https://www.sworldjournal.com/index.php/swj/article/view/swj32-01-045
DOI: 10.30888/2663-5712.2025-32-01-045

UDC 504.05:622.271:691.3

USE OF ROCK SLURRY IN THE SYNTHESIS OF GEOPOLYMERS: ENVIRONMENTAL AND TECHNOLOGICAL ASPECTS

Skyba G.V.
c.t.s., as.prof.
ORCID: 0000-0002-4981-4975
Zhytomyr Polytechnic State University,
Zhytomyr, Chudnivska 103, 10005

Abstract. *Stone slurry, as a secondary product of the stone processing industry, is considered a promising raw material for geopolymer materials. The study of its chemical composition showed a high content of* SiO_2 *relative to* Al_2O_3*, which meets the requirements for geopolymerization. An approach to environmentally safe pulp utilization by using it in alkaline synthesis is proposed. This method reduces the technogenic load and promotes the circular use of resources. Processing stone slurry is part of a sustainable development strategy. The results confirm the effectiveness of an innovative geoecological approach.*

Key words: *rock slurry, geopolymers, silica, geoecology, circular economy*

Introduction.

The current state of development of industry in Ukraine is characterized by significant amounts of waste generation, among which a special place is occupied by stone slurry - a suspension of solid particles in a liquid, which is formed as a result of technological processes of stone processing. The problem of utilization of rock slurry is becoming particularly relevant in the context of the aggravation of the environmental crisis and the need to transition to a more rational use of natural resources [1-3].

The problem of sludge disposal is particularly acute in regions with a developed stone processing industry, in particular in the Zhytomyr region, where a significant number of natural stone processing enterprises operate. Traditional methods of handling stone sludge are mostly limited to its disposal in landfills, which does not comply with modern principles of circular economy and sustainable development [4, 5].

The research is driven by the need to find and implement effective, environmentally friendly methods of sludge disposal that will not only reduce the negative impact on the environment, but also turn waste into valuable secondary raw materials.

Natural facing stone is a fossil resource and, from the point of view of the principles of sustainable development and the circular economy, the use of this resource must be economical, rational and complete. European legislation clearly classifies and regulates the behavior of waste in industry.

Analysis of literary sources.

Rock slurry is formed directly during the cutting of stone for its further processing and sale. It has been estimated that the extraction and processing of granite produces 40% of the volume of stone slurry in relation to the initial volume [5].

Modern approaches to industrial waste management are characterized by the search for more environmentally friendly and resource-efficient alternatives to traditional disposal methods. Landfilling, although still a common method, is associated with a number of environmental risks, including the formation of leachate that can potentially contaminate groundwater and soil, anaerobic decomposition with the formation of methane, significant land use, and possible dust pollution (Figure 1).

