Engaging man-made waste in the closed cycle of mining production

N Gorbatyuk¹ *, A Adigamov², S Shakhov³ and O Kobelev²

¹V.I. Vernadsky Crimean Federal University, Prospekt Vernadskogo, 4, 295007, Simferopol, Russia
²National University of Science and Technology «MISiS», Leninsky av., 4, 119991, Moscow, Russia
³VMM Holding Company «VNIIMETMASH», Ryazanskiy prospect, 8A, 109428, Moscow, Russia

*E-mail: gorbatyuk54@bk.ru

Abstract. The problems faced by the mining and construction industries are analyzed in the article. A unified concept is formulated to eliminate the problems that arise in the region of mineral extraction, together with solving the problems of expanding the raw material base of the construction sector. The idea of rational use of man-made waste from local mining enterprises and industrial waste for the construction and backfill mixes preparation is presented. The aspects of their application as an aggregate in mixtures are considered on the example of man-made waste (halite enrichment waste). It is noted that the use of man-made waste in construction and backfill mixes must be carried out after deep additional processing. Deep processing allows to maximize the use of useful components of man-made waste and eliminate the negative consequences of harmful ones. It is established that the best way of additional processing is the activation of man-made waste in disintegrators. It is proved that activation increases the strength of structures or cemented mass by 25-30%, reduces the consumption of binder by 40-50%, while maintaining the same strength characteristics. The use of man-made waste in construction and backfill mixtures expands the raw material base for the construction and mining sectors, allows to implement the concept of sustainable development of the region, and reduces the impact on the environment.

1. Referat
In this paper, studies on the use of man-made waste in construction and backfill mixtures are carried out. The utilization of man-made waste reduces the impact of geotechnology on the environment. Sustainable mining development and gentle technologies are the main concept of the research. This concept implies ensuring the safe conduct of work, environmental safety of subsurface development, reducing losses in the process of underground mining, increasing the stability of underground structures, increasing the service life of a mining enterprise, and solving the problems of rational use of natural resources. The results of the research allowed us to propose technical and technological solutions for rational sustainable economic development, taking into account all forms of the impact of geotechnology on the environment, and suggested ways to improve the technology of extracting minerals from the subsurface.

It is necessary to take into account that in the industrial massifs of mining and processing industries, a huge amount of waste has accumulated, which has useful components in its composition. Waste can be not only raw materials for the production of additional products, but also are man-made geo-resources. High-quality preparation of man-made waste for reuse in order to maximize the use of their positive qualities; extraction of useful components; exclusion of subsequent environmental impact is a top priority.
The use of man-made waste as an aggregate in construction or backfill material significantly expands the raw material base. The involvement of man-made waste allows them to be disposed of, which minimizes the risks of violating the ecological balance.

2. Introduction

The constant increase in the resources consumed determines the high rate of development of geotechnology and the intensification of mineral extraction, which is associated with certain risks, both industrial and environmental [1].

The problem of storing industrial waste from mining production: rocks from sinking and overburden operations and the processing sector: waste from enrichment and metallurgical processing increases every year [2]. Large areas of agricultural land are being seized for man-made massifs [3]. Industrial waste, with a visible relatively stable state during long-term storage after contact with water or other waste, becomes mobile and is carried out through the filtration systems of the earth's crust outside of industrial massifs, pollutes the environment and enters the human habitat [4]. In addition, small fractions of dump rocks, beaches of tailings dumps and slag heaps are sources of dust formation [5]. Industrial waste, including construction waste, has no less impact on the environment.

If solid man-made waste can be considered to be in a conditionally equilibrium state, then liquid, suspended matter (pulp) and gaseous waste begin to negatively affect the environment immediately after entering it.

The search for local cheap raw materials for the construction industry, which is designed to replace traditional building materials, will allow to meet their acute shortage [6, 7]. In turn, the effective use of man-made waste from mining and industrial production as raw materials for the manufacture of building materials, will create intermediate products in cyclic production and minimize the impact on the environment [8] and ensure the safety of underground workings or ground buildings and structures [9].

Waste from mining, processing and industrial production [10], as well as the secondary product obtained as a result of dismantling works in civil and industrial construction [11], may be suitable for use. The main conditions for their use are accessibility and neutral impact on the environment and human impact [12].

