 1. Chemical properties of used waste materials

Component	SiO2	Al2O3	Fe2O3	CaO
Tile powder (%)	63.29	18.29	4.32	4.46
Glass powder (%)	71.30	2.18	0.60	9.8
Expanded perlite (%)	74	14	-	-

In production, the variation of sodium concentration and expanded perlite (EP) as a lightweight filler was considered. EP was used only as a lightweight filler in the present study. Its potential micro-filler or pozzolanic contribution was not directly investigated and should therefore not be treated as a confirmed chemical mechanism. Three Na concentrations (3%, 6%, and 9% by binder weight) and two EP ratios (2% and 4%) were used, along with reference mixtures without EP. Mixture designs and dosages are given in Table 2.

Table 2. Mixture proportions

Na, %	3	6	9
waste tile powder/binder	0.40	0.40	0.40
waste glass powder/binder	0.60	0.60	0.60
caustic soda/binder	0.04	0.08	0.12
water/binder	0.30	0.30	0.30
perlite/binder	0-0.02-0.04	0-0.02-0.04	0-0.02-0.04

The production process was carried out as a three-stage mixing process. Initially, a specified amount of NaOH was dissolved in half of the mixing water to prepare the activator solution. It was allowed to cool to ambient temperature to prevent exothermic heat increase. The other half of the mixing water was mixed with EP. A period of time was allowed for the saturated EP to release its water. Waste tile dust, waste glass dust, saturated EP, and alkaline solution were mixed with a laboratory-type mixer. As shown in Figure 1, the resulting fresh geopolymer mixtures were poured into 4x4x16 cm prismatic steel molds in accordance with the TS EN 196-1 standard. The molds were compacted using a shaking table and their surfaces were smoothed. After 24 hours, the specimens were removed from the molds and subjected to a controlled heat cure at 60 °C for 3 hours. The specimens were then stored under standard laboratory conditions (23±2°C) to prevent water loss for 28 days of experiments.

Figure 1. Preparation and molding of the mixture.

2.2. Testing system

Physical properties were evaluated via unit weight and UPV tests. Tests were conducted to determine the effect of the porous structure of the EP added to ensure lightness on capillary water absorption and water absorption by weight. The specimens were dried at 105 °C for 24 hours. Their weights were measured. Capillary absorption was measured using vertically positioned specimens with sealed lateral surfaces. After 3 hours, the silicone around the specimens was cleaned and they were weighed. The amount of water absorbed capillaries from the lower surface was determined. This value was divided by the square root of the time to determine the capillarity coefficient. Water absorption was determined after 24 h immersion.

To determine the mechanical properties, a midpoint loading bending test, called a three-point bending test according to TS EN 196-1, was initially performed. A splitting tensile test, also called the Brazilian test, was performed on one of the two parts obtained from the bending test by applying a linear load (Figure 2). A compression test was performed on the other part by placing 4x4 cm steel plates aligned on its top and bottom surfaces. Bending, splitting tensile, and compressive strengths were calculated from the obtained values. All tests were conducted on at least three specimens.

Figure 2. Some tests performed on the specimens.

3. Discussion

The unit weight results shown in Figure 3 reveal that the expanded perlite (EP) content varies depending on the alkali concentration. Unit weights decreased with the addition of EP. In particular, in the 3% Na series, increasing the EP content from 0% to 4% resulted in a decrease in unit weight from 1753 kg/m³ to 1275 kg/m³, approximately 27.3%. A similar trend was observed in the 9% Na series, where the unit weight decreased from 1902 kg/m³ to 1362 kg/m³ (28.4%) with the addition of 4% EP. This is attributed to the porous structure of the expanded perlite used as a filler. However, a secondary trend emerges when the effect of alkali activator concentration is analyzed. At any constant EP dosage, an increase in Na content leads to an increase in unit weight. Increasing the Na concentration from 3% to 9% for the reference specimens (0% EP) increased the unit weight by approximately 8.5%, from 1753 kg/m³ to 1902 kg/m³. This phenomenon can be explained by high alkalinity. The higher concentration of Na ions facilitates the dissolution of alumina and silicates from waste tile and glass dust, may have promoted a denser reaction product, as indirectly suggested by the unit weight. Consequently, porous perlite particles successfully impart lightweight properties to the composite, while a higher alkali dosage results in a fuller structure. It has been observed that the developed composites, especially with the addition of 4% EP, can be evaluated as lightweight structural materials.

