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USE OF BUILDING MATERIALS FROM WASTE FOR THE MANUFACTURE OF A SARCOPHAGUS AND CARRYING OUT REPAIR AND CONSTRUCTION WORKS IN THE EXCLUSION ZONE

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Abstract. ***Problem statement.*** Industrial waste can often become the main raw material for the manufacture of building materials for special purposes. The use of such waste is the key to preserving ecosystems and reducing funding for repair and construction work at the Chernobyl NPP. ***The purpose of the work:*** determination of quality characteristics, in particular frost resistance and water absorption, of samples of building materials from sewage sludge at urban treatment plants and recycled polypropylene, determination of the main stages of raw material preparation and manufacturing of building products. ***Methodology.*** The work used methods of mathematical data processing to determine the optimal composition of sewage sludge and polypropylene in raw material mixtures for the manufacture of special-purpose building blocks. ***Scientific novelty.*** The work proposes non-traditional raw material components for the manufacture of building blocks, their ratio is evaluated to ensure the highest frost resistance and optimal water absorption indicators. It was established that the experimental samples of the blocks, according to the results of the tests, are not inferior in these parameters to other analogues produced from traditional raw materials. ***Practical value.*** The use of waste significantly reduces the cost of repair and construction work and allows you to reduce and then carry out remediation work in the territories of their traditional location – silt maps. ***Results.*** For the implementation of the specified technologies, raw material costs have been calculated, heat costs, temperatures, heating time of raw material mixtures, and cooling time of construction products have been determined. The optimal ratios of sewage sludge to polypropylene are 65–70 % (mass fraction): 35–30 % (mass fraction), which provides the highest frost resistance and optimal water absorption.

Keywords: *civil protection; life safety; waste; recyclable materials; building materials; frost resistance; water absorption; polypropylene*

ВИКОРИСТАННЯ БУДІВЕЛЬНИХ МАТЕРІАЛІВ ІЗ ВІДХОДІВ ДЛЯ ВИГОТОВЛЕННЯ САРКОФАГУ ТА ПРОВЕДЕННЯ РЕМОНТНО-БУДІВЕЛЬНИХ РОБІТ В ЗОНІ ВІДЧУЖЕННЯ

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Анотація. ***Постановка проблеми.*** Відходи промислових виробництв часто можуть стати основною сировиною для виготовлення будівельних матеріалів спеціального призначення. Використання таких відходів є запорукою збереження екосистем та зниження фінансування для проведення ремонтно-будівельних робіт на ЧАЕС. ***Мета роботи:*** визначення якісних характеристик, зокрема морозостійкості та водопоглинання, зразків будівельних матеріалів із осадів стічних вод на міських очисних спорудах та вторинного поліпропілену, визначення основних етапів підготовки сировини та виготовлення будівельної продукції. ***Методика.*** В роботі використовувались методи математичної обробки даних для визначення оптимального складу осадів стічних вод та поліпропілену у сировинних сумішах для виготовлення будівельних блоків спеціального призначення. ***Наукова новизна.*** В роботі пропонуються нетрадиційні сировинні компоненти для виготовлення будівельних блоків, проводиться оцінка їх співвідношення для забезпечення найвищих показників морозостійкості та оптимальних показників водопоглинання. Встановлено, що експериментальні зразки блоків за результатами перевірок не поступаються за вказаними параметрами іншим аналогам, що виробляються із традиційної сировини. ***Практична значимість.*** Використання відходів значно здешевлює проведення ремонтно-будівельних робіт та дозволяє зменшити, а потім провести роботи з ремедіації на територіях їх традиційного розміщення – мулових картах. ***Результати.*** Для впровадження вказаних технологій розраховані сировинні витрати, визначені витрати теплоти, температури, час нагрівання сировинних сумішей, час охолодження будівельних виробів. Оптимальними співвідношеннями осадів стічних вод до поліпропілену є 65–70 % (масова частка): 35–30 % (масова частка), що забезпечує найвищі показники морозостійкості та оптимальні показники водопоглинання.

