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Textile-reinforced concrete using composite binder based on new types of mineral raw materials

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Abstract. To determine the level of development of science, it is necessary to start with a particular stage in the development of society. At present, the purpose of building materials science is to create composites, which ensure safety of buildings and structures, including their protection against certain natural and man-made impacts. A new stage in construction materials science envisages the development of a technology for creating composites comfortable for a particular person. To implement this, a new paradigm for designing and synthesizing building materials with a new raw material base is needed. The optimization of the "human-material-habitat" system is a complex task, for the solution of which transdisciplinary approaches are required.

1. Introduction

Comfortable environment for human's habitations and effective labor activities can be affected by several surrounding changes. These changes include a temperature-humidity level, noise effect, an increase in the radio-magnetic background and others. Definitely, a sharp increase might occur under constant changes conditions due to acid-alkaline rains. To enhance the human performance, this can only be achieved by optimizing "human-material-habit" system [1].

The current stage in the development of building materials is characterized by achievements, largely conditioned by a monodisciplinary approach to research. The construction materials and concrete of a wide range of nomenclature used for the construction of buildings and structures meeting the requirements for ensuring strength and reliability have been developed [2]. A new period in the development of society and human evolution is characterized by the need to create favorable conditions for the existence of a human being, by changing architecture, the color of the environment, creating a safe environment, and so on [3]. This is a complex task, for the solution of which transdisciplinary approaches are needed [4, 5]. To achieve these goals, new building materials are needed that have a wide range of properties and required characteristics. One of such promising materials is textile-reinforced concrete.

Textile-reinforced concrete represents a relatively new composite material, consisting of high-strength fine-grained concrete and textile reinforcing mesh (Fig. 1). It was invented in the mid-90s in Germany and it was considered as a composite material that could not be subject to reinforcement corrosion [6]. To protect the reinforcing net, only a 3-4 mm thick concrete layer is required, which



makes it possible to produce thin-walled products and structures, while reducing the consumption of materials for the preparation of concrete.

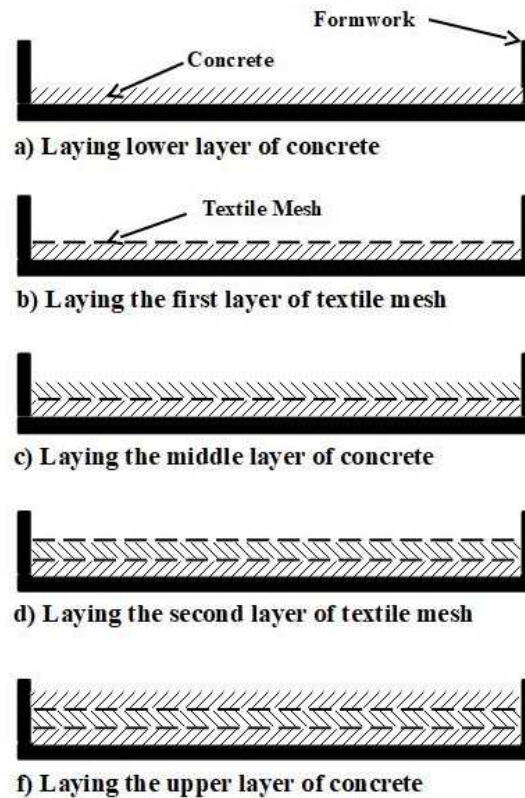


Figure 1. Scheme for creating textile – reinforced concrete.

Due to the combination of the properties of concrete and textile net, the composite has unique features that underline its exceptional feature. Due to the high tensile strength of carbon fibers and alkali-resistant AR-glass fibers, from which the net is woven, textile-concrete becomes practically a "flexible" material (Fig. 2).



Figure 2. Demonstration of the possibility of textile – reinforced concrete under impact bending load.

Nowadays, the composite material has a wide range of applications. It can be used for creation of small architectural forms, facade slabs, as basic material in reconstruction and reinforcement of buildings and others [7, 8]. However, based on this material, it is possible to create a complex material of a new generation with predetermined properties providing a safe human habitat. This requires a

general concept of targeted synthesis of neoplasms and creation of microstructures, which requires the development of a methodology for their study, description and statistical processing.

