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TECHNOLOGIES FOR PRODUCTION OF CONSTRUCTION MATERIALS AND PRODUCTS

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Concretes with nanoadditive of fired recycled concrete

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ABSTRACT: The practice of using recycled concrete from the broken concrete of substandard reinforced concrete products can become widespread in practice. The undoubted relevance of this topic is explained by the program for the renovation of the housing stock in the city of Moscow, which provides for the demolition of 5-storey residential buildings until 2032. The problem of recycling and reuse of construction waste becomes obvious to improve the environmental situation, as well as to reduce the cost of materials in construction and preserve natural resources.
The article deals with the nanostructuring of cement systems by means of introduction of ultra- and nanodispersed mineral additives. In this case, additional grinding of mineral additives is carried out in cavitation units. Nanostructuring provides the compaction of concrete structures and an increase in the strength properties of concrete.

KEYWORDS: recycled concrete, broken concrete, X-ray phase analysis, physical and chemical analysis, mineral fillers, cavitation grinding, structure, nanostructuring, strength.

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INTRODUCTION

In Russia, more than 15 million tons of construction waste is generated annually, 60% of which is classified as brick, concrete and reinforced concrete waste. The growth rate of these wastes is about 25% per year. According to the European Association for the Demolition of Buildings (EDA), established in 1976, about 2.5 billion tons of construction waste are generated annually on the planet, including 200 million tons in Europe. Construction waste of demolished dilapidated housing stock is accumulated with the waste received during the reconstruction of industrial and public buildings, engineering structures, as well as substandard products accumulated at the enterprises of the city's construction industry [1].

Previous studies [2, 3] have shown that materials obtained as a result of crushing can become a good alternative for natural materials for various purposes, including aggregates for concrete work. However, some unresolved issues related to the structural features of such a filler hinder its widespread use.

The issue of recycling and use of recycled concrete is also of great importance abroad. According to forecasts of the American Concrete Institute (ACI), the annual amount of waste in the country is expected to increase from 12 to 15 million tons over the next 10 years [4]. And in Belgium, due to the lack of natural resources, most of the natural materials must be imported from other countries. This leads to additional costs for transportation, strong impact on the environment and, as a result, high cost of the facilities being built.

MAIN FINDINGS

The cement industry annually increases the rate of production of high-quality cements. Indeed, it is not profitable to produce low-grade binders, since their production, as well as high-grade binders, is associated with high energy consumption for roasting and grinding of clinker, and is less cost-effective than the production of high-quality concretes M 400, 500, 600 [5]. This can be eliminated if costs for the production of a hydraulic binder are drastically reduced, for example, the cost of raw materials. The raw material for such a binder can be concrete scrap and construction waste.

The results of studies [6] of the influence of the dust-like part of the screenings of crushing of concrete scrap and rocks on the strength of cement stone showed that with the same percentage of dust-like fraction, the strength of the cement stone decreases least of all when the dust of the screening of concrete scrap is added to the cement. This screening exhibits the properties of a low-quality binder.

In [7], the effect of fired cement stone on the process of hydration and hardening of cement was studied, the ability of the residues of the binder in a fine aggregate to ensure the quality of the newly obtained cement was revealed. Based on the data of differential thermal analysis, the cement stone was fired at a temperature of 700°C and isothermal holding for 1 and 3 hours. Table 1 shows the results of strength tests.

The best result in terms of bending strength was shown by a specimen subjected to firing at 700°C for 3 hours, and in terms of compressive strength – a specimen subjected to firing for 1 hour at the same temperature. At the next stage, it was decided to investigate the structure and determine the nature of the phases contained in the material under study.

Chemical and physical technologies, of course, are the main ones in the production of nanodispersed particles. According to the degree of dispersion, it was proposed to classify ultrafine-grained materials depending on the average grain size in nm as follows [8]:

- Fine dispersed materials – 10^4–10^3 nm (10^{-1} µm);
- Ultradispersed materials – 10^3–10^2 nm (1–10^{-1} µm);
- Nanomaterials – less than 102 nm (<10^{-1} µm).

From the point of view of productivity and cost of the process of production of large-tonnage materials, a special place is occupied by the methods of mechanical and mechanochemical grinding, which, on an industrial scale, make it possible to obtain fine particles.

Work on the activation of cement suspensions was continued for other cavitators (rotary-pulsating devices, hydrodynamic emitters), which provided an increase in the strength of heavy concrete up to 40%. Fig. 1 shows the diagrams of equipment and pulse modes.

One of the promising technologies for the production of emulsions and dispersions is the cavitation technology of grinding. Cavitation is a physical phenomenon of the sequential formation, growth and collapse of microscopic bubbles in a liquid. The collapse of the bubble creates high localized temperatures and pressures. The cavitation effect can be achieved using acoustic and hydrodynamic cavitation.

Acoustic cavitation is induced by the passage of high frequency ultrasonic waves (16 kHz–100 MNts) through the liquid. When ultrasound passes through a liquid, zones of high and low pressure are formed, which leads to a rupture of the continuity of the liquid and the formation of cavitation. The conditions for the occurrence of cavitation depend on the intensity and frequency of ultrasound, the physical properties of the liquid, as well as the temperature and solubility of gases.

