Use of geonics scientific positions for designing of building composites for protective (fortification) structures

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Abstract. The examples of the implementation of the geological (geomimetic) positions in construction materials science are given in the work. The wall materials obtained with this technology have a much more developed surface than traditional wall materials. The second example of using such approaches is the development of internal care systems that will create a more highly organized structure of cement stone at the macro-, micro- and nano-scale levels and concrete in general at all stages: the stage of mixing, hardening and exploitation of the material. The regularities of the structure formation processes are revealed and the principles for increasing the efficiency of non-autoclaved aerated concrete due to application of composite binders, process control in a three-phase disperse porous system and the development of technological methods for the production of protective (fortification) structures are developed.

1. Introduction
A feature of modern science, is a narrow specialization. Of course, differentiation contributes to a significant increase in the accuracy and depth of knowledge about a narrow range of phenomena and processes, but at the same time leads to a weakening of the links between individual scientific disciplines. It goes to the point that experts in narrow areas of the same science often do not understand either theories or the methods of investigating each other.

This applies to scientists involved in the problems of the military-industrial complex. In addition, the situation here is complicated by the fact that military developments, although they are the most advanced in comparison with general civilian design, have been classified in the overwhelming majority of cases, so often researchers from different organizations work on one problem, not being able to compare the results with each other. And with earlier developments (including embedded ones) [1-3].

At the same time, a number of organizations of the Russian Federation tend to unite scientific potentials and existing developments for the common good - enhancing the country's defense capability. In particular, this refers to the scientific cooperation of the Far Eastern Federal University (Vladivostok) and the Belgorod State Technological University named after V.G. Shukhov (Belgorod) in the field of creation of protective (fortification) structures of a new generation.

In particular, prof. V.S. Lesovik has developed the positions of geonics (geomimetics) - a transdisciplinary science that solves engineering problems taking into account the knowledge obtained...
in the study of geological and cosmochemical processes and the results of their activities: minerals and rocks. Collaborating to prof. V.S. Lesovik the scientific school, which includes the authors of this article, is developing a new generation of protective (fortification) structures.

2. Results and Discussion
The movement of association began in science in the industrial society from the late 30-40-ies of the 20 century. Interdisciplinary research began. New knowledge has appeared at the junction of scientific research due to the synergistic effect. This is how geophysics, geochemistry, biotechnology, and new directions in cybernetics-bionics and geonics - emerged. Interdisciplinarity is characteristic for a post-industrial society, both in science and in education. But at the present time we are already talking about transdisciplinarity in the study. In fact, we are currently investigating complex systems. The classical approaches that existed earlier cannot allow new breakthrough results [4-5].

Transdisciplinarity research is based on the large-scale use and transfer of knowledge, patterns, cognitive schemes from one discipline to another, with the emergence of emergent properties, that is, properties that are not possessed by separate links in the system or discipline, but they are a consequence of the effect of system integrity. Cybernetics is one of the first transdisciplinarity areas. Bionics and geonics are the most important areas of cybernetics.

Bionics is a science borderline between biology and technology, solving engineering problems on the basis of analysis of the structure and life activity of organisms (Fig. 1). The geonics, one of the directions of cybernetics appeared at the end of the 20th century. In particular, the geonics can use the results of a study of geological processes for the development of technologies for the production of materials.

Fig. 1. Bionics - the application in the technology of biological structures, the most perfect in fundamental relationships and the most cost-effective "material"

Mankind is currently on the threshold of a very difficult stage of its development. The beginning of the 21st century is characterized by such problems as depletion of hydrocarbon reserves, environmental degradation, lack of fresh water, activation of natural and man-made disasters. Over the past 20 years, the number of natural processes disastrous in consequences has increased 4-fold, the number of floods 6-fold, the number of people affected by emergencies has increased from 2 to 154
million a year. Accordingly, it is necessary to develop protective structures of various types that can provide comfortable conditions for human life.

