International Journal of Computational and Experimental Science and ENgineering (IJCESEN)

Vol. 11-No.2 (2025) pp. 3710-3714

http://www.ijcesen.com

ISSN: 2149-9144

Research Article

Effect of Waste Barite Utilization on Physical and Mechanical Properties of Geopolymer Concrete

Şemsettin Kılınçarslan[1]*, Mahammat Wardougou Lony[2], Nuri Işıldar[3]

[1]Süleyman Demirel University, Faculty of Engineering and Natural Sciences, Department of Civil Engineering, 32200, Isparta-Turkiye

* **Corresponding Author Email:** semsettinkilincarslan@sdu.edu.tr - **ORCID:** 0000-0001-8253-9357

[2]Süleyman Demirel University, Institute of Sciences, 32200, Isparta-Turkiye

Email: mahamatlony09@gmail.com - **ORCID:** 0009-0005-9138-316X

[3]Süleyman Demirel University, Suleyman Demirel University, Natural and Industrial Building Material Applied Center, 32200, Isparta-Turkiye

Email: nuriisildar@sdu.edu.tr - **ORCID:** 0000-0001-6639-3650

Article Info:

DOI: 10.22399/ijcesen.2104
Received : 25 February 2025
Accepted : 07 May 2025

Keywords :

Geopolymer
Waste barite
Blast furnace slag
Mechanical properties
Density

Abstract:

In recent years, there has been a significant increase in studies aimed at utilizing waste materials in the production of sustainable building materials. In this context, geopolymer concrete, an environmentally friendly and durable alternative, has emerged as a promising construction material for the reuse of waste materials. This study investigates the potential use of barite waste in the production of geopolymer concrete. In the experimental studies, the water/binder ratio, sodium silicate, sodium hydroxide, and ground granulated blast furnace slag were kept constant, while barite waste was added at rates of 10%, 20%, and 30% in place of the sand used as aggregate. The effects of different proportions of barite waste on the flexural and compressive strength of geopolymer concrete were examined. The results revealed that an increase in barite content provided a partial improvement in mechanical properties. The highest compressive strength was recorded as 67.10 MPa in the sample containing 20% barite. As a result, it has been revealed that barite waste can be used as a potential building material in the development of environmentally friendly and durable building materials. Accordingly, further studies are recommended to explore different combinations containing barite waste.

1. Introduction

Today, the environmental problems arising from the harmful effects of global warming are largely associated with energy consumption. In this context, concrete—which accounts for a significant portion of energy use—stands out as one of the most widely used construction materials worldwide, with Portland cement (PC) as its primary binder [1,2]. However, the production of Portland cement has significant environmental impacts, primarily due to the calcination of limestone and the combustion of fossil fuels, together contributing to approximately 7–8% of global CO_2 emissions. [1,2,3,4]. This situation necessitates the development of alternative binder systems that require less energy, emit lower amounts of CO_2 , and possess similar engineering properties.

Recent studies show that industrial wastes such as fly ash, blast furnace slag, silica fume and rice husk ash can be utilized in concrete production to increase the strength properties and contribute to sustainability [5,6]. By using such materials, both waste disposal and cement consumption can be reduced. However, these solutions are not sufficient for binder materials with a wide range of applications and high-performance expectations. Therefore, the need for a new generation of building materials that can be produced without the use of cement, have low environmental impact and are competitive in terms of performance is increasing day by day [7,8]. In this direction, geopolymers are among the innovative materials that have attracted attention in recent years with their environmentally friendly structures, high mechanical strength and sustainability potential. First defined by Davidovits (1978), geopolymers are inorganic polymer binders obtained by alkaline activation of pozzolanic materials containing silicon and aluminium oxide [9]. These materials, which have a much lower carbon footprint compared to conventional PO, also allow for the recycling of industrial and mining wastes, reducing the use of natural resources and contributing to waste management processes. Especially materials with suitable chemical and physical properties such as blast furnace slag and barite beneficiation wastes are among the important alternative raw materials that can be evaluated in geopolymer production [10,11]. The direct use of barite material in concrete increases the density of concrete and improves its physical properties as reported in the literature [12,13,14]. This study investigates the production and performance of waste barite and blast furnace slag substituted geopolymer mortars and concretes for the conversion of industrial wastes into sustainable construction materials. The main objective of the study is to determine the physical and mechanical properties of these geopolymers produced by alkaline activation method, especially to comparatively evaluate the effects of concrete age (7 and 28 days) on flexural and compressive strength. In this context, waste barite obtained from Mining facilities located in Şarkikaraağaç district of Isparta, which is approximately 30,000 tons per year, were used. The findings suggest that the use of waste barite in the production of geopolymer concrete not only contributes to the disposal of environmental waste but also offers an important alternative for reducing carbon emissions by reducing the use of cement.

