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Energy-Efficient Concretes for Green Construction

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Abstract: Using of recent development in construction materials science, invention of green composite materials containing natural eco-friendly technogenic raw materials are desirable for reduction of energy consumption of environmentally friendly construction. One of these materials is energy-efficient non-autoclaved aerated concrete on composite cementing materials with crush off-corn of quartzitic sandstone.

Key words: Energy-efficient concretes, green construction, aerated concrete, composite cementing material, crush off-corn of quartzitic sandstone

INTRODUCTION

Economy of fuel and energy resources, improvement of the effectiveness of thermal protection of buildings and constructions, implementation of energy-effective materials and technologies are top-priority direction in development of Russian and world building industry.

Energy efficiency of buildings at the present time is one of important problems in environmental conservation and reduction of energy consumption. Trend of preliminary optimization of energy consumption in design of energy-efficient materials and construction of buildings with using of these materials is picking up now. One of these materials is aerated concrete which has high technical-and-economic efficiency proven by production and application history (Homann, 2010; Weber and Hullmann, 2002; Sakharov, 2010; Suleymanova, 2013).

For improvement of the effectiveness of "Man material life environment" system cooperation the transition to eco-friendly construction is of great current interest. Using of last development in building materials science, invention of green composite materials containing natural eco-friendly technogenic raw materials are desirable for reduction of energy consumption of green construction (Lesovik, 2013).

MAIN POINTS

"Green standards" are the approach to construction and exploitation of buildings that aims minimization of energy and natural resources consumption level through the whole service life of the building from design to demolition. Also they aim comfort improvement of room indoor environment and ecological safety for humans and nature.

The best known national systems of green standards in the world are BREEAM (United Kingdom) and LEED (USA). The "Green standards" voluntary certification system of items of immovable property became the first complex national green standard in Russia. The International Organization for Standardization (ISO) developed the new rigorous international standard ISO 50001 Energy management systems (GOST, 2012). In this connection, problems of energy saving, search and realization of energy-efficient technologies are top-priority and mean using of modern building materials in green construction, one of which is aerated concrete.

Aerated concrete is virtually all-purpose in construction. It is both constructional and heat insulation material which allows making of external walls that meet all normative requirements in thermal protection of buildings and constructions without use of additional heat insulation. Aerated concrete has the unique thermophysical properties that allows its widespread use for heat insulation of building envelope and eliminates main disadvantages common to heat insulation multilayer systems based on mineral and polystyrene products. Furthermore, monolithic building envelope made of non-autoclaved aerated concrete are free of disadvantages of small piece products based on this material and allow to exclude cold joints, significantly

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reduce shipping charges, period and cost of construction. Heat insulation of house foundation allows not only to save heat but also to extend the life of the whole building due to its high performance properties.

Efficiency of aerated concrete consists not only in reduction of heat losses during the building exploitation but also in economy in calculation of costs of wall construction which meet up-to-date requirements in thermal protection of buildings and constructions. It is important that aerated concrete is ecologically friendly building material which doesn't emit any toxic materials and harmful gases.

Furthermore, solutions of the problems of energy-efficient manufacture of aerated concrete products and their use in construction of buildings with improved thermal protection are interrelated. The less average density of output product the fewer raw materials are used for mix preparation and less power consumption is required on production stages. On the other side, products having lesser average density but sufficient level of strength class provide higher energy efficiency of enclosure. However, trend of wall materials average density reduction is not a propositional function of efficiency of bearing and enclosing structures. That's why structural and heat insulating elements with average density for example, D300 in carrying walls and other building parts are necessarily to be considered with account of not only thermal protection but also other important characteristics which determine carrying force and durability of constructions. Evolvable approach of energy efficiency of production and use of aerated concrete will allow educing of energy saving reserves as well as expanding of raw material base for its production and competitive growth.

The main ways of making aerated concrete with improved structure and quality parameters for green construction include development of composite cementing materials, sand mixtures on their basis having effective viscosity and making high-porous systems with use of different manufacturing methods (Suleymanova, 2011).

Crush off-corn of quartzitic sandstone taken from Lebedinski mining and concentrating company was recommended as mineral additive in production of composite cementing materials.

Massive research was carried out; wide range of concretes and reinforced concrete constructions on basis of shaly rock masses and quartzitic sandstone was developed. There was no experience of using quartzitic sandstone in global practice before because quartzitic sandstone belongs to rocks of greenshist facies metamorphism and occurs on depth of 300-500 m and deeper. Naturally, nobody in the world mines nonmetallic feed from such depth for building materials production. Quartz of quartzitic sandstone of greenshist facies metamorphism differs essentially from quartz of sands, granites and gneiss used in building materials industry. It is established that to obtain strength properties similar to granites it needs to use by 20-25% less cement due to peculiarity of quartzitic sandstone of greenshist facies metamorphism. There is theoretically substantiated hypothesis on the fact that quartzitic sandstone would be very efficient in producing of composite cementing materials.

