

INDUSTRIAL WASTE MANAGEMENT APPLICATIONS FOR HEAVY-WEIGHT CONCRETE PREPARATION

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Анотація

Розглянуто сучасні напрями використання промислових відходів у виробництві важких бетонів. Проаналізовано можливість застосування золошлакових матеріалів, золи-виносу теплових електростанцій, металургійних шлаків та інших техногенних ресурсів як мінеральних добавок і заповнювачів. Обґрунтовано їхній вплив на фізико-механічні властивості бетону, структуру цементного каменю та довговічність конструкцій. Показано економічну та екологічну доцільність часткової заміни традиційної сировини промисловими відходами.

Ключові слова: важкий бетон, промислові відходи, зола-винос, золошлакові матеріали, активна мінеральна добавка, шлак, цемент, структура бетону.

Abstract

Modern directions for the use of industrial waste in the production of heavy concretes are considered. The possibility of using ash and slag materials, fly ash from thermal power plants, metallurgical slags, and other technogenic resources as mineral additives and aggregates is analyzed. Their influence on the physical and mechanical properties of concrete, the structure of the cement stone, and the durability of structures is substantiated. The economic and environmental feasibility of partially replacing traditional raw materials with industrial waste is demonstrated.

Keywords: heavy concrete, industrial waste, fly ash, ash and slag materials, active mineral additive, slag, cement, concrete structure.

Introduction

One of the priority directions for the development of modern construction materials science is resource conservation and the incorporation of secondary raw materials into the production of heavy-weight concrete. Significant volumes of industrial waste accumulating in Ukraine create an ecological burden and require rational utilization. Every year, billions of tons of secondary materials accumulate in landfills, a significant portion of which can be used in construction [1]. Incorporating waste from the energy, metallurgical, and chemical industries allows not only for a reduction in the volume of construction waste but also for cutting the consumption of natural resources and energy in the production of heavy-weight concrete. According to research, the use of secondary resources makes it possible to reduce the cost of construction materials by 10-30% compared to their production from natural raw materials [1–3].

For heavy-weight concrete, this issue is particularly relevant, as its production is associated with significant consumption of cement and natural aggregates. Therefore, research into directions for utilizing industrial waste within the composition of heavy-weight concrete is scientifically and practically justified.

Research results

Heavy-weight concrete is characterized by an average density exceeding 2200 kg/m³ and is used in critical load-bearing structures. Its main components are cement, coarse and fine aggregates, and water. Partial replacement of individual components with technogenic materials allows for the modification of the concrete structure and the improvement of its operational properties.

One of the most common waste products is fly ash from thermal power plants. It can be used as an active mineral additive or as a finely dispersed aggregate. The use of fly ash in cement systems facilitates the formation of additional calcium hydrosilicates due to the pozzolanic reaction, which increases the density and durability of the concrete [5–9].

Replacing a portion of cement with fly ash leads to a reduction in shrinkage deformations due to the decreased water demand of the concrete mixture. By sorbing soluble alkalis from hydrated cement, fly ash participates in the formation of stable, water-insoluble hydroaluminosilicates [5-7]. Using fly ash as an active mineral additive helps increase the chemical resistance of cement concretes. A moderate content of fly ash in the mixture increases the water tightness of the concrete, which is due to the hydraulic properties of the fly

ash, the improvement of the particle size distribution of the concrete mixture, and the reduction of the open porosity of the concrete.

The physical and mechanical properties of fly ash are as follows: a) hydraulic activity $R_{st} = 0,4$ MPa; b) bulk density $p_{nZA} = 1150$ kg/m³; true density $p_{ZA} = 1,95$ g/cm³; specific surface area $S_{spec} = 2000...3000$ cm²/g. The chemical composition of the fly ash from the Ladyzhyn Thermal Power Plant is presented in (Table 1) [12].

Oxides	SiO ₂	TiO ₂	Al ₂ O ₂	FeO	MgO	MnO	CaO	Na ₂ O	K ₂ O	SO ₃	P ₂ O ₅
Mass fraction of oxides, % according to data	55,3	1,4	22,34	5,42	2,52	0,12	5,96	0,75	2,46	0,38	0,33

Table 1. Chemical composition of fly ash from the Ladyzhyn Thermal Power Plant

Table 1 indicates that the chemical composition meets the primary requirements for fly ash used in heavy-weight concrete.

Research shows that the inclusion of fly ash at 10-20% of the binder mass allows not only for a reduction in the consumption of expensive Portland cement but also for achieving concrete with the required strength characteristics through the optimization of the particle size distribution and densification of the structure [10]. It has been established that mechanical and chemical activation of fly ash significantly increases its reactivity and intensifies the structure-formation processes of heavy-weight concrete. This is due to the destruction of the inert vitreous shell of the ash particles, which opens access to the internal active phases and enhances the micro-filling effect in the concrete structure [6].