2. Material and Methods

2.1 Material

The alkali activators used in this study (NaOH and Na_2SiO_3) were supplied by Yenilab Laboratory and Educational Materials Chemistry Industry and Trade Co. Ltd., and their technical specifications are provided in Table 1. The waste barite used in this study was obtained from the barite mine facilities of located in the Şarkikaraağaç district of Isparta Province. The sample was sieved according to standard sand granulometry before being used in the experiments. The chemical composition of the waste barite was determined, and the analysis results are presented in Table 2. In addition, blast furnace slag, a by-product of the Karabük Iron and Steel Factory [15], was ground to cement fineness and utilized within the scope of the study. Pure water was used in the preparation of mortars. Polycarboxylate based super plasticizer was added at the rate of 0.7% of the total amount of binder to

Table 1. *Chemical and physical properties of alkali activators.*

Property	Sodium Hydroxide	Sodium Silicate
Chemical Formula	NaOH	$Na_2O_7Si_3$
Molecular Weight	40.00 g/mol	242.23 g/mol
Appearance	White Solid	Colorless Liquid
pH	14	11-12.4
Density	2.13 g/cm^3	1.3-1.5 g/cm^3

Table 2. *Chemical properties of waste barite and blast furnace slag*

Chemical Component	Waste Barite (%)	Blast Furnace Slag (%)
SiO2	35.66	35.0-45.0
BaO	17.20	-
Al_2O_3	13.71	9.0-13.0
CaO	4.45	30.0-40.0
Fe_2O_3	3.40	0.1-3.5
K_2O	3.11	0.5-2.0
SO_3	6.19	-
S	-	0.5-1.5
MgO	1.13	6.0-8.5
Others	1.81	3.45
LOI	13.34	-

ensure that the mortar mixtures could be placed in the molds without voids. Standard sand with a density of 2.56 g/cm³ and conforming to TS EN 196-1 CEN standard [16] was used in the production of the specimens. The granulometric properties of the standard sand used are presented in Table 3.

Table 3. *Granulometry of standard sand (TS EN 196-1)*

Sieve Aperture (mm)	Cumulative Remaining in Sieve (%)
2.00	0.00
1.60	7 ± 5
1.00	33 ± 5
0.50	67 ± 5
0.16	87 ± 5
0.08	99 ± 1

Technical specifications given in Table 1 were obtained from the manufacturer. Sodium hydroxide, one of the alkaline activators, was obtained as solid and made into aqueous solution at the desired molarity value (16 mol) in the laboratory environment. Sodium silicate was obtained directly as aqueous solution and used without any treatment.

2.2 Methods

Within the scope of this study, environmentally friendly geopolymer concrete production was realized by using waste barite at the rates of 10%, 20%, 30% instead of standard sand. The amounts of materials used in the study are given in Table 4. In this study, the contribution of temperature curing to the geopolymerization process and its effects on the disposal of waste materials were comparatively investigated in terms of flexural and compressive strength values. The specimens were cured in an oven at 60 °C for 24 hours for temperature activation and the effects of this process were evaluated.