The key factor in creating a cement matrix of textile-reinforced concrete is the selection of raw materials. It is necessary to use nontraditional natural raw materials (quartz sand, various natural fillers, etc.), but complex highly prepared silica-containing components with high free energy that are natural-technogenic processes, which allow to regulate the properties of the cement matrix, at all stages of the formation of a new composite, and significantly improve the quality of the starting material.

2. Scientific analysis

Technogenic sands, unlike natural sands, are formed due to intensive energy impact on the original rocks of different composition and genesis in a very short time. This determines their specific properties and applications.

Based on the developed classification of technogenic mechanogenic sands [9], waste resulting from concentration of ferruginous quartzite's, and, in particular, wastes of magnetic enrichment, belong to one of the large-tonnage types of waste from enrichment of the developed deposits. To identify the specificity of technogenic sands of this type, as raw materials for the production of fine-grained concrete and composite binder, the waste of wet magnetic separation of ferruginous quartzite's of the Russian Federation was studied.

The reserves of this type of man-made sand in the dumps of mining concentrators in Russia are tens of billions of tons, which allows us to consider them as a powerful raw material base for the building materials industry as a whole.

Tailings of wet magnetic separation of ferruginous quartzite of various deposits are characterized by a similar mineral composition and, in addition to quartz, contain ferruginous carbonates, silicates and, in small amounts, hematite and magnetite (3-5%). Quartz of ferruginous quartzite of various genesis has unique characteristics. It consists of three varieties: reactively metamorphosed (chalcedony), dynamo-metamorphic and contact-metamorphic generation.

The study of the iron ore deposit of Lebedinsky mining concentrator showed that magnetite (54.7%) and silicate-magnetite (22.8%) varieties of ferruginous quartzite predominate in its composition.

Based on the chemical composition of ferruginous quartzite's in Russia and CIS countries, the Kursk Magnetic Anomaly deposits have an elevated SiO₂ content (from 31 to 42%) [10], which leads to an increase in the quartz content in wet magnetic separation waste (Table 1). Hematite is found in the form of inclusions in the grains of digenetic quartz; as secondary - amphiboles, carbonates, feldspar and glist. The quartz present in wet magnetic separation waste in crushed form can participate in the formation of tumors and, consequently, the waste can be used in the production of low water consumption binders.

Table 1. Mineral composition of wet magnetic separation waste at Lebedinsky mining concentrator, %

Quartz	Hematite	Magnetite	Silicates	Carbonates
67-70	6-11	2-6	9-12	6-13

There are various ways to influence mechanical stresses on the structure of a solid body to activate chemical and physicochemical transformations, this can occur in various devices.

Concentration of ferruginous quartzites includes crushing and grinding, as a result of which chemical reactions occur and the structure of rock-forming minerals changes. Theoretical prerequisite for initiating and accelerating chemical reactions under mechanical action on various genesis quartz and other minerals is to increase the specific surface and crystal lattice deformation, and even partial amorphization. With the further deformation of minerals (beyond the yield point), their structure is

destroyed, and the energy of mechanical action goes to the formation, movement and multiplication of various structural defects.

Accumulated energy, in the tails under the influence of mechanical activation, activates the process of structure formation in the system "waste wet magnetic separation of ferrous quartzite - Portland cement".

The results that are mentioned above allow us to conclude that the tailings of wet magnetic separation represent technogenic polymineral fine sand, consisting essentially of the sharp-edged particles of quartz of various genesis. As secondary, there are feldspars, amphiboles, carbonates, magnetite's, hematite's.

Thus, concentration of ferruginous quartzite is a system of physical and mechanical effect on the initial polymineral rock of a complex structure, which results in the disintegration of minerals and separation into magnetite concentrate and wet magnetic separation tailings of the nonmetallic component, which energy should be used as a fine-grained aggregate and filler commodity components due to the energy of geological and technogenic impacts.