Ключові слова: *цивільний захист; безпека життєдіяльності; відходи; вторинні ресурси; будівельні матеріали; морозостійкість; водопоглинання; поліпропілен*

Problem statement. The Chernobyl disaster, unfortunately, had a large-scale impact on the environment. And even today, work continues on monitoring and implementing measures to protect the territories in the area of influence of the destroyed reactor. A sarcophagus is built above the reactor, which serves as a protective structure and protects the environment from radiation. At the same time, when the service life of the sarcophagus will have passed, the structure needs to be replaced and related construction and restoration work.

In addition, in the modern world, due to the needs of mankind, the production and consumption of plastic products is constantly increasing, which leads to the formation of large volumes of non-degradable waste. Most plastic containers and products in our country are taken to landfills that occupy large areas.

It should be borne in mind that today there are technologies for the processing of plastic waste and its reuse in the production of containers or other plastic products. Technologies for the disposal of plastic in the production of building materials are developing.

The use of waste for construction and restoration works under the conditions of their high-quality monitoring solves several important problems, namely, it reduces the cost of construction work, ensures the safety of the territory that has undergone significant radiation exposure, and creates prerequisites for waste disposal.

Analysis of publications. A huge number of world scientific periodicals still cover the problem of the Chernobyl disaster. In particular, in the articles [1–3] the problems of contamination of territories and ecosystems are investigated. In the articles [4–5] the information about the construction of a sarcophagus over the reactor that exploded is given.

A decrease in funding for construction and repair work in the Chernobyl NPP zone and replacement of the sarcophagus at the end of its service life will be facilitated by a decrease in the price of building materials, which can be

ensured by the use of waste as raw materials in the manufacture of building materials. The authors consider the possibility of using secondary thermoplastic and sewage treatment sludge to obtain building materials for special use.

The articles [6–7] provides information on the use of plastic in the construction industry. Trending research on using of post-consumer plastics in the production of wood-plastic composites for building components are shown in the article [8].

In the articles [9–10] The possibility of using thermoplastic and wastewater treatment waste to produce building blocks is shown.

Purpose of the work. The main purpose of the work was to determine the quality characteristics, in particular frost resistance and water absorption, of samples of building materials from sewage sludge and secondary polypropylene, to determine the main stages of raw material preparation and production of construction products.

Methodology. The work used methods of mathematical data processing: the values of frost resistance and water absorption for samples of building blocks with different ratios of raw materials were evaluated and compared. The optimal composition of sewage sludge and polypropylene in raw material mixtures for the manufacture of special-purpose building blocks was determined.

Results. In the course of research, the possibility of obtaining building materials from sewage sludge was confirmed, as well as the technology for their manufacture was developed.

Polypropylene (PP) is used to bind fine precipitates. PP waste is purchased from the enterprises that generate it.

Technologies for the manufacture of plastic and concrete blocks are based on the property of molten PP to melt at relatively low temperatures and quickly solidify when these temperatures decrease. When heated and mixed, small fractions of sewage sludge combine with molten masses of PP. Depending on the ratio of sewage sludge and PP waste, paste-like suspensions are formed, from which plastic blocks or artificial crushed stone are formed, which, when cooled, is used as an aggregate in the formation of blocks.

The process of manufacturing building materials using sewage sludge and PP waste includes the preparation of raw materials, mixing of raw materials in the required ratios, thermal heating of mixtures – at this stage, artificial crushed stone or a viscous mixture is produced for the formation of blocks, the formation of blocks.

When PP is heated above the melting point, volatile products of thermo-oxidative destruction may be released into the air. Therefore, it is important to strictly observe the temperature regime during the experiment and when providing production work.