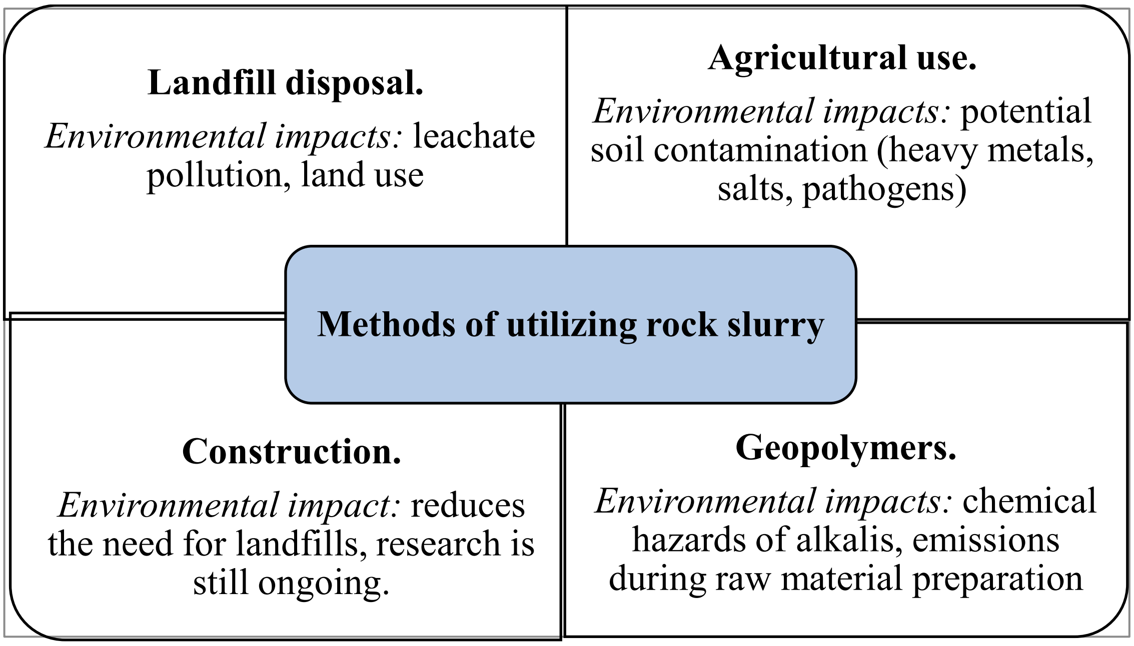

Figure 1 - Methods of utilizing rock slurry and their environmental impacts

Authoring

In line with the principles of the circular economy, there is growing interest in the use of sludge as a secondary raw material in various industries [6]. Rock processing sludge can be used as an aggregate in the construction industry, for example in concrete and cement mixtures, potentially improving certain properties of concrete. Successful implementation of such practices can create economic opportunities while reducing the environmental burden of waste disposal [7, 8].

Main text

The chemical composition of rock slurry is determined by the chemical composition of the starting material, i.e. the source of origin of the rock being processed. Based on open data provided by the State Enterprise "Geoinform", the chemical composition of facing natural rock in the main deposits of the Zhytomyr region of Ukraine was analyzed and established in Table 1.

Table 1 - Chemical composition of rocks of the main natural stone deposits of Zhytomyr region

Deposit	Al_2O_3	SiO_2	CaO	Fe_2O_3	FeO	MgO	TiO_2	MnO	Na_2O	K_2O
Granite										
Vasylivske	13,5	70,5	1,5	0,97	2,94	0,28	0,46	0,04	3,21	5,66
Zhezhelivske	14,5	68,6	2,1	5,92	-	1,94	0,72	0,05	3,16	3,29
Kapustynske	14,5	71,1	1,8	3,65	-	0,48	0,43	0,03	2,62	5,35
Kornynske	14,9	68,3	3,0	5,15	-	1,10	0,70	-	1,85	4,80
Gabbro										
Bukynske	13,5	56,2	6,2	1,90	-	2,65	3,05	-	3,14	2,35
Horbulivske	16,8	56,6	10,0	2,00	-	2,41	2,01	-	3,34	0,93
Kamyanobrydske	14,5	51,7	9,3	4,16	-	3,76	2,84	-	3,52	0,81
Slipchytske	17,6	52,3	8,8	9,09	-	4,10	0,98	-	3,18	0,66
Labradorite										
Golovynske	22,2	50,3	9,3	7,25	-	2,90	1,67	-	3,86	1,72

Authoring

For the manufacture of geopolymer, aluminosilicate raw materials with a ratio of aluminum oxide (Al_2O_3) to silicon oxide (SiO_2) content of 1:3 are required [9]. The generalized results of X-ray fluorescence analysis of stone slurry used in the study are presented in Table 2.