We copy geological processes, creating building materials. For example, an analog of fine-grained concrete is a sandstone (Fig. 2a), an analogue of concrete on a large aggregate is a conglomerate (Fig. 2b), and so on. But creating building materials we cannot yet achieve the quality and properties of natural analogues. For example, foamed glass with a density of 250-300 kg/m$^3$ has a compressive strength of at most 1.5 MPa, and porous basalts, volcanic porous rocks with the same density have a strength of 5-6 times greater. The same can be said for cellular concrete of hydration hardening or, for example, masonry solutions - this is an anisotropic texture that completely replicates (resembles) banded rocks. But if the mortar mortars in the structures have a tensile strength of about 1 MPa, the banded rocks have a tensile strength of up to 70 MPa. It is the study of the microstructure of rocks that has enabled us to significantly improve the quality of similar materials. Based on the imitation of natural processes, we created a wall material of increased strength, gas tightness and water resistance, we developed a wide range of composites using these rocks.

![Natural sandstone](a) ![Natural conglomerate](b)

**Fig. 2.** Natural sandstone (*a*) and natural conglomerate (*b*)

Intelligent building composites are offered - these are composites in which a system of interaction with the environment that positively influences the system "man-material-environment" is laid, these are composites of the future.

Prospectivity of the geological approach in the creation of intelligent building materials can be confirmed by such properties as:
- increased protective and physicomechanical characteristics of composites;
- adaptability of properties, structures to living conditions (different construction zones);
- energy saving, reduction of negative impact on the environment;
- multifunctionality of constructive solutions;
- a wide opportunity for regeneration (self-cleaning of the surface, "healing" of cracks, etc.).

Intellectual materials are composites that, when designed, contain a system of interaction with the environment that allows materials to react to external influences and positively influence the triad "man-material-environment". An algorithm for controlling the processes of structure formation in the development of intelligent composites is developed. When designing intelligent building composites, it is necessary to control the processes of structure formation at all levels, which will allow the material to react to emergence of extreme situations when operating protective (fortification) structures.

The design of the given structure of the material at the nanoscale is carried out with the help of the quadaron approach, and also with the method of crystal seeding; at the micro level due to the creation of crystallization centers and the regulation of properties by additives introduced; at the macro level,
rational selection of components, pore filling and empty, and by creating the closest packages is necessary (Fig. 3).

Fig. 3. The designing of the material at nano level

Nanopowders with a specific surface 1500 times greater than that of cement were obtained from the hydrothermal sources of Kamchatka. Addition of a nanopowder in an amount of 0.01% of the cement mass made it possible to increase the strength of high-quality concrete by a factor of 2 [6].

The condition of the contact zone between the core and the matrix largely determines the physico-mechanical properties of the composite material. It is known that the character of the course of the processes of structure formation in the contact zone is determined by adhesion bonds, the saturation of the active centers of the surface of the aggregate, and other factors that are of great importance in the formation of silicate products. The possibility of influencing the processes of further formation of the strength properties of the contact zone is very limited and in most cases the cause of the destruction of silicates under load is due to insufficient strength precisely in these areas. The contact zone determines the strength characteristics of silicates with aggregates also when they are used in corrosive environments and in conditions of cyclic freezing and thawing [7-9].

The basicity of the resulting hydrosilicates is easily regulated by the ratio of silica with alkali metal hydroxide in the core of the active granule. Such particles easily penetrate into the silicate matrix surrounding the granule, interact with portlandite, bind it to insoluble slow-moving complex compounds of calcium hydrosilicates. At the same time, a zonal increase in the true density of the silicate matrix is fixed from 2.21 to 2.54 g/cm$^3$, cracks and micropores are overgrown (Fig. 4).

The method for grinding a crystalline material, for example quartz sand, significantly affects the kinetics and completeness of the dissolution of the granular aggregate obtained therefrom. The use of a ball mill minimizes the crystal structure of the material to a minimum. The use of a planetary mill or a vibrator is more likely to disrupt the crystalline structure in the grinding process, which speeds up the dissolution processes of the granules. In the case of amorphous silica - perlite, flake, rock Tripoli, etc., mechanoactivation does not significantly accelerate the formation of sodium hydrosilicates and depends mainly on the amount of fine particles of amorphous silica.