For technologies of the manufacture of building blocks (concrete), preliminary mechanical dewatering of sewage sludge is provided, if they have not been previously dehydrated on silt maps or in another way, which is aimed at reducing energy costs during thermal heating of sludge. Sewage sludge generated at sewage treatment plants has a high humidity: 95–99 %. Their use under such conditions requires high energy costs for water evaporation, therefore it is economically unprofitable.

Today, wastewater treatment plants are actively implementing sludge dewatering methods. The most popular and economically justified among them are mechanical methods.

The most efficient equipment in this case is filter presses and centrifuges. However, centrifuges are more energy-intensive compared to filter presses. Therefore, the latter are recommended for use.

Grinding of PP during the experiment was carried out manually. The dependence of the heating time of raw material mixtures on the size of crushed polyethylene particles was checked.

During the experiment, PP was crushed to a particle size of 2, 4, 6, 8, 10, 12, 14, 16, 18, 20 mm.

Mixing sewage sludge and plastic before they are heated is aimed at increasing the area of contact of interacting substances and helps to improve the binding process.

The building blocks are formed by vibropressing in a vibropress.

The dependencies of frost resistance and water absorption of building materials on the mass fraction of sewage sludge in the raw material mixture are shown in Fig. 1, 2. The consequence of heat treatment of sewage sludge will be the destruction of pathogenic microorganisms, in particular, bacteria of the Escherichia coli group, contained in freshly formed sewage sludge.

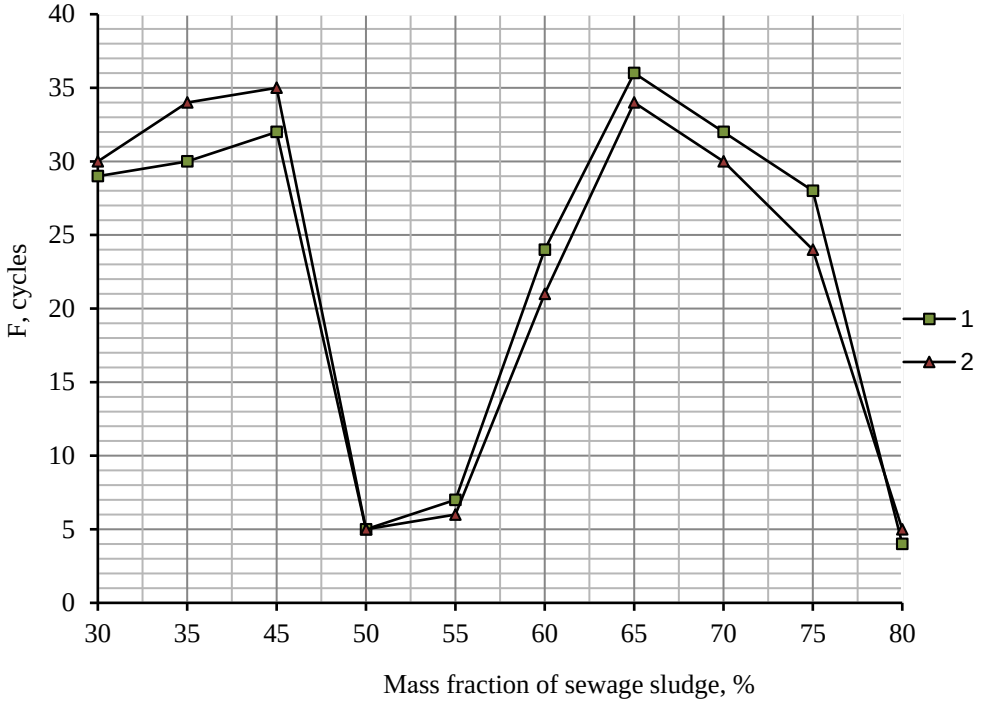

Fig. 1. Dependencies of frost resistance of building materials on the mass fraction of urban wastewater sludge in the raw material mixture: 1 – sewage sludge dehydrated 5–10 years ago; 2 – sewage sludge dehydrated 10–15 years ago