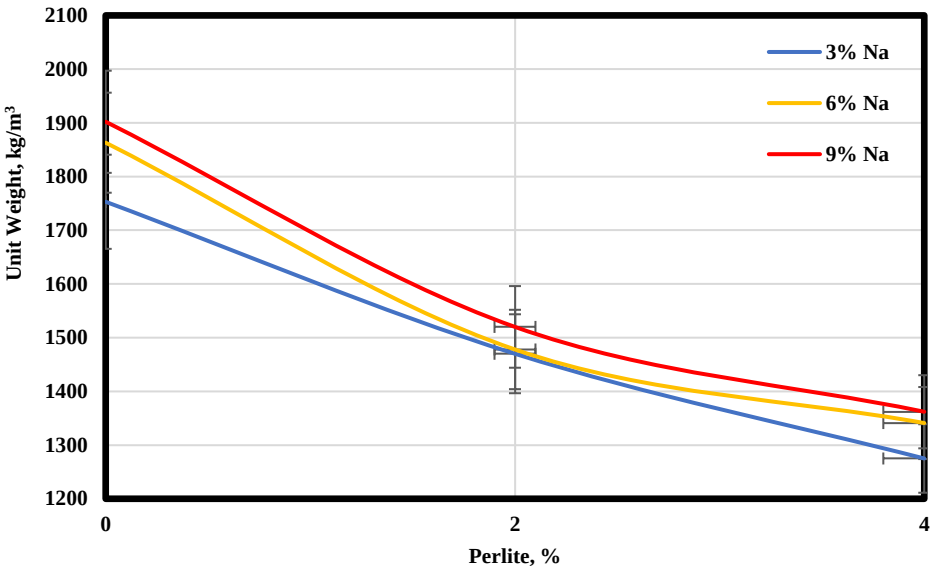

Figure 3. Variation in unit weight of geopolymer specimens with perlite content

Ultrasonic pulse velocity (UPV) values, varying depending on the amount of voids in the internal structure, are given in Figure 4. UPV results provide indirect information on internal continuity but cannot independently identify pore morphology or reaction products. Direct microstructural characterization is required for such confirmation. The addition of expanded perlite (EP) caused a significant decrease in the pulse velocity of the specimens. For example, for the 3% Na series, the UPV decreased from 2.59 km/s in the reference specimen to 0.494 km/s with the addition of 4% EP, resulting in a decrease of approximately 80.9%. This trend is consistent across all alkali levels. For example, in the 9% Na series, this decrease was determined to be 85.6%. The reason for these decreases can be attributed to the high porosity of the expanded perlite particles. Since voids do not transmit vibration, the path lengthens, which leads to a decrease in velocity. In particular, a significant inverse relationship was observed between alkali (Na) concentration and UPV values as the perlite content increased. In the reference groups without perlite, increasing the Na concentration from 3% to 9% caused a 10.4% decrease in UPV from 2.59 km/s to 2.32 km/s. Although high Na concentrations increase the density of the NASH gel, increased alkalinity can lead to a different pore distribution or localized microcracks

during rapid geopolymerization. Furthermore, the negative impact of high Na levels on UPV becomes more pronounced in series containing perlite. At 4% EP, the velocity decreased from 0.494 km/s (3% Na) to 0.333 km/s (9% Na), a decrease of 32.6%. This suggests that at high alkali dosages, the interaction between the caustic activator and porous perlite may lead to increased microporosity.