Table 4. *Mixture composition data (kg/m³)*

Specimens	SS/SH	SS* (g)	SH* (g)	Blast Furnace Slag (g)	Waste Barite (g)	Standard Sand (g)	Plasticizer (g)
G	2.78	320.5	115	600	0	1350	3
GWB10	2.78	320.5	115	600	160	1215	3
GWB20	2.78	320.5	115	600	352	1188	3
GWB30	2.78	320.5	115	600	481	945	3

*SS: Sodium silicate solution
*SH: Sodium Hydroxide solution (16 mol)

Geopolymer concrete mixtures were prepared in accordance with the proportions specified in Table 3. During the mixing process, the liquid components sodium hydroxide (SH), sodium silicate (SS), and superplasticizer were first mixed until a homogeneous solution was obtained. Subsequently, the solid components, including ground granulated blast furnace slag, waste barite, and standard sand, were thoroughly mixed. The resulting solid mixture was then gradually added to the liquid mixture and blended in a 5 liter mortar mixer until a uniform consistency was achieved.
After the mixture reached the desired homogeneity, the casting process was carried out by applying vibration to the previously prepared molds and placing them in three stages. The mold, waste barite and bending test used in the study are shown in Figure 1.

Figure 1. *Produced geopolymer concretes*

Three specimens were produced for each series containing different proportions of waste barite. The geopolymer concrete mixtures prepared within the scope of the experimental study were placed in 40×40×160 mm prism molds with the help of vibration for flexural and compressive strength tests in accordance with TS EN 196-1 standard [16].
After temperature activation, various physical and mechanical tests were performed on the specimens that gained strength on the 7th and 28th days (Figure 2). Within the scope of the experimental study, the changes in the physical and mechanical properties of the specimens such as density, flexural strength and compressive strength were analyzed comparatively. The relationships between the data obtained were evaluated using statistical methods.

Figure 2. *Flexural and compressive strength testing of specimens*

3. Results and Discussions

Within the scope of the study, the densities of the specimens made with waste barite used instead of sand at different ratios were investigated. The specimens were cured in an oven at 60°C for 24 hours and then the density (air dry) values were measured. In the analysis, a linear relationship was observed between the proportion of waste barite and sand and density, and the accuracy of this relationship was statistically proven with a very high R^2 value of 0.9993 (Figure 3). The results have been shown that the density of the samples changes significantly as the waste barite content increases and this change is predictable.
In the subsequent stages, the flexural and compressive strengths of the specimens on the 7th and 28th days were examined. The results presented in Figure 4 and 5 show the strength properties of the

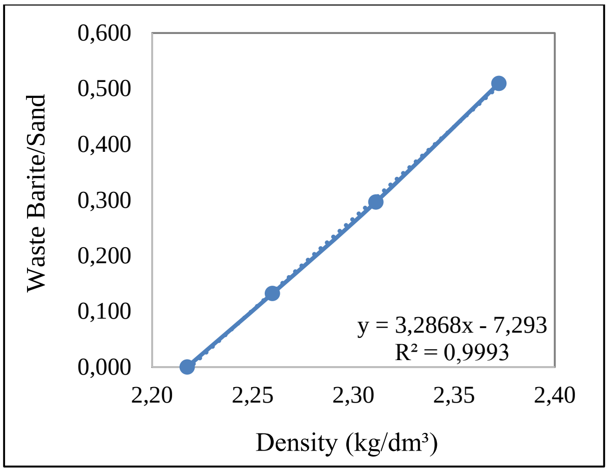

Figure 3. *Relationship between waste barite/sand ratio and density.*

specimens containing different proportions of waste barite at both time intervals. In the mechanical tests performed on both the 7th and 28th days, no significant change was observed in the strength values depending on time. However, the relationship between the specimens was consistent in both measurements, confirming each other and yielding coherent results. Despite the statistically insignificant changes, it was determined that the use of waste barite at different proportions had a notable effect on the mechanical properties of the specimens.