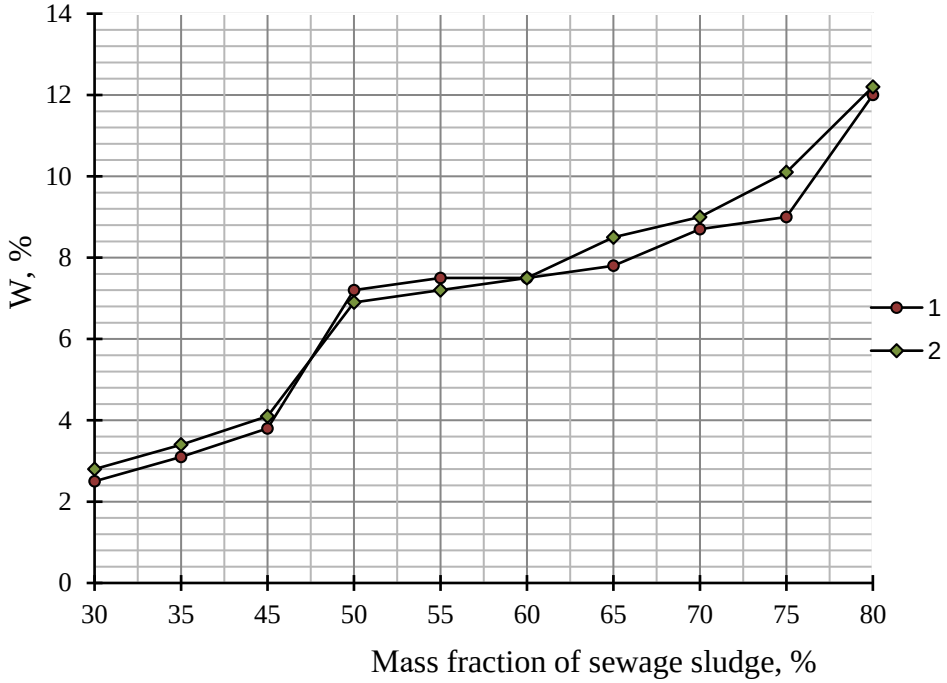

Fig. 2. Dependencies of water absorption of building materials on the mass fraction of urban wastewater sludge in the raw material mixture: 1 – sewage sludge dehydrated 5–10 years ago; 2 – sewage sludge dehydrated 10–15 years ago

The frost resistance of blocks with a mass fraction of sediments of 35–45 % in the raw material mixture is about 30 cycles. With an increase in the proportion of sewage sludge in the raw material mixture, brittle pebbles are formed, which have low strength, which causes a sharp decrease in the frost resistance of products.

With a further increase in the mass fraction of sediments and reaching 65–70 %, frost-resistant crushed stone is formed. A more detailed description of the dependence of the frost resistance of crushed stone on the mass fraction of sewage sludge in the raw material mixture is given in Figure 1.

A microbiological analysis of sewage sludge was carried out with the determination of the LCP and ZMC indices and a significant excess of the norm for the content of Escherichia coli bacteria in the freshly formed sewage sludge was revealed.

Considering that metals and some chemical compounds are contained in sewage sludge in concentrations higher than the regulated normative values for the content of these substances in soils, there is a danger of their entering the soil and groundwater, since contaminated sludge is in direct contact with the soil, which necessitates the development of a technology for the disposal of these wastes.

Table 1

Main characteristics of building blocks

Name of indicators	Characteristics of building blocks
Color	Black or other when chemical dyes are added
Density, kg/m^3	1 100–1 500
Strength, kg/cm^2	50–100
Frost resistance	F25– F50

For the implementation of these technologies, raw material costs have been calculated, heat costs, temperatures, heating time of raw material mixtures, and cooling time of construction products have been determined.

Table 1 shows the main characteristics of building blocks from sewage sludge and PP.