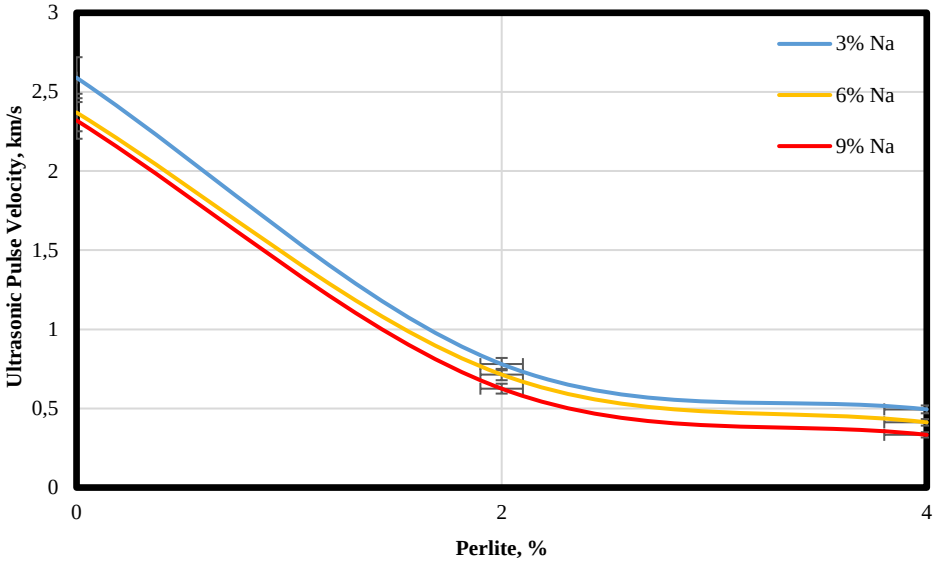

Figure 4. Variation in ultrasonic pulse velocity of geopolymer specimens with perlite content

The water absorption values of geopolymer composites, expressed as percentages by mass, are shown in Figure 5. Figure 5 reveals a significant relationship between EP content and the water absorption capacity of the specimens. For the 3% Na series, water absorption increased from 10.8% in the reference specimen to 32.1% with the addition of 4% EP, showing an increase of approximately 196%. Similarly, in the 6% Na series, this increase was 183%. This significant increase in water absorption is primarily due to the highly hydrophilic and open-pored structure of expanded perlite. As a lightweight aggregate, EP imparts a wide network of interconnected voids and capillary channels to the geopolymer matrix. This facilitates the entry and storage of water through capillary action. Increasing the alkali concentration (%Na) resulted in a denser structure and a decrease in water absorption. This decrease was determined to be 19.6% at a constant EP content of 2%, when the Na content was increased from 3% to 9%. This downward trend is even more pronounced in the reference groups, where water absorption decreased from 10.8% to 6.7% as Na concentration increased from 3% to 9%. This behavior is due to the increasing amount of Na ions, which increases the dissolution of waste tile and glass dust, leading to the formation of a denser NASH gel. Although the addition of EP increases porosity and thus water absorption, high alkali dosages partially restrict water penetration pathways by helping to densify the binder matrix surrounding the perlite particles.