Table 2 - Generalized results of X-ray fluorescence analysis of rock slurry

Components	Mud from basic rocks (labradorite, gabbro), wt, %	Mud from acidic rocks (granite), wt, %
SiO_2	50,79 ± 0,25	65,80 ± 0,24
Al_2O_3	19,30 ± 0,20	15,17 ± 0,18
Fe_2O_3	9,31 ± 0,15	4,35 ± 0,10
K_2O	0,86 ± 0,15	4,25 ±0 ,10
MgO	3,47 ± 0,09	1,56 ± 0,06
CaO	9,71 ± 0,15	3,55 ± 0,09
TiO_2	1,89 ± 0,07	0,579 ± 0,029
Na_2O	3,70 ± 0,09	3,44 ± 0,09
P_2O_5	0,277 ± 0,014	0,1750 ± 0,0031
MnO	0,121 ± 0,0060	0,0236 ± 0,0027
V_2O_5	0,0380 ± 0,0024	0,0380 ± 0,0024
SrO	0,0646 ± 0,0032	0,0646 ± 0,0032
ZnO	0,0123 ± 0,0060	0,01123 ± 0,0060
As_2O_3	0,0875 ± 0,018	0,0875 ± 0,018

Authoring

Comparing the chemical composition of fine-dispersed waste from stone processing of basic and acidic rocks, an increase in the content of silicon oxide in the waste of acidic rocks is observed. This indicates the advantage of such stone slurry for use in the manufacture of geopolymer materials

Considering that stone processing enterprises are supplied with stone from various deposits, we conducted an X-ray fluorescence analysis of stone slurry formed at the most powerful enterprises of the Zhytomyr region. Since the ratio of aluminum oxides and silicon in the slurry is important for the manufacture of geopolymer materials, Table 3 presents the content of these components.

Table 3 - X-ray fluorescence analysis of the main components of slurry from stone processing enterprises in Zhytomyr region

Components	LLC "Quant" (labradorite)	LLC "Nikogran" (gabbro, granite)	LLC "Grantech" (gabbro, granite, labradorite)	LLC "Keranit" (gabbro, granodiorite)
SiO_2, wt, %	56,710	65,800	68,33	61,01
Al_2O_3, wt, %	17,840	15,170	14,03	15,43
$SiO_2 : Al_2O_3$	3,18	4,34	4,87	3,95

Authoring

Thus, the ratio of $SiO_2 : Al_2O_3$ in the slurry at the presented stone processing enterprises is more than three, which meets the requirements for raw materials for the production of geopolymers.

Using rock slurry as a basis for aluminosilicate materials for geopolymerization

The geopolymerization process is a chemical reaction of aluminosilicate oxide minerals with an alkaline solution. This process is quite fast, during which geopolymer blocks are formed using polymer bonds in three-dimensional sialate chain structures (Si – O – Al – O). The amount of aluminum oxide and silicon oxide in the structure affects the degree of polymerization of the reaction and their bonding and the characteristics of the geopolymer (Figure 2). The chain structure of the formed polysialate is represented in the form of the formula:

$$M^{n+} [- (SiO_2) \cdot z - AlO_2]_n \cdot w\ H_2O$$

where M^{n+} is an alkali metal cation (K^+, Na^+), z is a value of 1–3 or higher depending on the reaction chemistry, n is the degree of polymerization, and w is the degree of hydration [10, 11].

The polymerization process is described by the chemical transformations presented in Figure 2 [10, 11].