The use of man-made waste of all types of production directly in the extraction of minerals or in the creation of products for the construction industry will eliminate the costs of construction and operation of man-made storage facilities.

Often, it is proposed to preserve the pristine nature and mineral diversity of the Earth by transferring mining production to cosmic bodies [13]. But the lack of technical possibilities for implementation [14] and unresolved legal issues [15] postpone the implementation of this idea for the distant future.

3. Problems, objects and methods of research

The use of man-made waste from mining and construction is an important issue worldwide [16-18]. Despite the importance of the issue of re-use of man-made waste, it has a fairly local size and significance. Understanding the problems also depends on the experience of the people involved in the implementation and implementation of technologies for the reuse of man-made waste. Until now, the idea of using man-made waste has been realized by using it to prepare a backfill composite for the extraction of minerals by geotechnology with the laying of the developed space [19, 20]. The possibility of using large volumes of man-made waste can be realized in large infrastructure construction projects: the construction of roads and railways, flood protection systems-dams, etc. [21]. In addition, man-made waste can be used to prepare building composites for building foundations, monolithic structures, concrete blocks, and bricks. To implement the task of using man-made waste in civil construction, it is necessary to solve a number of the following tasks:
1. define the concept of implementing the ideas of non-waste (low-waste) production, excluding the formation of waste and assuming their use as an intermediate product in a closed cycle of the main or auxiliary production;

2. ensure the environmental cleanliness of the waste used;

3. develop and implement technologies that ensure the preparation of waste for use.

If the solution to the first problem lies in the legal and contractual sphere and consists in understanding "how flexible the customer is with regard to the use of waste" and "how much the company, which is responsible for man-made massifs, wants to dispose of them", then the implementation of the next two is in the scientific plane, and the possibility of solving them will be considered in this study.

As it was noted earlier, industrial waste, being a powerful source of disturbance of the ecological balance, can serve as raw materials for the production of construction and laying materials [22]. However, it should be remembered that the chemical components contained in man-made waste can negatively affect both the technical characteristics of the mixture and the environment [23]. To this it is necessary to add that a huge amount of waste has accumulated in the industrial massifs of mining and processing industries, which have useful components in their composition, which can be not only raw materials for the production of additional products, but also are industrial geo-resources [24]. Deep processing of man-made waste will increase the completeness of the extraction of the useful component [25]. In the context of increasing consumer demand for extracted raw materials and building materials, increasing the requirements for the completeness and complexity of the use of the mineral resource base and involving waste in the creation of materials for the construction industry is a paradigm for the further development of science [26].

Thus, the primary task is the high-quality preparation of man-made waste for use in order to maximize the use of their positive qualities, extract useful components and eliminate the subsequent impact on the environment [27, 28].

4. Results and discussions

The purpose of this study is to develop a technological and theoretical basis for the rational use of man-made waste from mining and processing production in the creation of construction and laying materials, which will improve the environmental situation of the region, develop a highly effective advanced technology for deep processing and disposal of man-made waste.

In previous studies, the rationality of the use of mechanical activation for processing tailings and off-balance ores was justified. Activation treatment allows for a 10-20% increase in the extraction of a useful component from man-made waste. Based on the economic and technical analysis of various technologies, it was found that the most effective is the mechanochemical technology of deep processing of man-made waste from mining and processing production. This technology combines the methods of mechanical and chemical activation treatment in disintegration plants.

In addition to useful components, man-made waste contains components that can subsequently have a negative impact on composites or products made from them (softening, excessive swelling or increase in volume, caking, etc.), as well as, due to instability, disrupt the ecological balance. It is necessary to take into account a number of economic, environmental and other restrictions when using waste from mining and industrial production in the laying composite.

Therefore, deep processing of industrial waste by the method of mechanochemical activation in order to extract useful components for additional profit and neutralize components that have a negative impact on the manufactured products and the environment, is seen as a fairly promising direction of development in the field of repeated (low-waste) technologies in the production of construction and laying materials.

When creating construction and laying composites, they are currently engaged in the development of fundamentally new materials. The creation of innovative building or laying material is made by structural changes in its internal structure due to the formation of new or secondary crystal structures. This increases the strength characteristics of solidified structures or solid wood. At this stage, the most
affordable and cheap method to influence the properties of the composite is the activation treatment of its components or the finished mixture as a whole [29].