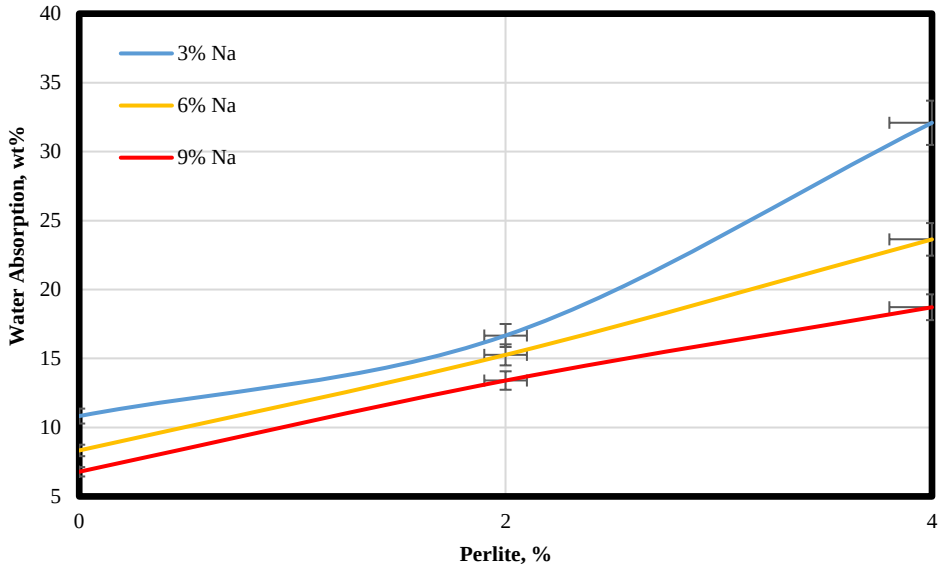

Figure 5. Variation in water absorption of geopolymer specimens with perlite content

The capillarity coefficients calculated based on the amount of water absorbed by the geopolymer specimens via capillary action are shown in Figure 6. Figure 6 shows that as the EP content increases, the capillarity coefficient also increases. For the 3% Na series, the coefficient showed a 434% increase with the addition of 4% EP compared to the reference group. In the 9% Na series, the addition of 4% EP caused the coefficient to increase by approximately 860% compared to its reference. This significant increase is related to the porous structure of EP. Perlite particles increased the rate of water absorption within the binder matrix. Increasing the alkali concentration reduced the capillary water absorption rate, leading to a decrease in the capillarity coefficients. In the reference specimens, increasing the Na concentration from 3% to 9% reduced the capillarity coefficient by 53.9%. This decrease was determined to be 17.2% at the 4% EP level. High Na concentrations facilitate the geopolymerization of waste glass and tile dust, resulting in a denser and less bound NASH gel. This dense matrix constricts the capillary

channels surrounding the perlite, increasing resistance to moisture transport. Consequently, while EP increases capillary activity, it has been determined that using higher alkali dosages improves the impermeability of the lightweight composite.

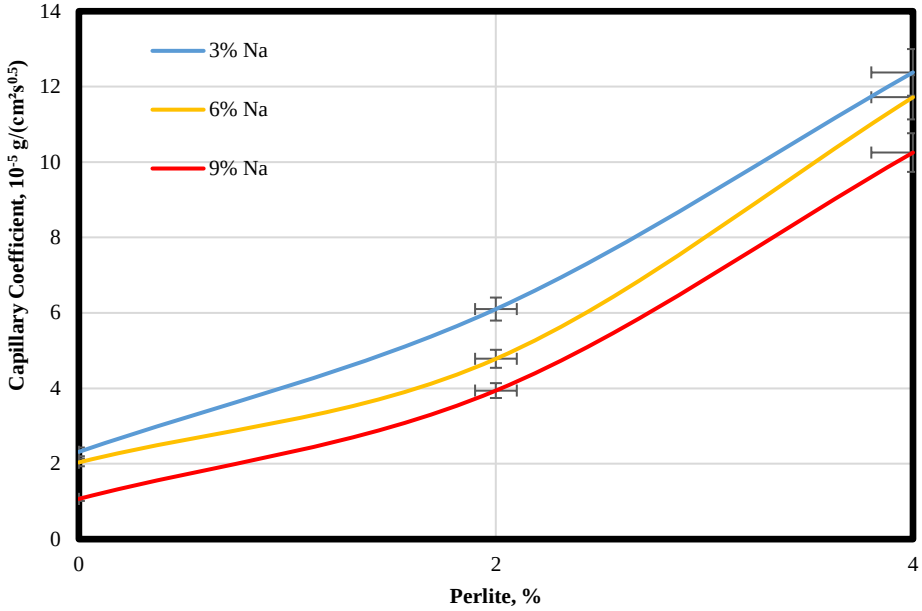

Figure 6. Variation in capillary coefficient of geopolymer specimens with perlite content