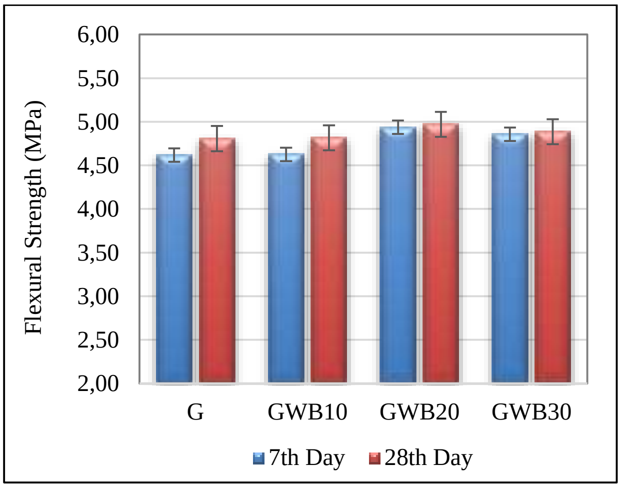

Figure 4. *Flexural strengths of the specimens at 7 and*

There are small differences in the flexural strengths of the samples, but the flexural strength that is relatively higher than the others is measured as an average of 4.94 and 4.97 MPa for the 7-day and 28-day samples with 20% waste barite added, respectively. The lowest strength was recorded as approximately 4.62 and 4.82 MPa for the control and 10% samples.

In the compressive strengths, more noticeable differences are observed. The average compressive strength for the 7-day and 28-day samples with 20% waste barite added was measured as 66.4 and 67.10 MPa, respectively, while the lowest strength was recorded as approximately 58.5 and 59.0 MPa for the control and 10% samples.

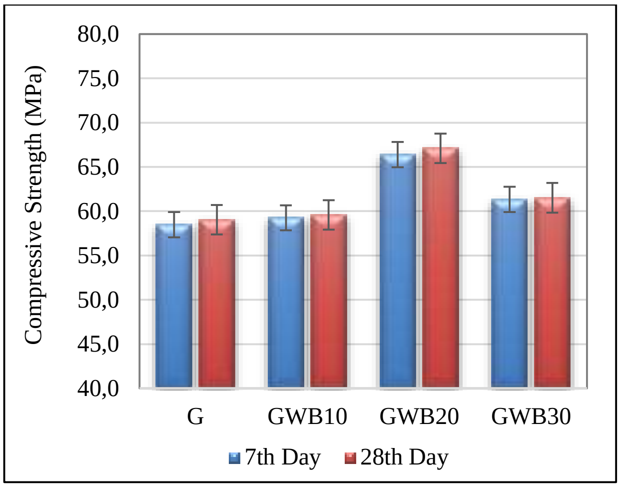

Figure 5. *Compressive strengths of the specimens at 7 and 28 days*

4. Conclusions

The mechanical tests conducted on the 7th and 28th days, no significant change was observed in the strength values depending on time depending on the days.
In this study, where waste barite aggregate was used in different proportions instead of standard sand, it was physically observed that the increase in the waste barite aggregate percentage increased the density of geopolymer concrete, while it caused micro cracks in mixtures containing 30 percent waste barite. The highest flexural and compressive strengths were obtained in samples containing 20% waste barite.
The obtained flexural and compressive strength results are consistent with each other and show that the appropriate use of waste barite aggregate has the potential to improve the mechanical properties of geopolymer concrete.
In this context, future studies that include different mole ratios, various curing conditions and the use of different waste materials in geopolymer concrete production can contribute significantly to the literature by increasing the sustainability of the material.

Author Statements:

- **Ethical approval:** The conducted research is not related to either human or animal use.