Mechanical activation should be understood as one of the methods of processing the composite components separately or as a finished mixture, as a result of which the properties of the components are used most fully [30, 31].

One of the promising methods of activation is the mechanical activation treatment of the mixture components in disintegrators (Figure 1).

Due to the uneven redistribution of velocities in the working body of the disintegrator, large internal stresses arise (Figure 2), which allow us to exclude the further formation of hydrate bonds on the surface of the grains of the aggregate of the mixture [32-34].

Industrial waste is subjected to activation treatment in disintegrators before it is mixed with other components of the construction or laying composite [35, 36]. Activation processing of the ingredients leads to an increase in strength characteristics and an improvement in the uniformity of structures and artificial massifs [37]. This makes it possible to use man-made production waste as part of the construction and laying composite to create a new material [38, 39].

Consider the use of activation treatment of halite waste used as an aggregate in construction or backfill composites (Table 1, Figure 3). Since the salts are soluble in water, a saturated salt solution was used as a recluse.

The construction or laying composite obtained based on activated industrial waste is less susceptible to stratification, since it is more difficult to "give" water, is more mobile and homogeneous in composition (Figure 4). The use of industrial waste that has undergone activation treatment in disintegrators, in construction and laying composites allows to increase the strength of structures or monolith mass by 25 – 30% or reduce the consumption of binder by 40 – 50%, while maintaining their previous strength characteristics.

**Table 1.** Kinetics of strength gain of mixtures based on halite waste with and without activation with different content of components.

| №   | content of components, mass. % | ratio of saturated solution to solid | strength of samples under uniaxial compression, MPa | duration of hardening, days |
|-----|-------------------------------|-------------------------------------|-----------------------------------------------|-----------------------------|
|     | waste activated waste cement |                                     |                                               |                             |
| 1   | - 99 1                          | 0.125                               | 0.125 1.5 2.1 2.3                           |                             |
Figure 3. The kinetics of the strength set of the backfill with different content of the binder component and the aggregate (enrichment waste) astringent/waste: 1 – 1/99; 2 – 2/98; 3 – 0/100.

Figure 4. Effect of the duration of activation of industrial waste on
1-solubility; 2-specific surface area of non-aggregated powders; 3-specific surface area of disaggregated powders; 4-amorphization; 5 – comparison of the growth of specific surface area and strength.

5. Conclusions
The use of industrial waste (halite enrichment waste) in the construction or backfill composite becomes possible after their activation treatment in the disintegrator.

The disintegrative effect on man-made waste in combination with chemical treatment makes it possible to additionally extract useful components from man-made waste, which improves the financial stability of the enterprise. Mechanochemical technology significantly increases the mineral resource base of the mining and processing enterprise and expands the environmentally safe and affordable basis for the use of man-made waste as components in construction and building materials.

The use of industrial waste (halite enrichment waste) in construction and laying materials, after activation treatment by means of a disintegrator, increases the strength characteristics of the construction monolith and the laying mass by 25 – 30% or reduces the consumption of cement by 40 – 50% while maintaining the strength characteristics of the laying array.

The use of man-made waste as an aggregate in construction or laying material significantly expands the raw material base of the construction sector, allows them to be disposed of, which minimizes the risks of environmental balance violations.
The idea of non-waste (low-waste) production allows not only to expand the raw material base for each of the industrial sectors, but also to implement the concept of sustainable development of the region. This approach, in addition to improving the economic performance of the mining and processing enterprise and the construction sector, will now lead to a high multiplier social and environmental effect.