The changes in flexural strength of geopolymer composites depending on EP mix ratios and activator concentration are shown in Figure 7. In general, flexural strength decreases with the addition of EP. In the 3% Na series, the flexural strength showed a decrease of approximately 77.9% with the addition of 4% EP compared to the reference specimen. Similarly, in the 6% Na series, this decrease was 69.4%. This loss of strength can primarily be explained by the replacement of a dense binder matrix with porous perlite particles. The presence of EP creates discontinuities that facilitate rapid crack propagation under flexural loads. The effect of alkali concentration on flexural strength showed a nonlinear trend. In the reference groups, the flexural strength remained constant around 5.9 MPa. However, the effect of high alkalinity became more pronounced in perlite-mixed specimens. For example, in specimens with 4% EP added, increasing the Na concentration from 3% to 6% resulted in a 37.6% increase in flexural strength. This indicates that higher Na concentrations increase the dissolution of waste tile and glass dust, resulting in a dense bond structure that enhances resistance to bending effects. However, reaching 9% Na led to a decrease in strength to 1.65 MPa, a 7.7% reduction compared to 6% Na. This is due to the fact that excessive alkalinity causes microcracks or a more brittle geopolymer gel structure.

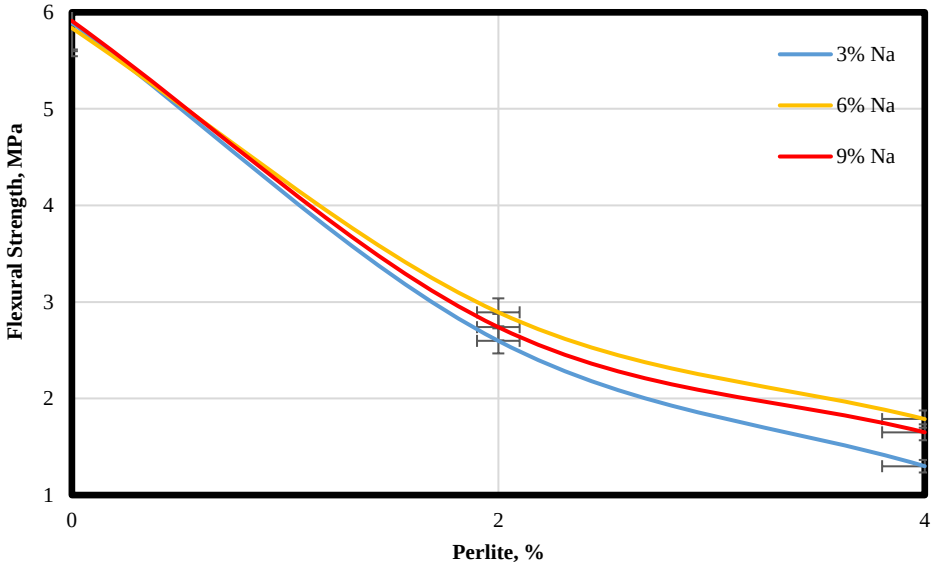

Figure 7. Variation in flexural strength of geopolymer specimens with perlite content

Figure 8 shows that the compressive strength of geopolymer composites decreased with increasing addition of EP. For the 3% Na series, the compressive strength decreased by 79.4% in the specimens with 4% EP addition compared to the reference specimen. In the 6% Na series, this decrease was 78.8%. This high rate of decrease can be attributed to the increased porosity of the porous perlite within the geopolymer. Due to their low internal strength and brittle structure, EP particles act as voids within the geopolymer matrix. Under compressive loading, these porous particles cannot provide effective resistance. The reduction in the effective cross-sectional area capable of carrying the load lowers the

strength. When the effect of alkali concentration was examined, increasing the Na concentration from 3% to 6% in the reference groups increased the compressive strength by 11.5%, while reaching a Na concentration of 9% resulted in a 7.9% decrease in compressive strength compared to 6% Na. This shows that the 6% Na dosage provides the ideal alkalinity for forming a dense NASH gel. The decrease in compressive strength at high alkali levels can be attributed to the formation of a more brittle structure due to excessive hydroxide ion concentration. This situation at 6% Na is consistent with perlite-mixed specimens. While the EP inclusion rate is the most important factor affecting compressive strength, the selection of alkali dosage has been shown to be effective in reducing strength losses.

