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Design and Usage of High Quality Small-Grained Fibre Reinforced Composites Based on Industrial Materials of Kursk Magnetic Anomaly Region for the Purpose of Repairing of Buildings and Constructions

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INTRODUCTION

The Russian Federation is the largest country in the world, with the area more than 17 millions square kilometers and as a result, there are a lot of buildings and constructions of different functionality. The most part of these constructions was build more than 30 years ago and nowadays, from the point of their technical condition, they can not meet the requirements of technical documents and exploitation terms, so they need to be repaired and strengthened (Figure 1).

At present fiber-reinforced concrete (FRC) has got the wider application, for repairing and strengthening of buildings and constructions allover the world. Fiber-reinforced concrete is concrete containing fibrous material which increases its structural integrity. Fibers may be steel fibers, glass fibers, synthetic fibers and natural fibers. Within these different fibers the character of fiber-reinforced concrete changes depending on varying concretes, fiber materials, geometries, distribution, orientation and densities [1].

From the technical-and-economic point of view it is rational to use local raw materials during the process of FRC preparing and from the ecological point of view - waste products of different manufactures.

It is necessary to use different composite binding materials for FRC preparation, the production of which has the connection with the usage of high effective super- and hyperplasticizing admixtures. During the process of technical-and-economic analysis of widely spread and available plasticizers, we have chosen several types of superplasticizing admixtures, which were produced in Russia and in Europe. Using this superplasticizing admixtures, during the production of composite binding materials, let us obtain the compressive strength more than 90 MPa. Not least, important moment, during the process of composite binding materials production, is the correct selection and usage of different cement components [2, 3].

The important factor, during the process of composite binding materials producing is the right choice of applied equipment. Preparation of such type of binding materials has the connection with using of different type of milling equipment. The research allowed to discover that using of vibrating mill (Fig. 2) instead of traditional ball mill, helps to obtain more quantity of small size grains (the size up to 30 micro meter more than 10 %, in equal specific surface) in composite bindings (Fig. 3). This fact can not but have positive effect on physical and mechanical characteristics of produced concrete and FRC based on this composite binding materials [2].

Besides, the research of milling kinetics in vibrating mill and in traditional ball mill helps to detect, that milling process in vibrating mill goes on more intensively up to specific surface 500 sq. m / kg, with the subsequent reductive of milling intensity. Moreover, the milling process in the ball mill, occurs relatively slow, with steady growth of specific surface (Fig. 4) [4, 2].

In the XXI century, the important environmental task becomes recycling and using of different waste products in different conditions. Raw waste products investigation of Central Black Earth Region allowed to find out that it is most reasonable to use technogenic sands of the Kursk magnetic anomaly region (KMA), in particular quartzite sandstone milling screenings. Micro structure research of the quartzite sandstone milling screenings surface and other passing produced materials (plates, wastes of wet magnetic separation and etc.) helps to discover, that it has highly-developed surface, which creates a positive effect on the adhesion with cement matrix.

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Fig. 1: Damages of reinforced concrete constructions after 35 ± 5 years of exploitation in the condition of environmental activity