References
[1] Khayrutdinov A et al 2020 Stress-strain behavior control in rock mass using different-strenght backfill Mining Informational and Analytical Bulletin 10 pp 42-55 doi:10.25018/0236-1493-2020-10-0-42-55
[2] Gorbatyuk S et al 2020 Technologies for applying Ni-Au coatings to heat sinks of SiC-Al metal matrix composite material Materials Today: Proceedings 38 pp 1889-1893 doi:10.1016/j.matpr.2020.08.581
[3] Kongar-Syuryun Ch et al 2021 Geotechnology using composite materials from man-made waste is a paradigm of sustainable development Materials Today: Proceedings 38 pp 2078-2082 doi:10.1016/j.matpr.2020.10.145
[4] Valiullin I et al 2021 Application of a discrete double-row scraper cleaner as an efficient procedure of cleaning of belt conveyors aimed at transporting bulk materials Metallurgist 64 pp 1340-1346 doi:10.1007/s11015-021-01124-x
[5] Rybak J et al 2021 Utilization of mineral waste: a method for expanding the mineral resource base of a mining and smelting company Metallurgist 64 pp 851-861 doi:10.1007/s11015-021-01065-5
[6] Kerimov R and Shakhov S 2020 Use of metallized raw materials in electric furnace steelmaking Metallurgist 64(1-2) pp 128-135 doi:10.1007/s11015-020-00974-1
[7] Niemiec D et al 2017 Selected black-coal mine waste dumps in the ostrava karviná region: an analysis of their potential use IOP Conf. Series: Earth Environ. Sci. 95 042061 doi:10.1088/1755-1315/95/4/042061
[8] Rybak J et al 2021 Geomechanical substantiation of parameters of technology for mining salt deposits with a backfill Mining Science 28 pp 19-32 doi:10.37190/msc212802
[9] Wyjadłowski M et al 2021 Investigation of the diaphragm wall isolation of vibrations' transferred through the subsoil IOP Conf. Series: Mater. Sci. Eng. 1015 012059 doi:10.1088/1757-899X/1015/1/012059
[10] Khayrutdinov M et al 2020 Cementless backfill mixtures based on water-soluble manmade waste Bulletin of the Tomsk Polytechnic University, Geo Assets Engineering 331(11) pp 30–36 doi:10.18799/24131830/2020/11/2883
[11] Kawalec J et al 2017 Application of crushed concrete in geotechnical engineering - selected issues IOP Conf. Series: Earth Environ. Sci. 95 022057 doi:10.1088/1755-1315/95/2/022057
[12] Zástěrová P et al 2016 Analysis the purposes of land use planning on the hard coal tailing dumps IOP Conf. Series: Earth Environ. Sci. 44 022034 doi:10.1088/1755-1315/44/2/022034
[13] Khayrutdinov M et al 2020 Planetary technology. prerequisites for the formation of a new scientific discipline Gornaya Promyshlennost 3 pp 113–120 doi:10.30686/1609-91922020-3-113-120
[14] Gugunskiy D et al 2020 Legal models for activities on the exploration and utilization of space resources: towards the «Space-2030» Agenda Advances in Intelligent Systems and Computing 1100 pp 657-664 doi:10.1007/978-3-030-39319-9_73
[15] Khayrutdinov A 2020 Current issues of mining activities on celestial bodies: International law aspects Advances in the Astronautical Sciences 170 pp 895–902
[16] Kawalec J and Warchal T 2015 Dynamic replacement columns with aggregate transition zone stabilized by geosynthetics for embankment foundation over weak deposits Geotechnical Engineering for Infrastructure and Development - Proceedings of the XVI European
Kulikova E and Ivanikov A 2020 The terms of soils removal from the defects of the underground structures’ lining J. Phys. Conf. Series 1425 012062 doi.org/10.1088/1742-6596/1425/1/012062
[35] Albagachiev A et al 2020 Determination of rational friction temperature in lengthwise rolling
CIS Iron and Steel Review 19 pp 33-36 doi:10.17580/cisirs.2020.01.07

[36] Kobelev O et al 2009 Effective production of large pipe blanks Steel in Translation 39 (6)
pp 501-505 doi:10.3103/S0967091209060163

[37] Pimenov G et al 1991 Making of large-sized solid-forged blanks Tyazheloe Mashinostroenie 9
pp 21-24

[38] Kobelev O et al 1998 Analysis of the electrocapillary curves and adsorption process models in
copper || Boron + Aluminium oxide melt Zeitschrift fur Physikalische Chemie 203 pp 143-
158 doi:10.1524/zpch.1998.203.Part_1_2.143

[39] Kobelev O et al 1995 Electrocapillary curve of copper in boroaluminate melt Rasplavy 1 pp 39-
45