Table 2

Dimensions and weight of building blocks

Name of indicators	Characteristics of building blocks
Nominal dimensions, mm	390:190:188
by length	+–3
by width	+–3
by thickness	+–4
product weight, no more than, kg	20
deviation of the ribs from straightness and edges from flatness, no more than, mm	+–3
deviation of the side and end faces from perpendicularity, no more than, mm	+–2

The dimensions and mass of building blocks are shown in Table 2.

Conclusions

For the manufacture of blocks with sufficient strength, frost resistance and low water absorption, it is necessary to use a raw material mixture with a mass fraction of wastewater sludge of 35–45 %. For the implementation of these technologies, raw material costs are calculated, heat and temperature costs, heating time of raw material mixtures, cooling time of building products are determined. It has been determined that the experimentally produced samples of blocks according to the results of practical tests are not inferior in frost resistance and water absorption to other analogues produced from traditional raw materials. They are recommended to be used in construction, restoration and construction work in order to ensure safety in the exclusion zone.

REFERENCES

1. Talerko N. Reconstruction of 131I radioactive contamination in Ukraine caused by the Chernobyl accident using atmospheric transport modelling. Journal of Environmental Radioactivity. 2005, vol. 84 (3), pp. 343–362. URL: https://doi.org/10.1016/j.jenvrad.2005.04.005

2. Talerko N. Mesoscale modelling of radioactive contamination formation in Ukraine caused by the Chernobyl accident. Journal of Environmental Radioactivity. 2005, vol. 78 (3), pp. 311–329. URL: https://doi.org/10.1016/j.jenvrad.2004.04.008

3. Beresford N.A., Fesenko S., Konoplev A., Skuterud L., Smith J.T. and Voigt G. Thirty years after the Chernobyl accident : What lessons have we learnt? Journal of Environmental Radioactivity. 2016, vol. 157, pp. 77–89. URL: https://doi.org/10.1016/j.jenvrad.2016.02.003

4. Chernobyl : From Accident to Sarcophagus. Producing Power. Pp. 136–169. URL: https://doi.org/10.7551/mitpress/9229.003.0009

5. Pretzsch G., L'Homme V., Seleznev A.N. and Seredynin E.S. The Chernobyl Sarcophagus Project of the German-French Initiative. Role of GIS in Lifting the Cloud Off Chernobyl. 2002, pp. 85–95. URL: https://doi.org/10.1007/978-94-010-0518-0_7

6. Agarwal S. and Gupta R.K. Plastics in Buildings and Construction. Applied Plastics Engineering Handbook. 2017, pp. 635–649. URL: https://doi.org/10.1016/b978-0-323-39040-8.00030-4

7. Acuña-Pizano H., González-Trevizo M.E., Luna-León A., Martínez-Torres K.E. and Fernández-Melchor F. Plastic composites as sustainable building materials : a thermal and mechanical exploration. Construction and Building Materials. 2022, vol. 344, pp. 128083. URL: https://doi.org/10.1016/j.conbuildmat.2022.128083

8. Ribeiro L.S., Stolz C.M., Amario M., da Silva A.L.N. and Haddad A.N. Use of Post-Consumer Plastics in the Production of Wood-Plastic Composites for Building Components : a systematic review. Energies. 2023, vol. 16 (18), pp. 6549. URL: https://doi.org/10.3390/en16186549

9. Levytska O., Dolzhenkova O., Sichevyi O. and Dorhanova L. Masonry Unit Manufacturing Technology Using Polymeric Binder. Chemistry & Chemical Technology. 2020, vol. 14 (1), pp. 88–92. URL: https://doi.org/10.23939/chcht14.01.088

10. Levytska O., Trus I., Gomelya M. and Alekseyenko S. Technology of Utilization of Polypropylene Waste and Wastewater Sediments by Production of Building Blocks. Ecological Engineering. Environmental Technology. 2022, vol. 23 (2), pp. 50–59. URL: https://doi.org/10.12912/27197050/144995

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