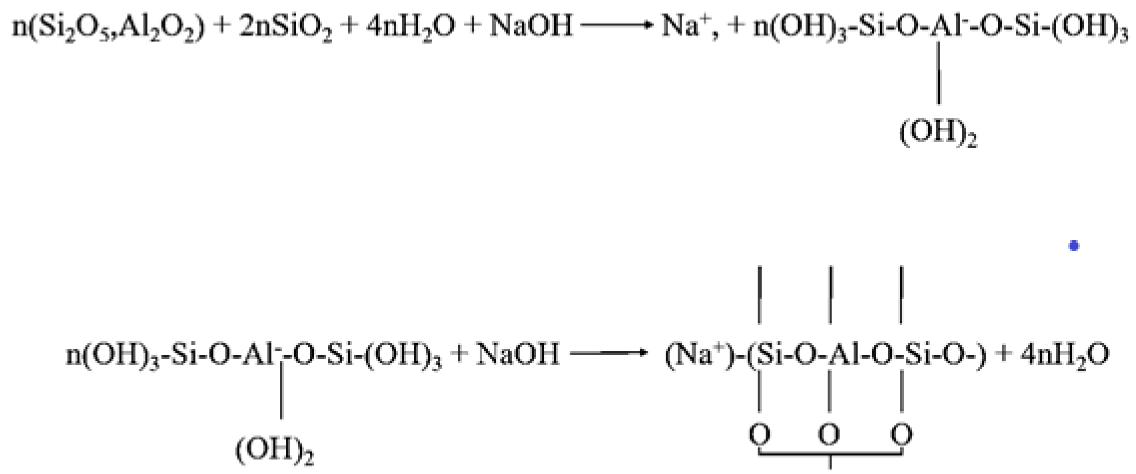

Figure 2 - Scheme of the polymerization process in the presence of alkali

Resources: [10, 11]

The structure of polysialate depends on the spatial arrangement and organization of alternately linked tetrahedral structures $[SiO_4]^{4}$- and $[AlO_4]$- with a common oxygen. They can form several such repeating units (monomers) as shown in Figure 3 [9]. However, the mechanism of geopolymerization is not yet fully understood.

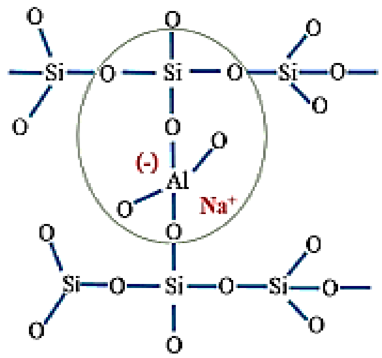

Figure 3 - Formation of polysialate and its chemical structure

$(SiO_2 : Al_2O_3 > 3)$

Resources: [9]

Analysis of scientific research allows us to state that the geopolymerization process consists of three stages:

- dissolution of aluminosilicate and destruction of intermolecular bonds in the presence of a precursor and an alkaline activator by hydrolysis;

- reorientation and transport of ions into monomers;
- polycondensation of monomers into polymer structures.

To obtain a geopolymer from rock slurry, we used sodium hydroxide as the main activator [12]. Studies were conducted using sodium hydroxide of different concentrations. The best results were obtained when using an 8M sodium hydroxide solution. For comparison, studies were conducted using potassium hydroxide (KOH) as an activator. In our case, using rock sludge as a filler, the geopolymerization reaction occurred more slowly and required higher temperatures. Theoretically, this can be explained by the difference in the atomic radii of sodium and potassium cations. Sodium cations have a smaller radius compared to potassium cations, thereby ensuring faster polymerization. A high concentration of the activator leads to a significant increase in the strength of the geopolymer at an early stage of the reaction. Due to their alkaline properties, such materials are resistant to acids.

At this stage, we are working out an effective method for obtaining geopolymer from finely dispersed waste from stone processing production with further research into the physical and technical properties of the obtained specimens.

Summary and conclusions.

Rock slurry is a significant geoecological factor that is formed as a result of industrial activities, in particular mining and stone processing industries. Research on methods of utilization of rock slurry and its impact on the environment shows that for effective and environmentally safe handling of this type of waste, an integrated approach is necessary, taking into account both the physicochemical properties of the slurry and the economic feasibility of the selected methods.

The analysis of the chemical composition of stone slurry showed the possibility of using it as a filler in geopolymerization reactions. In finely dispersed waste from stone processing production, the ratio of components $SiO_2 : Al_2O_3 > 3$, which meets the criteria of raw materials that can be used in alkaline synthesis of geopolymers.

The use of rock slurry to create new materials demonstrates an innovative geoecologically oriented processing method.