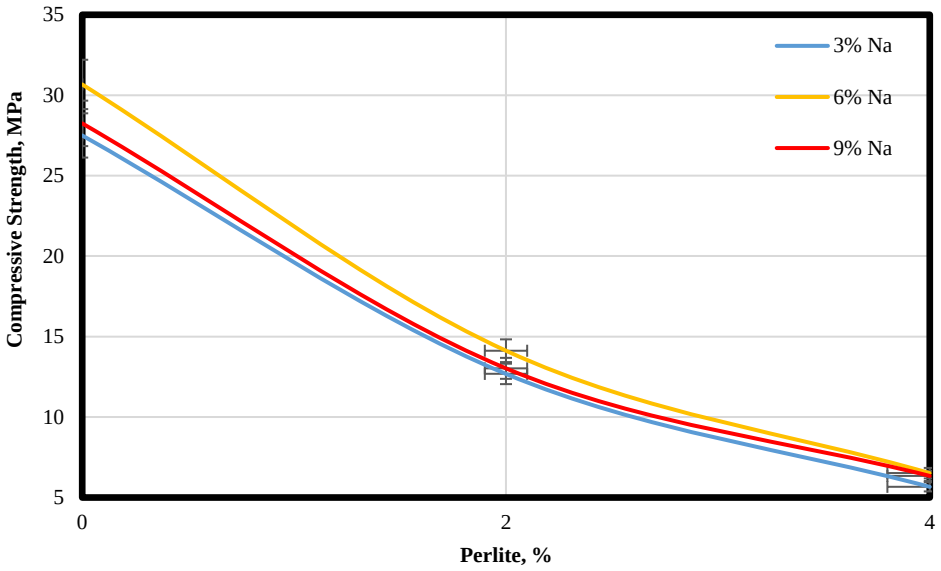

Figure 8. Variation in compressive strength of geopolymer specimens with perlite content

Figure 9 shows the splitting tensile strength results of geopolymer composites. Examination of Figure 9 reveals that the splitting tensile strength results exhibit similar behavior to other strength results. For the 3% Na series, when comparing the splitting tensile strength with the reference specimen results, the addition of 4% EP resulted in a 77.8% decrease. In the 6% Na series, this decrease was determined to be 68.3%. This decrease is a consequence of the low tensile capacity of the expanded perlite particles and the porosity in the binder matrix. Microcracks and void distribution are effective in splitting tensile strength. EP particles create structural weaknesses in the splitting section. When the effect of sodium concentration on splitting tensile strength was examined, while similar results were obtained in the reference specimens, it was observed that the 6% Na dosage was effective for the perlite-filled specimens. For example, in specimens with 4% EP added, increasing the Na concentration from 3% to 6% resulted in a 31.5% increase in strength, while increasing it to 9% caused an 11.6% decrease compared to 6% Na. Within the limits of the present mixture design, 6% Na provided the most balanced mechanical performance for the expanded-perlite-containing mixtures.