Building materials science, as well as geology (geomimetics), pay great attention to the creation of new high-strength, smart materials. They should have an ordered structure, formed neoplasms have high strength and low permeability, have the ability to self-heal structural defects and eliminate softening porosity. These properties are possessed by our silicate products at the stage of their manufacture and autoclave processing [10-11].
Another new approach is the use of composite sinter-based binders, which create the most favorable conditions in the early stages of structure formation and hardening of the system. This leads to a reduction in stresses in the hardening composite and, as a consequence, to a decrease in the number and size of microcracks, which determines the technical and economic effectiveness of using a sinter-based composite to produce a concrete mixture used in dry hot climates. It is known that volcanic tuff is heteroporous rock. The pore space of this rock is very complex in its form and consists of a combination of pores of various sizes. Under operating conditions under various loads, microcracks self-liquidate due to the interaction of moisture contained in tuff particles with unreacted clinker minerals. Particles of tufa in the process of exploitation give up their stored capillary-retained water, and this will lead to activation of the processes of structure formation and the synthesis of a denser homogeneous structure of materials during the hardening and exploitation of concretes, these are so-called intelligent composites.

Introduced by prof. V.S. Lesovik, the concept of "technogenic metasomotosis" is a complex mechanism. This is recrystallization, and diffusion, and dehydration, crystal-chemical transformations, etc. And the whole complex of complex physico-chemical transformations, that is, technogenic metasomotosis, when these phenomena are taken into account when designing the material, will allow the material, reacting to external influences, to self-heal defects that are formed during operation and restore its original characteristics.

The next step is development of the intelligent composites of a new generation with a hybrid matrix. In particular, the results obtained in the study of meteorites can be used to create hybrid composites with unique properties.

Taking into account the position of the geonics (geomimetics) prof. V.S. Lesovik proposed "The law of affinity of structures". It implies the design of layered composites and repair mixtures at nano-, micro- and macro- levels similar to the base matrix, which leads to a significant increase in adhesion and durability of materials.

The fundamental basis for designing materials for various purposes is the physico-chemical approach to understanding the aggregate of the structural and associative properties of microscopic formations: compounds, molecules, atoms, but even knowledge of the microstructure is insufficient to predict the final microscopic properties of the system being created. To assess the characteristics of the material, the entire complex of interactions, both its individual components and structural organizations, is taken into account. Considering the essence of the affinity of building composites, we mean the concept and properties of the chemical affinity of elements, Speaking of building materials,
we first of all take into account the chemical composition of the constituent elements from which these materials are created. But the main criterion for assessing the characteristics of affinity, according to prof. V.S. Lesovik and prof. L.Kh. Zagorodnjuk, is the strength and durability of the contact layer. When creating a material, taking into account the affinity of the structures, it is necessary to take into account the structural features of the structure of the material itself and take this into account when laying it in the structure, as well as in its further operation.

For example, concrete scrap from products and structures that have been in operation for decades, especially after steaming, after grinding does not show sufficiently active binding properties due to the almost complete hydration and carbonization of clinker minerals and hydrate phases. However, even the products of the crushing of the oldest scrap differ by a much higher physicochemical affinity with the cement matrix of the concrete than conventional disperse additives such as quartz or limestone sand, screening of granite and other acidic silicates, and the like. In this regard, ground crushing screening, especially characterized by an increased content of Portland cement component, can be attributed to the active fillers of the binder and concrete mixture as a whole. It is known that when cement is mixed with various technogenic products in the presence of a superplasticizer, which facilitates the process of the binding of the binder and prevents the aggregation of the crushed cement particles, astringents with increased chemical activity and reduced water demand with a specific surface of 450-550 m$^2$/kg are obtained.

The theoretical basis for improving the physico-mechanical characteristics and durability of building materials can be technogenic metasomotosis in building materials science. This is a stage in the evolution of building materials, characterized by the adaptation of the composite to changing conditions during the operation of protective (fortification) structures. This chemical interaction in the system "Binder-aggregate-additive-pore solution-environment" with a change in the chemical composition, in which dissolution of the original components and the synthesis of tumors occurs almost simultaneously. Technogenic metasomotosis is a complex mechanism. This is recrystallization, and diffusion, and dehydration, crystal-chemical transformations, transformation in the crystal lattices of the mineral, autogenesis (separation of the solid phase and solutions).

Additive technologies or layer-by-layer synthesis technologies are one of the most dynamically developing areas in science today. For a fairly short process of time that has passed since the appearance of the 3D printer, people have learned to print dishes, toys, cars and even human organs and tissues. The range of items that can be printed using a three-dimensional printer is constantly expanding.

