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Improving efficiency of polystyrene concrete production with composite binders

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Improving efficiency of polystyrene concrete production with composite binders

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Abstract. According to leading marketing researchers, the construction market in Russia and CIS will continue growing at a rapid rate; this applies not only to a large-scale major construction, but to a construction of single-family houses and small-scale industrial facilities as well. Due to this, there are increased requirements for heat insulation of the building enclosures and a significant demand for efficient walling materials with high thermal performance. All these developments led to higher requirements imposed on the equipment that produces such materials.

1. Introduction

Due to increased requirements for heat insulation of the building enclosures, there is a significantly increased demand for efficient walling materials with high thermal performance.

Currently, there is a special need for new solutions of issues in thermal protection of buildings and structures in accordance with the modern requirements imposed by current construction regulations. Due to this, there is a demand for new structural and thermal insulating building materials and products meeting such requirements, technologically simple and satisfying the conditions of economic efficiency [1-3].

2. Materials and methods

The material was prepared using composite binders and cement as a binder and polystyrene foam balls ranging in size from 2 to 5 mm (the density of 15 kg/m^3) as a lightweight aggregate. The polystyrene foam grains have a functional envelope consisting of polyvinyl acetate resin, being formed at the surface of the polystyrene foam grain. The polystyrene foam is produced from suspension polystyrene, in its finished form it is a solid thermoplastic foam consisting of fused grains.

The strength characteristics of the tested composition were determined on cubic samples 10x10x10 cm. Removal of the formwork was performed after 24 hours; then, the samples were stored at a temperature of 20°C and relative humidity of 60% until the testing. When the samples had reached the age of 7 and 28 days, tests were performed with the laboratory test press IP-500 at a loading rate of 0.1 MPa/sec. Heat conductivity was determined with a dedicated heat conductivity meter ITS-1. The ITS-1 instrument consists of an electronics unit and a heat-measuring unit integrated in one housing. The instrument is intended to operate at an ambient temperature ranging from +10 to +35°C.

3. The results of the research

Polystyrene concrete is a concrete where grains of expanded polystyrene serve as aggregate. By its properties, polystyrene concrete is a light concrete; however, it has a number of significant distinguishing features. Among its advantages, there is a possibility to vary its density over a wide range; as a result, polystyrene concrete may serve as both heat insulating and structural materials.

Currently, low density polystyrene concrete is used in Western Europe in freeze-proof foundation for railroads, in production of walling panels, roofing heat insulation, for warm foundations in buildings for livestock. In Germany, this material, under the name of Radipor, is successfully replacing mineral wool boards and other less efficient heat insulation materials.

It seems feasible that the polystyrene concrete may be used in production of window headers and attic floor slabs. It is a prospective material for production of large-scale wall slabs.

It is known that this type of concrete has a specific set of strength and deformation properties. Developing and putting into production the structural polystyrene concrete on the basis of technogenic aggregates as a material for load-bearing reinforced concrete structures have an important environmental significance.

A substantial increase in production of polystyrene concrete products requires deeper and more thorough studies of properties of this «new» building material [4, 5]. New studies will allow specifying rational areas of application for the efficient polystyrene concrete structures, increasing their quality and durability.

Nowadays, development of the construction industry at a rapid rate made raw material shortage for building materials production a current issue. Due to this, a timely task for the construction industry is to turning its attention to the use of anthropogenic feed. Among those, by-products of the mining industry, in particular those of wet magnetic separation (WMS), produced during ore benefication have the largest capacity by volume. Studies of WMS composition and properties, as well as comparative studies involving other anthropogenic sands currently applied in building material production have shown that it is possible to use this feed as a component of a composite binder, allowing reducing consumption of the binder (being the most energy-intensive and costly component) without loosing any strength of the final product [6-8].

Recycling of industrial wastes that are accumulated in dumps and cover vast areas, increasing the anthropogenic load on the environment, is a current task for the modern material science. Building material production industry plays a special role in this issue because nowadays it is the only branch capable of widespread and efficient use of industrial waste, resolving the resource conservation issues in construction and protecting the environment at the same time.

WMS waste from this deposit has a specific composition and properties due to its genesis, production technology and ore treatment technology.

They appear as an anthropogenic fine-dispersed sand, dark-gray in color with the apparent density of 1545 kg/m^3 and the fineness modulus of 0.75; at that, the most prominent fraction is 0.14 and less.

The mineral composition of the WMS waste significantly differs from that of quartz sand, which is traditionally used in building material production; it is largely represented by olivine, dolomite, calcite and biotite (Table 1). At that, in comparison with WMS waste from other deposits, ones from Kovdor are characterized by lower silica content and higher magnesia content.