3. Materials and methods

To determine the impact of technogenic raw materials of Kursk Magnetic Anomaly, silica-containing materials, slag and wet magnetic separation were tested.

To obtain binders, the following materials were used: Portland cement CEM I 32.5 N GOST 31108-2003 Closed Joint Stock Company Belgorodsky Cement, Novolipetsk blast-furnace granulated slag with $M_o = 1.14$ and $M_a = 0.2$ and waste of wet magnetic separation (WMS) of ferruginous quartzite's With $M_k = 0,6$, additive Polyplast CP-1 (Table 2).

Table 2. Chemical composition of technogenic raw materials

Oxide	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	CaO	MgO	SO ₃	K ₂ O	Na ₂ O	MnO	CO ₂
Slag	37,1	7,3	0,65	-	41,4	9,4	1,83	0,59	0,35	1,02	-
WMS	77,8	0,57	6,58	7,12	1,5	2,26	0,128	-	-	-	3,63

The physical and mechanical properties of technogenic sands used are associated with a complex set of factors, the most important of which are mineral composition, density, water demand, and others.

Waste of Wet magnetic separation of ferruginous quartzite's and slag are characterized by large values of water demand and true density, as compared to screening of quartzite sand and natural sand (Table 3).

Table 3. Physical properties of technogenic sands used

Name	Slag	WMS	Quartzite sand screenings	Tavolzhanka sand
Packing density, dry basis, kg/m ³	1090	1300	1490	1448
True density, kg/m ³	2820	2800	2670	2630
Water demand, %	15	24	5,5	7
Fineness modulus	2,71	0,9	3,5	1,38

The main feature of technogenic sands used for the production of composite binders is their chemical and mineral composition. So, natural sands are represented mainly by quartz, and technogenic sands contain various minerals. Despite the fact that the lower content of quartz in the composition of man-made sand causes a slight decrease in the activity of composite binders on its

basis, the polymineral composition contributes to the reduction in energy intensity of grinding of the binder.

To improve the efficiency of the processes of the structure formation of binders obtained on a filler with a specific surface of 200 m²/kg, blast-furnace granular slag was introduced into the system. Formulations of CB 20 with a different ratio of fillers (slag and wet magnetic separation waste) were developed (Table 4). These components were taken at the same level of dispersion (200 m²/kg) and ground with cement for 5 minutes. It should be noted that the amount of additive was introduced as a percentage of the weight of the cement.

Table 4. Compositions and characteristics of binders

№	Type of binder	Cement, %	Slag, %	Wastes of wet magnetic separation %	D, %	Compression strength, MPa	
						7 days	28 days
1	CB 20	20	-	80	0,7	4,2	12,1
2	CB 20	20	20	60	0,7	5,0	14,9
3	CB 20	20	40	40	0,7	8,4	18,3
4	CB 20	20	60	20	0,7	9,5	25,4
5	CB 20	20	80	-	0,7	12,6	33
6	CB 30	30	35	35	0,7	9,1	22,1
7	CB 40	40	30	30	0,7	16,1	30,1
8	CEM I 32,5 N	100	-	-	0,7	29,5	42,4

4. Results and Discussion

The results of the tests, binding to strength, indicate a higher activity of compositions on the mixed filler compared to binders on WMS alone.

Since the rapid cooling of the slag melt prevents (or stops) its crystallization, allowing the internal energy stored in the slag to be released as the heat of formation and crystallization of chemical compounds, this increases the ability of the finely ground granulated slag to solidify when water is closed in the presence of hardening agents.

Provision of strength indicators for astringents with a slag component with the simultaneous introduction of waste WMS of ferruginous quartzites occurs due to a general increase in the specific surface area of both cement particles and man-made fillers, and as a result, the increase in the number of smallest particles, increase in the proportion of surface defects of large inclusions, Activity of slag due to finer grinding, creation of high-density packing of astringent particles. Simultaneously, the particles and wastes of wet magnetic separation of ferruginous quartzites, and slag, act as substrates and centers of crystallization during the hydration of the binder.

For further studies, compositions 4 and 7 were chosen. These binders have strength of about 43% (CB 20) of the strength of pure cement, and the strength of CB 40 is already 73% of the strength.