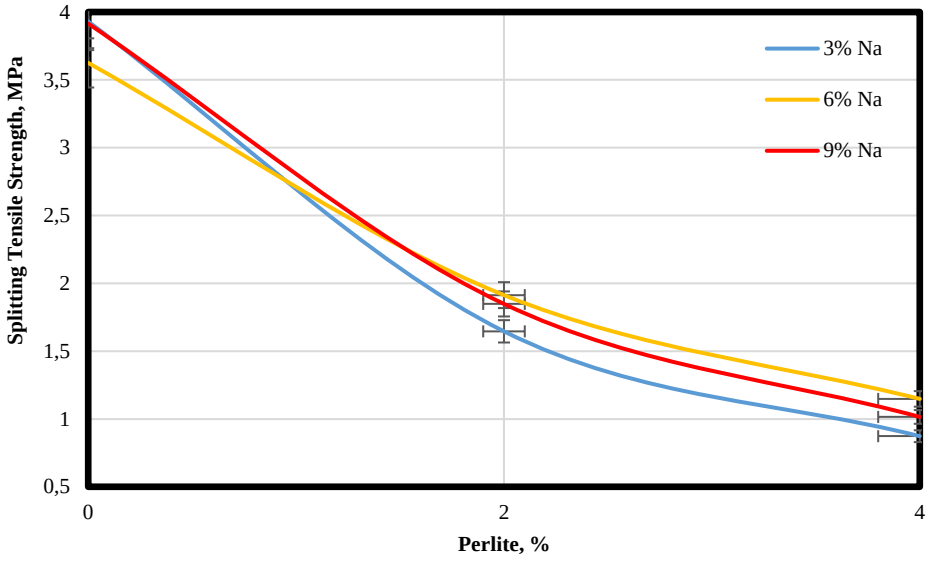

Figure 9. Variation in splitting tensile strength of geopolymer specimens with perlite content

When the performance of these developed composites is compared with the literature, it is seen that the unit weight values determined in this study are consistent with the results of similar lightweight geopolymer studies (1250–1700 kg/m³) [12]. When the compressive strength results are examined, it can be said that the obtained values are mostly comparable to lightweight geopolymers given in the range of 0.5–21 MPa [13, 14]. The water absorption and capillarity results show parallelism with previous studies on the fact that the connected pore structure increases the water absorption rate [15]. The obtained results are both consistent with the existing literature and provide new comparative data.

4. Conclusion

The results obtained from this experimental research on waste-based lightweight geopolymer composites are summarized as follows:

- The addition of 4% EP reduced the unit weight of the waste-based geopolymer by up to 28.4%. Lightweight geopolymer composites were obtained by reducing the unit weight value to 1275 kg/m³.
- UPV values decreased significantly with the addition of EP. This rate, reaching 85.6%, confirmed that perlite prevents sound wave propagation due to its high internal porosity and that this void structure exhibits a uniform distribution.
- The addition of 4% EP led to a significant increase in water absorption by twofold and capillarity coefficients by eightfold due to the interconnected macroporosity of perlite particles.
- At a concentration of 6%, it was determined that increasing the density of the NASH gel provided the best mechanical performance in all perlite-mixed groups.
- Although a significant decrease in compressive and flexural strength was observed in geopolimer specimens with 4% EP addition, the specimens maintained their structural integrity. Compressive strengths ranging from 5.66 to 6.51 MPa are suitable for various lightweight partition wall and insulation applications.
- Splitting tensile strengths showed similar behavior to compressive strength. The 6% Na series showed the highest splitting tensile strength among perlite-filled specimens.

Based on comprehensive experimental results, this study concludes that 6% Na concentration is the most effective activator dosage as it balances the rapid geopolymerization of waste tile/glass dust without leading to the embrittlement observed with 9% Na. The developed composites are more suitable for non-structural lightweight components, partition blocks, or insulation-oriented applications rather than primary load-bearing structural elements. The absence of direct microstructural characterization, thermal conductivity testing, freeze–thaw resistance, sulfate resistance, and long-term durability testing should be considered as limitations of the present study. For future studies, it is recommended to determine the preheating temperature and duration required for activation. In addition to determining thermal conductivity coefficients, their resistance to chemical and physical external influences should be investigated. Furthermore, the use of fiber reinforcement can be explored to reduce the strength loss observed at high perlite ratios. This has the potential to increase the structural application areas of the resulting geopolymers.

Declaration of Conflict of Interests

The authors declare that there is no conflict of interest. They have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1.] Alsalman A., Assi L. N., Kareem R.S., Carter K., Ziehl P., Energy and CO^2 Energy and CO2 emission assessments of alkali-activated concrete and Ordinary Portland Cement concrete: A comparative analysis of different grades of concrete. Cleaner Environmental Systems, 2021, 3: 100047. https://doi.org/10.1016/j.cesys.2021.100047

[2.] Elhag A.B., Raza A., Khan Q.U.Z., Abid M., Masood B., Arshad M., Deifalla A.F, A critical review on mechanical, durability, and microstructural properties of industrial by-product-based geopolymer composites. Reviews on Advanced Materials Science, 62(1), 2023, 20220306. https://doi.org/10.1515/rams-2022-0306

[3.] Sbahieh, Sami, Gordon McKay, Sami G. Al-Ghamdi. "Comprehensive analysis of geopolymer materials: Properties, environmental impacts, and applications." Materials 16.23 (2023): 7363. https://doi.org/10.3390/ma16237363.