Table 1. Mineral composition of the WMS waste

Fractional makeup	Weight ration of a mineral, %wt			
	Olivine	Calcite	Dolomite	Biotite
WMS waste	48.4	25.8	16.0	9.8
Fraction 0.63–0.14	31.9	44.2	13.5	10.4
Fraction less than 0,14	31.2	28.6	20.7	19.5

To obtain polystyrene foam with high performance characteristics, to reduce the clinker content and to optimize the structure formation processes, it is desirable to use highly active composite binders

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to facilitate a uniform structure of material. Use of anthropogenic feed, such as BIF WMS waste, for production of such binders and as an aggregate allows significantly reducing the cost of the polystyrene concrete.

Nowadays, production of a new generation of highly efficient binders is accompanied by adding complexity to their composition. The following binder compositions were obtained: fine-milled cement and composite binders, consisting of cement and CB additives, using BIF WMS waste as a silica-containing component. CEM I 42,5N cement, produced by Belgorodsky Tsement CJSC (Belgorod) was selected as a base for production of such binders. The composite binder was obtained by finish milling of the portland cement together with Polyplast-PREMIUM, a plasticizing additive, until reaching specific surface of 600 m^2/kg.

Table 2. Physical and mechanical properties of the composite binders

Binder's name	Specific surface, m^2/kg	Initial setting, hours	Final setting, hours	Activity	
				when bending, MPa	when comparing, MPa
CEM I 42,5N	320	2.30	3.30	7.8	51.3
TMTs – 100	600	2.15	3.15	15.2	67.4
KV-100	600	1.50	2.50	18.1	78.9
KV-80 (MMS)	600	2.05	3.00	10.9	56.9

The research and analysis of the data have shown that the composite binders with the WMS waste aggregate have high strength characteristics, comparable to those of portland cement.

The structure of the cement stone of the composite binders is denser and less porous in comparison to the regular cement stone. During the initial hydration, additive particles of the aggregate-infused composite binders adsorb significant volumes of water, thus lowering the water/binder ratio; it leads to activation of the structure formation processes and synthesis of finer calcium hydrosilicate crystals, which is undoubtedly reflected in optimization of the cement stone's microstructure in comparison to the control samples.

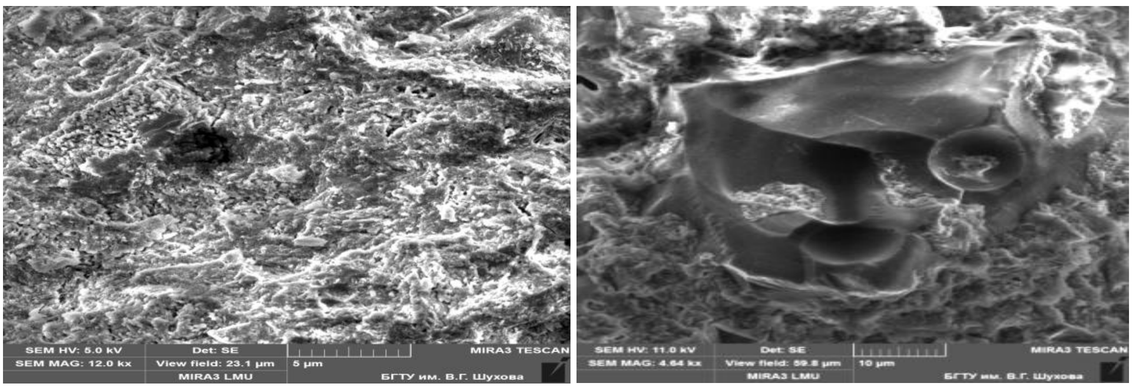

Figure 1: The microstructure of the composite binder cement stone: on the left - CB – 80 (WMS), on the right - CB – 100.

It was found out that the optimization of the structure formation processes in the composite binders proceeds by sequential new growths during the hardening of the «clinkers – aggregate – water – superplasticizer» system, determined by different intensity and reaction time of the aggregate particles with the clinker hydration product due to genesis and surface morphology of the particles.

To evaluate applicability of the composite binders, several polystyrene concrete compositions were developed and their properties studied. The analysis of the results has shown positive influence of the composite binders onto compressive strength and other properties.

Table 3. Physical and mechanical characteristics of the polystyrene concrete

Type of binder	Composition, kg/m^3				Density of concrete, kg/m^3	R_{av}, MPa	Heat conductivity coefficient W/m°C
	Binder, kg/m^3	Polystyrene, m^3	Water, l/m^3	Additive, kg/m^3			
CEM I 42,5N	150	1	100	0.8	200	0.21	0.058
KV-80 (MMS)	140	1.1	90	0.8	190	0.33	0.054
TMTs-100	110	1.3	95	0.8	170	0.37	0.045
KV-100	90	1.5	85	-	150	0.49	0.039

4. Conclusion

The polystyrene concrete compositions, which were developed on the basis of composite binders produced from fine-milled mineral components, binder and additives, are characterized with the compressive strength higher than that of compositions using traditional aggregate, while the consumption of the costly cement component is lower.

5. Acknowledgments

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