Fig. 2: Vibrating mills MV-20 and MV-60

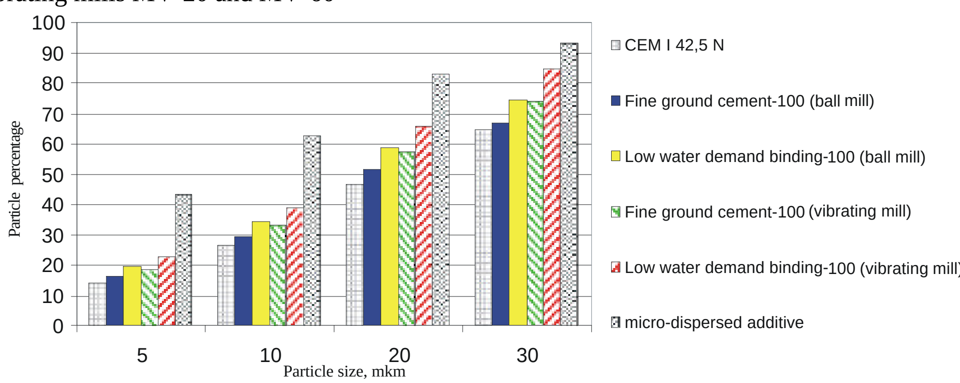

Fig. 3: Particles percentage in the intervals of 5, 10, 20 and 3: Micro meter

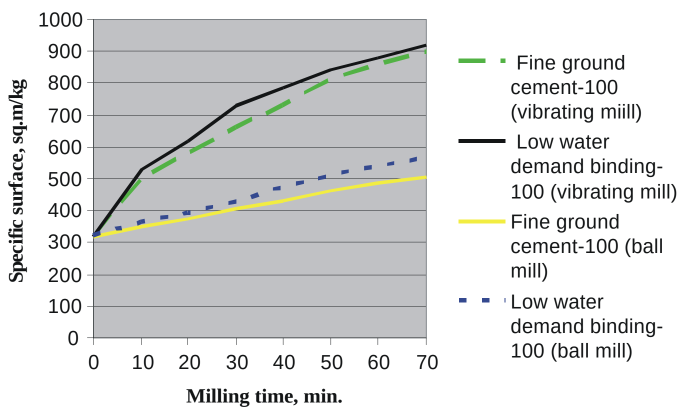

Fig. 4: Milling kinetics of binding materials in ball mill and vibrating mill

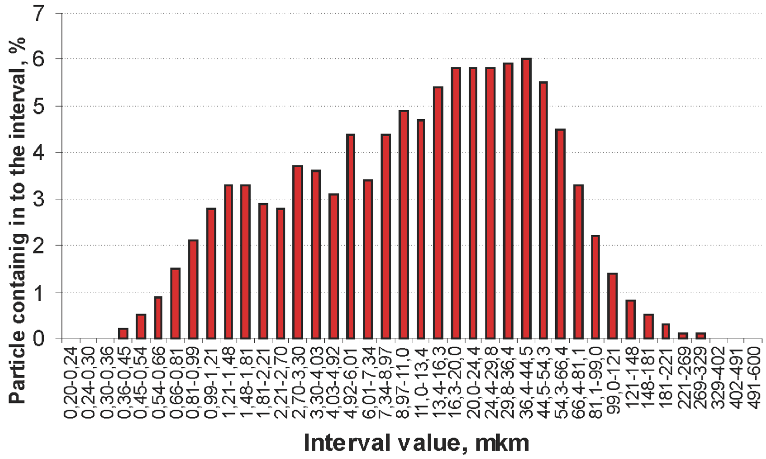

Fig. 5: Graph of parts distribution of micro additive in size

Chemical analysis of waste products of the Kursk magnetic anomaly region (KMA), helped to determine that quartzite sandstone milling screenings mainly include greenshist facies metamorphism quartz (greenschist facie). This fact, under certain conditions, can cause positive effect on the composite microstructure formation.

The main aspect, during the process of production of high effective FRC composites, is optimization of its structure both on the micro- and macro- level. Effective hyper-plasticizers, composite binding materials, produced by means of using modern developments in the area of machine industry were used for optimization on micro level. What is more, micro- dispersed silica-containing additive which has specific surface 700 sq. m / kg was developed and used. This additive is produced from the waste products of the Kursk magnetic anomaly region (KMA). Introduction of this additive into the concrete structure allows to reduce binding material consumption, thus increasing strength and operational characteristics. Particle-size study of the powder of micro- dispersed additive by the method of laser granulometry on the Microsizer-201 unit allowed to find out that the additive has poly-fractional composition (Fig. 5). This fact indicates high reactive capacity and as a result, increases density of cement stone [2, 3].

For FRC structure optimization on macro level it is necessary to do qualitative assessment and fibre component selection. During the work performance the main fibre types, which are offered on the market at the present time, were analyzed. They are as follows:

- Steel wave fibre;
- Steel anchor fibre;
- Machine-cut steel fibre;
- Recycled fibre, which is produced from auto tyres;

In the process of fibre component selection, we took into account the index of ratio of the fibre length to its diameter. This index is very important in the design process of high quality FRC.

In the course of the research work, the influence of different reinforcement percentage of all above mentioned fibre types, on the FRC strength were studied. It is determined that in case of using anchor, machine-cut or wave fibre, the highest physical and mechanical results can be achieved at weight reinforcement percentage from 3.3 to 3.6. In case of using fibre which is produced from auto tyres, reinforcement percentage by weight, in which it is possible to get maximum physical and mechanical results can come to 8 percent [2].

It is discovered that optimization of micro- and macro-structure, by means of using composite binding materials, effective hyper- plasticizing admixtures, micro- dispersed additive, fibre reinforcement component, technogenic sands allows to get FRC, based on KMA materials, with characteristics which meet the requirements to the repairing mixtures and even excelling them (Table 1).