In conditions of hydrodynamic cavitation, a passive hydrodynamic disperser (hereinafter – PHD) is used for the formation and collapse of bubbles. Its design includes cavitation bodies, which are metal rods of a circular cross-section; when passing through the continuity of water, it breaks, and cavitation bubbles are formed. To ensure high fluid pressure, a vertical centrifugal pump is used, which provides pressure up to 6 atm [9, 10, 11].

METHODS AND MATERIALS

When performing the work, the following method of physical and chemical analysis was used – X-ray. The work was carried out on a DRON-3 device with a GUR-8 goniometer and a copper anti-cathode. The phases were

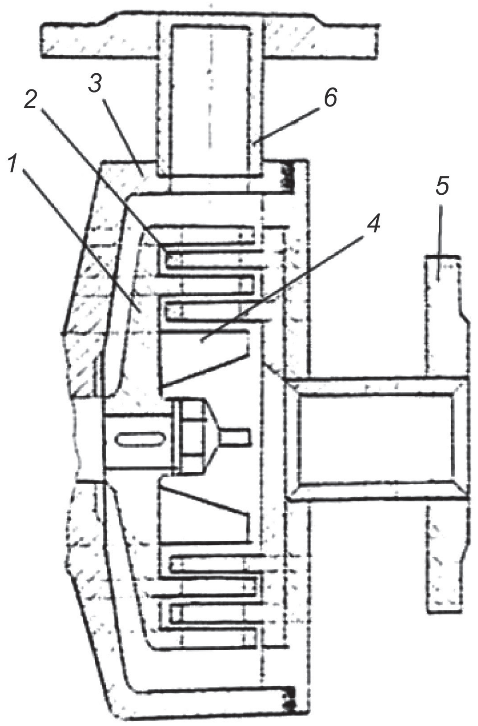
Table 1

Strength of cement stone PC M500 and cements with the addition of fired cement stone

Composition of the tested cement	Flexural strength, kgf/cm²			Compressive strength, MPa		
	1 day	3 days	7 days	1 day	3 days	7 days
PC	24.9	47.9	53.1	21.0	48.2	51.1
PC + 10% CS-1	17.5	37.5	47.5	14.8	42.7	48.8
PC + 10% CS-2	15.0	37.3	43.6	10.5	39.9	51.0
PC + 10% CS-3	13.3	31.7	41.4	10.1	39.6	45.4

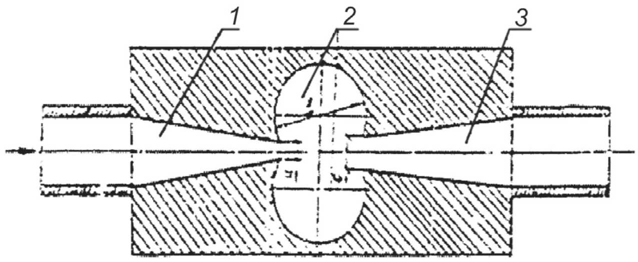
Notation:
CS-1 – cement stone at a firing temperature of 700°C, firing time 3 hours;
CS-2 – cement stone at a firing temperature of 700°C, firing time 1 hour;
CS-3 – cement stone without firing;
PC – ordinary Portland cement (M500).

Impulse modes

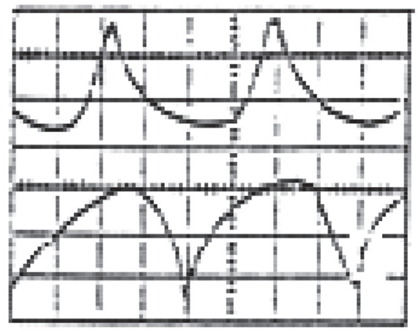


Rotor-pulsation installation: 1 – rotor; 2 – stator; 3 – hull; 4 – impeller; 5 – flange; 6 – connection

Hydrodynamic activation



Layout of hydrodynamic emitter:
1 – inlet nozzle; 2 – resonating chambers; 3 – exit nozzle



Types of pressure impulses, formed in medium in two resonant chambers of hydrodynamic emitter

Fig. 1. **Wave processes of activation**

identified using the JCPDS international card index. The phase composition of the analyzed samples is determined from the position and intensity of the corresponding diffraction lines on the X-ray diffraction patterns. In the quantitative analysis, the integral intensity of the most pronounced diffraction peaks of the corresponding compounds was measured.

The investigated old concrete (about three years of hardening) was crushed to a size of 5–25 mm, then it was fired at a temperature of 700°C, after which it was ground by hand in an iron mortar. Next, the test material was sieved through a 008 sieve.

Comparative analysis of X-ray diffraction patterns (Fig. 2, 3) of the studied secondary cement stone showed that the sets of the main diffraction maxima on the X-ray diffraction patterns correspond to the data of the international card index JCPDS, as well as tables on interplanar distances (d, Å) [8].