Crush off-corn quality coefficient of silica-containing component is significantly higher than that of sands and granites quartz. Both autoclaved and non-autoclaved aerated concretes as well as composite, nanostructured cementing materials and other materials for green construction on basis of quartzitic sandstone of greenshist facies metamorphism were made (Lesovik, 1998, 2009; Gridchin, 2002; Strokova, 2004a, b; Lesovik *et al*., 2012).

Crush off-corn of quartzitic sandstone having lattice energy accumulated in consequence of geologic and man-made impacts allow to make composite cementing materials having better grindability and efficient specific surface of 500-550 m^2/kg with initial grinding velocity U_0 = 9.13 $m^2/(kg{\cdot}min)$ and inhibition coefficient k_t = 0.0007 kg/m^2 that provides reduction of energy consumption during grinding process. And topologic estimation of granulometry of composite cementing materials containing crush off-corn of quartzitic sandstone revealed presence of recessive maxima of content of fraction m = 5 that let to refer it to high-density in terms of particles packing density.

Composite cementing materials on clinker basis with crush off-corn of quartzitic sandstone have optimized rheological properties allowing to synchronize period of intense structure formation with period of gassing during the bloating of gas-concrete mixture.

Microsized fillers in composite cementing material take an active part in process of hydration. When hardening amorphous component of composite cementing material with crush off-corn of quartzitic sandstone leads to higher rate of hydration of clinker minerals in comparison with cement.

Composite cementing materials on clinker basis with content of crush off-corn of quartzitic sandstone up to 30% having compression strength no <80 MPa were obtained due to use of energy potential of microsized fillers of different origin with multimodal distribution of particles of cementing material with adjustable rheological properties compatible with process of energy-efficient aerated concrete porous structure formation. Composite cementing materials allow to produce monolithic aerated concrete as a heat insulating material in adverse conditions.

Optimized compositions of aerated concretes on basis of composite cementing materials with crush off-corn of quartzitic sandstone for monolithic construction are defined through variation of main technology factors: water-solid ratio (X_1) ranged from 0.45-0.65, aluminium paste content (X_2) within the range from 0.4-0.8% of composite cementing material mass and microsized filler content (X_3) chalk stone from 0-20%.

Mathematical models of dependences of average density and strength of aerated concrete on basis of composite cementing material with crush off-corn of quartzitic sandstone are:

$$\rho_a = 252.46\text{-}18\cdot X_1\text{-}31\cdot X_2\text{-}22.3\cdot X_3 + 171.02\cdot X_1^2 + 136.02\cdot X_2^2 + 49.52\cdot X_3^2 + 100\cdot X_1\cdot X_2 + 25\cdot X_1\cdot X_3 + 7.5\cdot X_2\cdot X_3$$

$$R_s = 1.43\text{-}0.85\cdot X_1\text{-}0.395\cdot X_2\text{-}0.256\cdot X_3 + 0.49\cdot X_1^2 + 0.26\cdot X_2^2 + 0.066\cdot X_3^2 + 0.31\cdot X_1\cdot X_2 + 0.18\cdot X_1\cdot X_3 + 0.063\cdot X_2\cdot X_3$$

The models obtained allow to keepX output parameters on target level by variation of main technology factors in a proper way.

Aerated concrete on basis of composite cementing materials with crush off-corn of quartzitic sandstone used for monolithic construction is characterized by uniformly distributed porous structure with average pore diameter of 0.25 mm. Monolithic aerated concrete with average density of 270-300 kg/m^3 has high constructive and technical properties: compression strength is 1.5-1.7 MPa, heat conductance λ = 0.06-0.07 W/m•°C, resistance to frost is F15-35.

Monolithic gas-concrete mixture can be made of raw ingredients on the construction site but the efficient way is to use dry gas-concrete mix on the construction site. Dry gas-concrete mixes were obtained on basis of composite cementing material and complex blowing agent. Polydisperse cellular structure is fixed due to composite cementing material having accelerated hydration processes.

Non-autoclaved aerated concrete made of dry concrete mix is characterized by high physical and mechanical properties: average density grade D400, strength grade B1.5, heat conduction coefficient λ = 0.08 W/(m•°C), frost resistance grade F50 (Suleymanova *et al*., 2009).

RESULTS

On the ground of revealed regularities of porous structure formation the improved efficiency of non-autoclaved aerated concrete on basis on composite cementing materials was ascertained. That provides to produce products, monolithic aerated concrete and dry building mixes with improved properties.

Energy-efficiency measures on exterior walls heat insulation with use of non-autoclaved aerated concrete on basis of composite cementing material are low-cost and fast-payback, investment-attractive for small and medium business.

Energy-efficient non-autoclaved aerated concrete on basis of composite cementing materials with crush off-corn of quartzitic sandstone was used in construction of free-standing residential buildings in floor foundation outfitting. Also it was used as a heat-insulating material in grouted masonry.

CONCLUSION

The aggregate of presented results allowed to produce investment-attractive non-autoclaved aerated concrete on basis of composite cementing materials for green construction with non-conventional types of raw materials which are not used extensively for building materials production, occur in laid-up state in Earth crust and will become a basis of raw materials source of advanced countries of the world in course of time.

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