- **Conflict of interest:** The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper
- **Acknowledgement:** The authors would like to thank Suleyman Demirel University Scientific Research Projects Coordination Department (BAP) for their contributions
- **Author contributions:** The authors declare that they have equal right on this paper.
- **Funding information:** The authors declare that they have carried out this study by providing funding from SDU BAP (FYL-2024-9571) project.
- **Data availability statement:** The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

References

[1] Habert, G., De Lacaillerie, J. D. E., & Roussel, N. (2011). An environmental evaluation of geopolymer based concrete production: reviewing current research trends. *Journal of cleaner production*, 19(11), 1229-1238.

[2] Nimwinya, E., Arjharn, W., Horpibulsuk, S., Phoo-Ngernkham, T., & Poowancum, A. (2016). A sustainable calcined water treatment sludge and rice husk ash geopolymer. *Journal of Cleaner Production*, 119, 128-134.

[3] Masi, G., Rickard, W. D., Vickers, L., Bignozzi, M. C., & Van Riessen, A. (2014). A comparison between different foaming methods for the synthesis of light weight geopolymers. *Ceramics International*, 40(9), 13891-13902.

[4] Zhou, W., Yan, C., Duan, P., Liu, Y., Zhang, Z., Qiu, X., & Li, D. (2016). A comparative study of high- and low-Al2O3 fly ash based-geopolymers: The role of mix proportion factors and curing temperature. *Materials & Design*, 95, 63-74.

[5] Komnitsas, K. A. (2011). Potential of geopolymer technology towards green buildings and sustainable cities. *Procedia Engineering*, 21, 1023-1032.

[6] Villaquirán-Caicedo, M. A., & de Gutiérrez, R. M. (2018). Synthesis of ceramic materials from ecofriendly geopolymer precursors. *Materials Letters*, 230, 300-304.

[7] A. Nikolov, H. Nugteren, and I. Rostovsky, (2020). Optimization of geopolymers based on natural zeolite clinoptilolite by calcination and use of aluminate activators, *Construction and Building Materials*, 243, 118257.

[8] B. C. McLellan, R. P. Williams, J. Lay, A. van Riessen, and G. D. Corder, (2011). Costs and carbon emissions for geopolymer pastes in comparison to ordinary portland cement, *Journal of Cleaner Production*, 19(9); 1080-1090.

[9] Geopolymer Chemistry and Applications, by Joseph Davidovits, 1st edition March 2008, *2nd edition June 2008.*

[10] Provis, J.S.J. van Deventer (Eds.), Alkali-activated Materials: State-of-the-Art Report, RILEM TC 224-AAM, *Springer/RILEM, Dordrecht*, 2014.

[11] Çelik, M.Y., Sabah, E., 2008. The geological and technical characterisation of Omer-Gecek geothermal area and environmental impact assessment of geothermal heating system in Afyon, Turkey. *Environmental Geology* 41 (48), 942–953.

[12] Akkurt, I., Altindag, R., Basyigit, C., & Kilincarslan, S. (2008). The effect of barite rate on the physical and mechanical properties of concretes under F–T cycle. *Materials & Design*, 29(9), 1793-1795.

[13] Kilincarslan, S., Akkurt, I., & Basyigit, C. (2006). The effect of barite rate on some physical and mechanical properties of concrete. *Materials Science and Engineering*: A, 424(1-2), 83-86.

[14] Kılınçarslan, Ş., İnce, E. Y., Tuncay, E. B., & Yağmurlu, F. (2018). Clustering Analysis of Normal Strength Concretes Produced with Different Aggregate Types. Open Chemistry, 16(1), 918-922.

[15] Kardemir, (2025). Karabük demir çelik sanayi ve ticaret A.Ş. *https://www.kardemir.com/urunler*.

[16] TS EN 196-1, 2016. Methods of testing cement - Part 1: Determination of strength. *Turkish Standards Institute.*