CONDUCTING THE EXPERIMENT

The X-ray diffraction pattern of the original secondary cement stone shows predominant diffraction maxima with d = 9.7712; 5.6087; 3.8750; 4.3851 Å, indicating the presence in it of ettringite, tetracalcium thirteen-hydroaluminate with d = 2.8847 Å, tetra-calcium nineteen-hydroaluminate with d = 2.7883 Å; calcium hydrosilicate with d = 2.5623; 2.4106; 1.7570 Å, alite with d = 2.7466; 2.6944 Å.

After firing, decomposition of ettringite, partial decomposition of calcium hydrosilicate is observed. The X-ray diffraction pattern after heat treatment shows the appearance of calcium hydroxide with clinker residues.

Then we compare the X-ray diffraction patterns of the samples obtained with the addition of 10% secondary filler with a control sample (PC 500).

According to the data presented in Figure 2 on the X-ray diffraction pattern of the control sample (PC 500) there are diffraction maxima of ettringite with d = 9.3093; 7.2545; 2.7798; 2.1834; 1.7972 Å, monobarium aluminate tetrahydrate with d = 4.9143; 1.9275 Å, portlandite Ca (OH) 2 with d = 3.1157; 2.6292 Å, alite with d = 2.7425; 3.0329; 1.7649 Å. After the introduction of an additive of 10% secondary cement stone, the presence of hexagonal eight-water calcium hydroaluminate with d = 2.4454 Å is observed.

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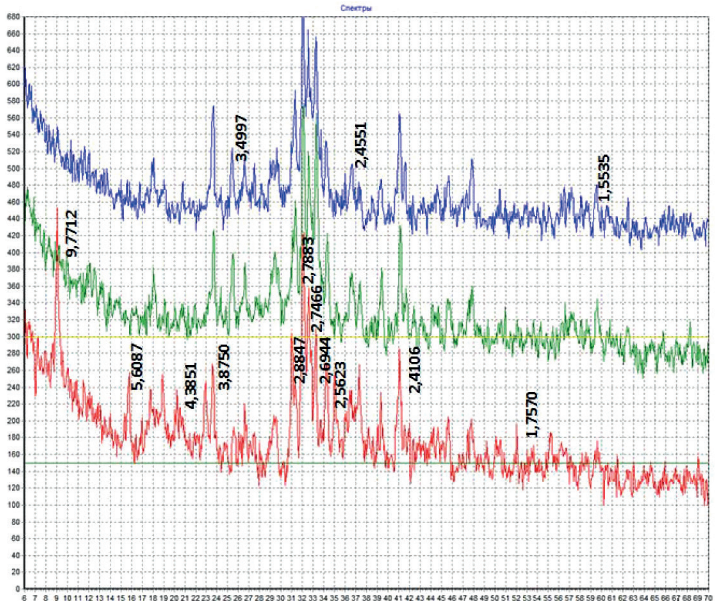
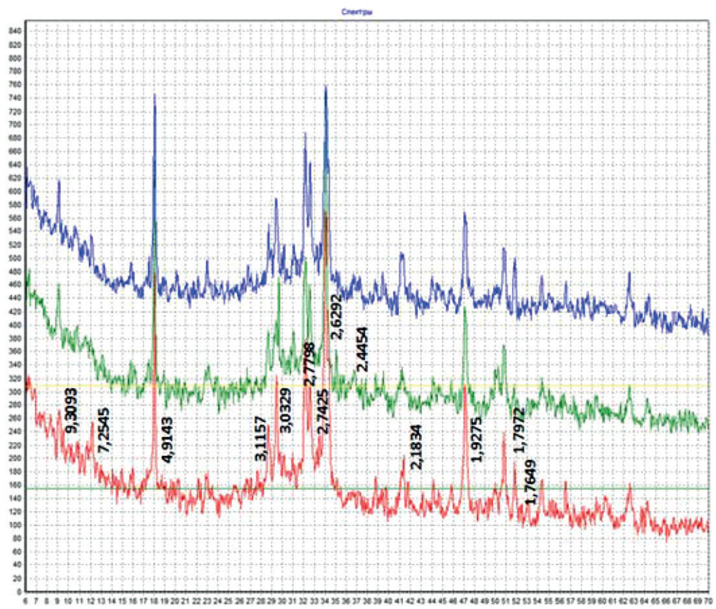


■ Old concrete stone subjected to firing (700°C, 3 hours)

■ Old concrete stone subjected to firing (700°C, 1 hour)

■ Old cement stone (~3 years of hardening)

Fig. 2. **Radiographs of the original and fired recycled cement stone**



■ PC+10% (3 hours of firing at 700°C)

■ PC+10% (no firing)

■ Control sample (PC 500)

Fig. 3. **X-ray diffraction patterns of samples with an additive (10%) after 90 days of hardening**

CONCLUSION

The early 2000's are marked by the start of the works on the problem and features of nanostructured high-tonnage materials. In this case, nanostructures do not cover the entire volume of materials, but form some kind of nanostructured layers in the total volume of the material. Therefore, one could expect obtaining additional structural bonds and an increase in the strength of massive materials and an improvement in technical properties by a factor of 2–2.5.

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