Without taking into account the changes taking place in the environment, now it is impossible to pass to the development of 3D additive technologies. The fundamental basis for the design and creation of composites for additive technologies is the transition to transdisciplinarity research, which is now leading, including the direction of geonics (geomimetics). Examples of additive technologies can often be found in nature. For example, masonry solutions are a layer-by-layer synthesis. Brick masonry is an analog of layered rocks. But if the mortar mortars in the structures have a tensile strength of about 1 MPa, the banded rocks have a tensile strength of up to 70 MPa. It is the study of the microstructure of rocks that has enabled us to significantly improve the quality of similar materials.

The introduction of additive technologies (layer-by-layer application) is impossible without the use of the "The law of affinity of structures". It involves the design of layered composites and repair systems at the nano-, micro- and macro-level similar to the base matrix, which leads to a significant increase in the adhesion and durability of materials. When we need to create a single whole composite and thus only the law of affinity of structures allows us to do this.

3. Conclusion
The examples of the implementation of the geological (geomimetic) positions in construction materials science are given in the work. The wall materials obtained with this technology have a much more developed surface than traditional wall materials. The second example of using such approaches
is the development of internal care systems that will create a more highly organized structure of cement stone at the macro-, micro- and nano-scale levels and concrete in general at all stages: the stage of mixing, hardening and exploitation of the material. The regularities of the structure formation processes are revealed and the principles for increasing the efficiency of non-autoclaved aerated concrete due to application of composite binders, process control in a three-phase disperse porous system and the development of technological methods for the production of protective (fortification) structures are developed.

Implementation of the concept of designing the building composites of the future made it possible to create high-strength concretes with a compressive strength of up to 200 MPa.

References
[1] Ibragimov R. The influence of binder modification by means of the superplasticizer and mechanical activation on the mechanical properties of the high-density concrete. ZKG International, 2016. No69 (6) pp.34-39.
[2] Zagorodnjuk L.H., Lesovik V.S., Volodchenko A.A., Yerofeyev V.T. Optimization of mixing process for heat-insulating mixtures in a spiral blade mixer. International Journal of Pharmacy and Technology, 2016. No.8(3) pp.15146-15155.
[3] Ibragimov R.A., Pimenov S.I. Influence of mechanochemical activation on the cement hydration features. Source of the Document Magazine of Civil Engineering, 2016. No.62 (2) pp 3-12.
[4] Gladolev E., Suleimanova L., Lesovik V. High reaction activity of nano-size phase of silica composite binder. International Journal of Environmental and Science Education, 2016. No.11(18) pp.12383-12389.
[5] Fediuk R.S. Mechanical Activation of Construction Binder Materials by Various Mills. IOP Conference Series: Materials Science and Engineering, 2016. No.125(1) pp.012019.
[6] Lesovik V.S., Potapov V.V., Alfimova N.I., Ivashova O.V. Increase in the effectiveness of binders due to the use of nanomodifiers. Building materials, 2011. No. 12 pp. 60-62.
[7] Cai J., Hu X., Xiao B., Zhou Y., Wei W. Recent developments on fractal-based approaches to nanofluids and nanoparticle aggregation. International Journal of Heat and Mass Transfer, 2017. No.105 pp. 623-637.
[8] Morsy M.S., Al-Salloum Y.A., Almusallam T.H., Abbas H. Mechanical properties, phase composition and microstructure of activated Metakaolin-slaked lime binder. KSCE Journal of Civil Engineering, 2017. No.21(3) pp. 863-871.
[9] Logbi A., Kriker A., Snisna Z. Effects of mineral additions on durability and physico-mechanical properties of mortar. AIP Conference Proceedings, 2017. No.1814 pp. 020032.
[10] Parthiban K., Saravana Raja Mohan K. Influence of recycled concrete aggregates on the engineering and durability properties of alkali activated slag concrete. Construction and Building Materials, 2017. No.133 pp. 65-72.
[11] Mohammadinia A., Arulrajah A., Sanjayan J., Bo M.W., Darmawan S. Strength development and microfabric structure of construction and demolition aggregates stabilized with fly ash-based geopolymers. Journal of Materials in Civil Engineering, 2016 No. 28(11) pp.04016141.