Acknowledgment

I would like to sincerely thank the organizers of the 2nd European Chemistry School for Ukrainians – Professor Stefan Wuttke (Academic Centre for Materials and Nanotechnology, AGH University of Science and Technology, Kraków, Poland) and Professor Joanna Goscianska (Adam Mickiewicz University in Poznań, Poland), as well as the world-renowned lecturers from across Europe who delivered insightful talks on key areas of modern chemistry.

The school provided an extremely valuable experience and helped deepen my understanding of recent advances in polymer chemistry, materials science, and related technologies.

References:

1. Afonso P., Pires V., Faria P., Azzalini A., Lopez L., Mourao P., Martins R. (2024). A new approach to the reuse of waste from the extraction and processing industry of natural stone binders: development of stone composites. Sustainable Development. No. 16(1). Article 64. DOI: https://doi.org/10.3390/su16010064.

2. Zichella L., Bellopede R., Spriano S., Marini P. (2018). Preliminary investigations on stone cutting sludge processing for a future recovery. Journal of Cleaner Production. № 178. pp. 866–876. DOI: https://doi.org/10.1016/j.jclepro.2017.12.226.

3. Bragina L. L., Ryabinin S. O., Fedorenko O. Yu., Degurko O. P., Melnyk S. O.(2020). Current state and prospects for the use of stone mining and stone processing waste in silicate industries (review). Scientific research on refractories and technical ceramics. No. 120. P. 196–210. URL: http://nbuv.gov.ua/UJRN/vognetryv_2020_120_21

4. Bashynskyi, S. I., Bletsko, M. I., Panasyuk, A. V., Prypoten, Yu. K., & Ostafiychuk, N. M. (2023). Research on the physicochemical properties of fine-dispersed waste from stone processing enterprises in order to determine the strategy of behavior. Technical Engineering, (1(91), 271–279. https://doi.org/10.26642/ten-2023-1(91)-271-279.

5. Serena A. Integrated method for recycling stone wastes and system there of : пат. WO 2013/084173 A1 : МПК B03B 9/06, C04B 18/16, C04B 7/26. № PCT/IB2012/056950 ; заявл. 04.12.2012 ; опубл. 13.06.2013. 30 с. URL: https://patentimages.storage.googleapis.com/fd/f0/82/941d5091c940ec/WO2013084173A1.pdf

6. Provis, J. L.; Van Deventer, J. S. (2009). Geopolymers: Structures, Processing, Properties and Industrial Applications. Elsevier: New York, N Y, USA. p. 454. DOI**:** 10.1533/9781845696382

7. Unis Ahmed, H.; Mahmood, L. J.; Muhammad, M. A.; Faraj, R. H.; Qaidi, S. M. A.; Hamah Sor, N.; Mohammed, A. S.; Mohammed, A. A. (2022). Geopolymer concrete as a cleaner construction material: An overview on materials and structural performances. Clean. Mater., 5, 100111. DOI**:** 10.1016/j.clema.2022.100111

8. S. Dawczynski, R. Krzywon, M. Gorski, W. Dubinska, M. Samoszuk. (2017). Geopolymer concrete - applications in civil engineering. P. 332-341

9. Hua Xu, J.S.J. Van Deventer. (2000).The geopolymerisation of alumino-silicate minerals. J. Miner. Process. V. 59. N. 3. P. 247–266. https://doi.org/10.1016/S0301-7516(99)00074-5

10. Davidovits, J. (1991). Geopolymers: inorganic polymeric new materials. J. Thermal Anal. 37, 1633–1656. DOI: 10.1007/BF01912193.

11. Davidovits, J. (1994). Geopolymers: inorganic polymeric new materials. J. Mater. Educ. 16, 91–139. https://www.geopolymer.org/library/technical-papers/3-geopolymers-inorganic-polymeric-new-materials/

12. Somna R., Saowapun T., Somna K., Chindaprasirt P. (2022). Rice husk ash and fly ash geopolymer hollow block based on NaOH activated. Case Stud. Constr. Mater. 16: e01092. DOI: 10.1016/j. cscm.2022. e01092.

Article sent: 25.07.2025