Another promising direction is the use of metallurgical slags as aggregates or components of binder systems. Metallurgical slags are characterized by sufficient strength, wear resistance, and composition stability. With a rational selection of the particle size distribution, they can partially replace natural crushed stone in heavy-weight concrete, ensuring the required strength and durability indicators [7].

The use of complex active mineral additives based on industrial waste allows for a denser microstructure of the cement stone. Studies have established that combining fly ash with alkaline or aluminoferrite components facilitates the intensification of hydration processes and the formation of additional crystal hydrates [3-5].

Thus, industrial waste in the composition of heavy-weight concrete can perform several functions: as an active mineral additive, a micro-filler, and a partial aggregate substitute. Its application allows for the regulation of the material's structure, density, strength, and durability.

The environmental component is also an important aspect. Reducing the extraction volumes of natural aggregates and cutting CO₂ emissions aligns with modern principles of sustainable development. The rational use of technogenic resources contributes to the formation of closed-loop technological cycles in the construction industry.

Conclusions

Therefore, the conducted analysis confirms that the use of industrial waste in the production of heavy-weight concrete is a technically justified, economically viable, and ecologically necessary direction for the development of modern heavy-weight concrete preparation. The incorporation of thermal power plant fly ash as an active mineral additive ensures the densification of the heavy-weight concrete structure, increased water tightness, corrosion resistance, and durability, while also allowing for a reduction in Portland cement consumption without a loss of strength. Metallurgical slags and other technogenic materials can be effectively used as alternative aggregates, providing the necessary physical and mechanical indicators for heavy-weight concrete. Complex mechanical or chemical activation of waste intensifies hydration processes and contributes to the formation of a denser and more stable microstructure. Thus, the rational use of industrial waste allows for the simultaneous reduction of the cost of heavy-weight concrete, a decrease in the consumption of natural resources, and a reduction in the environmental burden, which aligns with the principles of resource conservation and the sustainable development of the construction industry.

REFERENCES

1. Serdiuk V. R. Fly ash as an important raw material resource for the production of cellular concrete / V. R. Serdiuk, B. I. Avgustovych // Modern technologies, materials and structures in construction. - 2013. - No. 2. - P. 22-28.
2. Ocheretnyi V. P. Small-piece wall materials using industrial waste / V. P. Ocheretnyi, V. P. Kovalskyi // Bulletin of Vinnytsia Polytechnic Institute. - 2005. - No. 1. - P. 16-21.
3. Ocheretnyi V. P., Kovalskyi V. P., Mashnytskyi M. P. Complex active mineral additive based on industrial waste // Concrete and reinforced concrete in Ukraine. - 2008. - No. 1(41). - P. 6-9.
4. Kovalskyi V. P., Bondar A. V., Varchuk R. V., Burlakov V. P. Modified dry construction mixture based on perlite aggregate // Modern technologies, materials and structures in construction. - 2017. - Vol. 22, No. 1. - P. 17-20.
5. Kovalskyi V. P., Ocheretnyi V. P. Complex ash-cement binder modified with an alkaline aluminoferrite additive: monograph. - Vinnytsia : VNTU, 2010. - 98 p.
6. Kovalskyi V. P., Sidlak O. S. Methods of activating TPP fly ash // Bulletin of Sumy National Agrarian University. - 2014. - No. 10(18). - P. 47-49.
7. Dvorkin L. I., Pashkov I. A. Building materials from industrial waste. - Kyiv: Vyshcha shkola, 1989. - 208 p.
8. Popov S. V. Fine-grained dense concrete with special properties using aggregates from TPP ash and slag materials of Donbas: abstract of thesis. - Makiivka, 2003. - 20 p.
9. Kovalskyi V. P., Sidlak O. S. Use of TPP fly ash in building materials // Modern technologies, materials and structures in construction. - 2014. - No. 1. - P. 35-40.
10. Serdiuk V. R., Lemeshev M. S., Khrystych O. V. Ash-cement binder for the production of cellular concrete // Modern technologies, materials and structures in construction. - 2011. - No. 1(10). - P. 57-61.
11. Lemeshev M. S., Khrystych O. V., Bereziuk O. V. Complex processing of technogenic waste from the chemical industry and metalworking production // Materials of the XI International Scientific and Practical Conference. - 2015. - P. 60-62.
12. Dvorkin L. I., Dvorkin O. L., Korneichuk Yu. A. Effective cement-ash concrete. - Rivne, 1998. - 196 p.

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