5. Reflections

Tailings of wet magnetic separation of ferruginous quartzite's can be considered as ferruginous sands. The problem of studying the role of ferruginous inclusions contained in the tailings is primarily to determine the effect of hematite and magnetite on the formation of cementing substances and other properties, since the content of these iron oxides in the tails (in addition to the silicon oxide) is predominant.

Of great interest is control over physical and mechanical properties of concrete mixtures by treating them with a magnetic field in order to intensify the processes of structure formation [11-12].

During the passage of a liquid electrically conductive medium through magnetic fields, the system senses a combined electromagnetic influence. This changes the distribution of the density of electron clouds of ions and polarization of electron clouds of water molecules occurs, therefore the energy of near and far hydration changes. Under the influence of the magnetic field, the ions are polarized, deformed and their solvation is reduced. The effect of magnetic fields on the water structure is explained by the presence of water bonds. Their behavior under the influence of the magnetic field explains the behavior of water and water-dispersed systems. Thus, the magnetic field changes the structure of the mixtures, the degree of hydration, and the trajectory of the motion of the ions, causes asymmetry in the hydrate shells and creates the conditions for the formation of ionic associations as crystallization centers.

The analysis of acoustopolarigrams showed that after magnetic processing the samples become more anisotropic. This is due to the magnetic properties of the iron compounds, present in the wet magnetic separation waste. When a magnetic field is applied along one of the faces, the magnetic particles of the wet magnetic separation waste of ferrous quartzites tend to unfold along the magnetic lines. This leads to an increase in the anisotropy of concrete as a whole. Also, after magnetic treatment, the macrodefects of large pores and voids of concrete decrease. All this contributes to increasing the strength of concrete.

Of great importance is the induced electric current that arises when a magnetic field is applied, and the conditions for hydration of ions are violated and favorable conditions are created for their convergence and the formation of crystalline centers. In this case, the magnetic field causes the asymmetry of the hydration shells of water ions in the mixture, creating more favorable conditions for the formation of ionic associations, which are the centers of crystallization. Therefore, the magnetic field, without affecting the rate of crystallization, increases the number of crystallization centers during solidification of mixtures, resulting in a more finely crystalline, low-porosity structure with better strength and filtration properties.

An important role of iron, present in the mixture based on waste, belongs to the wet magnetic separation, as a causative agent of crystallization. Ferromagnetic iron oxides that are a part of crystalline particles can exhibit a striation effect, leading to a fragmentation of the embryo, as a result of which the number of crystallization centers increases and, accordingly, the rate of hydration of concrete increases.

6. Conclusion

Thus, optimization of processes of structure composite binding occurs by ensuring the sequential growth of the neoplasms hardening system "clinker minerals - quartz various genesis - slag - water - superplasticizer" caused by varying the intensity and time of interaction of polygenetic quartz and slag particles made from the hydration products of clinker minerals. Regional-metamorphosed (chalcedony), as well as partially dynamo-metamorphic quartz generation of waste of MMC of ferruginous quartzites, intensively bind calcium hydroxide to small-crystalline insoluble calcium hydrosilicates. In this case, the contact-metamorphic variety and larger slag particles act as substrates and crystallization centers. This helps to reduce the number of defects, to reduce the crystallization pressure and to optimize the structure of the material.

Using the theoretical foundations of geonics (geomimetics), new types of raw materials with high internal energy, the possibility of magnetic interference on the contained in natural and technogenic materials magnetite opportunities magnetic activation allow one to intensify the process of structure formation textiles, concrete cement matrix, to increase performance and to create a protective basis of long-acting adverse conditions that affect a person.

The future of building materials is due to the implementation of interdisciplinary and transdisciplinary approaches, using a new source of raw materials (natural and man-made materials with high free internal energy), man-made theory of metasomatism in building materials, the law of the affinity structures, other achievements of building materials and related sciences. Using a

transdisciplinary approach can significantly extend the possibility of using textile-concrete in order to optimize the human habitat, including through the creation of new architectural complexes.

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