Mixtures of small-grained FRC based on composite binding materials have higher physical and mechanical, nonrigid and operational characteristics. This fact can be explained by better dimensional particle packing in the composite material and peculiarities of structure formation. The usage of composite binding material and micro- dispersed additive, which has active surface, accelerates the process of new growth elements fusion, which is characterized by the decrease of structure formative period at the expense of binding of calcium hydroxide, which come into being during the process of alite hydration and formation of compact composite microstructure. This fact can be proved by the analysis of

Table 1: Characteristics of optimized FRC

FRC proportions	Concrete aver age density, kg/m^3	Compres-sion resistance, R, (MPa)	Wear capacity, G, (/F<^{2}	Concrete water absorption by weight, W, %	Freeze-thaw, F, cycles	Prism strength, (MPa)	Young's modulus E_b•10G^3 , Mpa
Concrete mix based on composite binding material, hyper- plasticizing admixture and micro- dispersed additive (check sample)	2390	96,4	0,33	2,2	F600	60,1	50,9
Composite binding material, steel fibre (anchor), hyper- plasticizing admixture and micro- dispersed additive	2410	113,1	0,23	2,1	F700	83,1	72,1
Composite binding material, steel fibre (wave), hyper- plasticizing admixture and micro- dispersed additive	2420	124,3	0,23	2,1	F700	91,2	79,6
Composite binding material, steel fibre (recycled fibre), hyper- plasticizing admixture and micro- dispersed additive	2470	104,2	0,24	2,2	F700	74,1	61,5

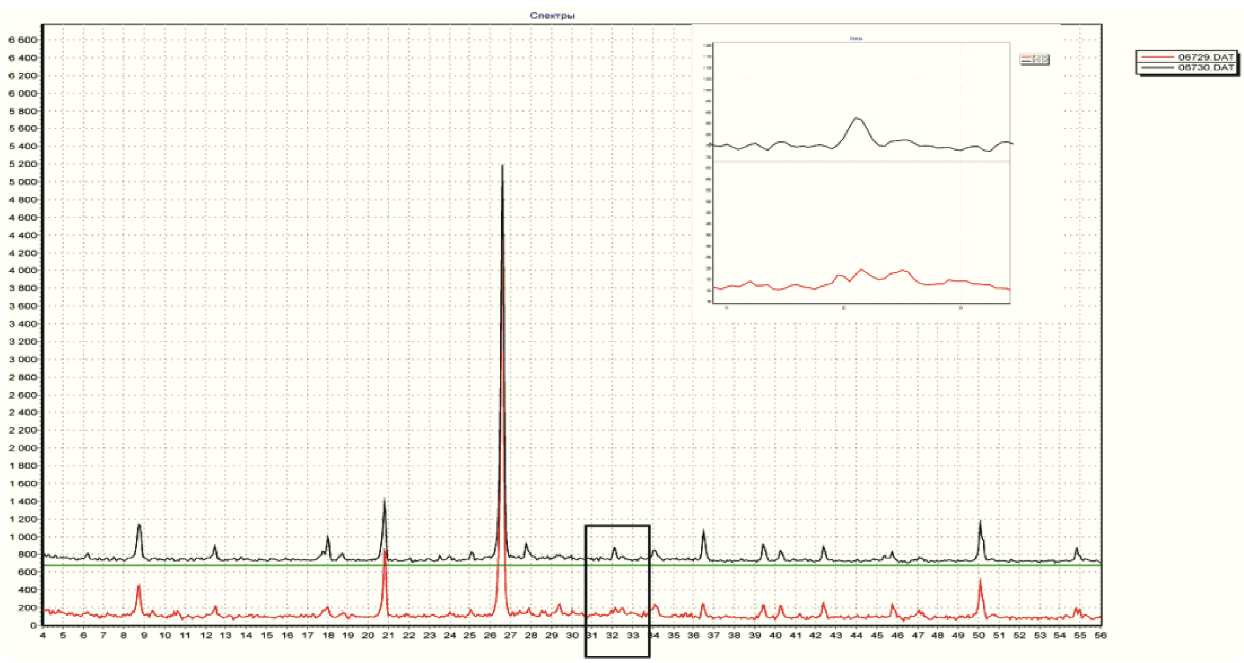

Fig. 6: X-ray diagrams of cement stone of small-grained concretes

X-ray diagrams, which allowed to compare small-grained FRC cement stone based on composite binding material with addition of micro- dispersed additive and plasticizing admixture and concrete based on CEM I 42.5 H (Fig. 6) [2, 5].

In conclusion, the possibility of getting small-grained FRC, which have compression resistance more than 124 MPa, flexural strength – more than 23 MPa, freeze-thaw - F700, prism strength – more than 91 MPa has been proved. The results can be attained due to the usage of composite binding materials, steel fibre (wave), micro- dispersed silica-containing additive, which is produced from the waste products of the Kursk magnetic anomaly region (KMA) and hyper- plasticizing admixtures. The offered compositions are possible to use for repairing and strengthening of buildings and constructions and also for production of elements with high operational requirements.

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