[4.] Purchase CK, Al Zulayq DM, O'Brien BT, Kowalewski MJ, Berenjian A, Tarighaleslami AH, Seifan M. Circular Economy of Construction and Demolition Waste: A Literature Review on Lessons, Challenges, and Benefits. Materials. 2022; 15(1):76. https://doi.org/10.3390/ma15010076

[5.] Rivera J.F., Cuarán-Cuarán Z.I., Vanegas-Bonilla N., De Gutiérrez R.M., Novel use of waste glass powder: Production of geopolymeric tiles. Advanced Powder Technology, (2018), 29(12), 3448-3454. https://doi.org/10.1016/j.apt.2018.09.023

[6.] Wan X, Ren L, Lv T, Wang D, Wang B. Research on Alkali-Activated Systems Based on Solid Waste-Derived Activators: A Review. Sustainability. 2025; 17(1):254. https://doi.org/10.3390/su17010254

[7.] Rupwate A.B., Kulkarni S.A. Geopolymer Concrete Optimization: A Critical Review of Supplementary Materials and Performance Enhancement. Journal of Mines, Metals & Fuels, (2025), 73(2). https://doi.org/10.18311/jmmf/2025/47459

[8.] Phiri R., Rangappa S.M., Siengchin S., Oladijo O.P., Ozbakkaloglu T., Advances in lightweight composite structures and manufacturing technologies: A comprehensive review. Heliyon, (2024), 10(21). https://doi.org/10.1016/j.heliyon.2024.e39661

[9.] Kioupis D, Skaropoulou A, Tsivilis S, Kakali G. Properties and Durability Performance of Lightweight Fly Ash Based Geopolymer Composites Incorporating Expanded Polystyrene and Expanded Perlite. Ceramics. 2022; 5(4):821-836. https://doi.org/10.3390/ceramics5040060

[10.] Zhou X., Shen J., Micromorphology and microstructure of coal fly ash and furnace bottom slag based light-weight geopolymer. Construction and Building Materials, (2020), 242, 118168. https://doi.org/10.1016/j.conbuildmat.2020.118168.

[11.] Zhang M, Qiu X, Shen S, Wang L, Zang Y. Mechanical and Thermal Insulation Properties of rGFRP Fiber-Reinforced Lightweight Fly-Ash-Slag-Based Geopolymer Mortar. Sustainability. 2023; 15(9):7200. https://doi.org/10.3390/su15097200

[12.] Top S, Vapur H, Altiner M, Kaya D, Ekicibil A. Properties of fly ash-based lightweight geopolymer concrete prepared using pumice and expanded perlite as aggregates. Journal of Molecular Structure, 1202, (2020) 127236. https://doi.org/10.1016/j.molstruc.2019.127236

[13.] Szabo R, Dolgos F, Debreczeni A, Mucsi G. Scale-up experiments of expanded perlite-geopolymer composite block with special regard to the effect of water. Construction and Building Materials, 464, (2025) 140166. https://doi.org/10.1016/j.conbuildmat.2025.140166

[14.] [14.] Polivoda N, Melnychuk M, Kozub B, Ostapchuk R, Babych Y. Properties of Perlite-Based Geopolymer as a Thermal Insulation Material for Building Efficiency. In Design, Simulation, Manufacturing: The Innovation Exchange, 76-87, (2025) Cham: Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-96413-8_8

[15.] Karakaş H, Ilkentapar S, Durak U, Örklemez E, Özuzun S, Karahan O, Atiş C.D. Properties of fly ash-based lightweight-geopolymer mortars containing perlite aggregates: Mechanical, microstructure, and thermal conductivity coefficient. Construction and Building Materials, 362, (2023), 129717. https://doi.org/10.1016/j.conbuildmat.2022.129717

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