Fine-Grained Concrete of Composite Binder

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Abstract. The article is devoted to the application of industrial wastes for the production of high-quality concretes with specified characteristics. The composite binders with low water demand (BLW) have been developed. Their strength is approximately twice the strength of the initial cement, and dilute BLW with 50 - 70% of the ground slag or quartz sand in their composition provide the same strength as the original Portland cement. It was proved that the quartzite sand screening can be used as a filler in the preparation of fine-grained concretes.

1. Introduction
One of the main tasks of the building materials industry in the 21st century is to ensure the construction of efficient, low-energy and environmentally friendly materials, manufactured using harmless technologies with the introduction of local raw materials, waste and by-products of industry [1-3].

Currently, more than 30% of mortars and concretes in our country are produced with the introduction of chemical additives and fillers of different nature [4-5].

At the current level of the development of building materials science, in the criteria for improving the methods of delicate chemical and structural analysis, it is of the greatest interest to study the mechanisms of the effect of chemical additives and fillers on the processes of hydration and hardening of cement compositions, from molecular to macrostructure.

Using of production waste in the building materials manufacture is widely studied in the world science, including the author's team of the Far Eastern Federal University [2-3].

Despite the fact that there are enough theoretical and experimental studies concerning the use of waste in the production of building materials, their main qualities are not always and completely used: dispersity, aggregate state, the presence of chemically intensive phases (the ability to chemical interaction, hydration, and hardening) and presence of surfactants.

2. Results and Discussion
It is known that the theoretical strength of concrete is much higher than practical, that is, the use of potential possibilities of concrete is still small. This is due to the fact that there is no consensus on the structure of concrete, its behavior under load before the formation of microcracks, there is no clear idea of the strength of concrete, its physical properties, the criteria for assessing the theoretical strength and destructive process, ways to reduce the defects in the structure of concrete, knowledge of the resistance of concrete to destruction from the joint action of the load and the environment and much more [6-10].
When developing composite materials, two problems must be solved:
1) implement the selection of components;
2) determine the formulation and modes of the manufacturing process, ensuring the production of a material with the optimal structure and specified properties.

Russian scientists have developed and manufactured binders with low water requirements (BLW), which at one time laid the foundation for the development of composite binder technology. The joint grinding of Portland cement with an increased dosage of superplasticizer and in some cases with an active mineral additive made it possible to obtain BLW with very different properties (Table 1).

### Table 1. Properties of binders with low water requirements.

| Composite binders | Consist | Compressive strength (14 d), MPa, $R_{\text{compress}}$ | Compressive strength (28 d), MPa, $R_{\text{compress}}$ |
|-------------------|---------|--------------------------------------------------------|--------------------------------------------------------|
| Portland cement   | 100     | 28                                                     | 50                                                     |
| BLW-100           | 100     | 14                                                     | 95                                                     |
| BLW-50            | 50      | 17                                                     | 60                                                     |
| BLW-30            | 30      | 21                                                     | 45                                                     |

It turned out that the strength of the BLW is approximately two times higher than the strength of the initial cement, and dilute BLW with 50 to 70% of the ground slag or quartz sand in their composition provided the same strength as the original Portland cement. Approximately 70 to 80% of the total contribution to the increase in strength was achieved due to a reduction in the water requirement of the mixture and the preparation of cement stone and mortar at sufficiently low values of the water-cement ratio and, accordingly, an increase in their density, and 20-30% due to an increase in the fineness of the grind and the specific surface of the cement And the creation of a more solid and monolithic fine-grained structure of the material [11-13].

The degree of influence of disperse additives on the general properties of composite materials can be explained by the following provisions. Composite materials are multicomponent and multiphase systems in which, when certain conditions are created, unique nonadditive properties are formed that are not inherent in the constituent components separately. For example, the main structural feature of polymeric composites is their ability to form specific structures of filler and matrix particles, such structures can include fractal (cluster) structures. Their formation is a process of self-organization in the composite, while a significant part of the energy transferred to the components of the composite is expended on the formation and flow of complex physicochemical processes in a dispersed medium. The phenomenon of self-organization is mainly due to the excess of surface free energy in the dispersive system. The phenomenon of self-organization in such a system makes it possible to control the properties of the composite in a controlled manner, as well as predict the change in its properties during the entire lifetime of such a product, because of the high adaptive variability of the system.

Numerous studies have shown that the most effective are composite binders obtained by intensive mechanochemical treatment of Portland cement with a mineral additive in the presence of a powdery superplasticizer.

In this paper, the task was to obtain finely dispersed binders with a specific surface area of 500 m$^2$/kg obtained on the basis of CEM I 42.5N produced by JSC Vostokcement. The dispersity of binders was evaluated by the specific surface area, which was monitored on the CPI-100 instrument. The tests were carried out at room temperature, the astringent was taken in a state of natural moisture.

The results of determining the specific surface of binders are given in Tables 2, 3, 4, and the kinetics of grinding is shown in Figure 1.
Table 2. Results of determination of specific surface area BLW-90.

| Type of binder | Duration of the binder grinding, h | Air temperature, °C | Layer height, cm | Device constants | Time of passage, s | Specific surface area, m²/kg |
|---------------|---------------------------------|---------------------|------------------|-----------------|-------------------|-------------------------|
|               | 0                               |                     | 1.17             |                 | 7.2               | 305                     |
|               | 1                               |                     | 1.20             |                 | 8                 | 319                     |
|               | 1.5                             | 20                  | 1.25             |                 | 447               | 8                      | 362                     |
| BLW-90        | 2                               |                     | 1.29             | 31.6            | 449               | 8.2                    | 398                     |
|               | 2.5                             |                     | 1.21             |                 | 11.8              | 407                    |
|               | 3                               | 21                  | 1.23             | 402             | 12.2              | 440                    |
|               | 4                               |                     | 1.17             | 448             | 12.7              | 501                    |

Table 3. Results of determination of specific surface area BLW-100.

| Type of binder | Duration of the binder grinding, h | Air temperature, °C | Layer height, cm | Device constants | Time of passage, s | Specific surface area, m²/kg |
|---------------|---------------------------------|---------------------|------------------|-----------------|-------------------|-------------------------|
|               | 0                               |                     | 1.15             |                 | 7.2               | 328                     |
|               | 1                               |                     | 1.17             |                 | 8                 | 351                     |
|               | 1.5                             | 23                  | 1.15             |                 | 447               | 8                      | 383                     |
| BLW-100       | 2                               |                     | 32.5             | 449             | 8.2               | 412                    |
|               | 2.5                             |                     | 1.17             | 402             | 11.8              | 445                    |
|               | 3                               |                     | 1.18             |                 | 12.2              | 495                    |
|               | 4                               |                     | 1.16             | 448             | 12.7              | 517                    |

Table 4. Specific surface area of binders, m²/kg.

| No | Duration of the binder grinding, h | BLW-90 | BLW-100 |
|----|---------------------------------|--------|---------|
| 1  | Base cement CEM I 42.5N         | 305    | 328     |
| 2  | 0.5                            | 319    | 351     |
| 3  | 1                              | 362    | 383     |
| 4  | 1.5                            | 398    | 412     |
| 5  | 2                              | 407    | 445     |
| 6  | 2.5                            | 440    | 495     |
| 7  | 3                              | 501    | 517     |
| 8  | 4                              | 305    | 328     |

Figure 1. Kinetics of grinding.
Aggregates are an important part of concrete and usually take up to 80% of its volume. They form a rigid framework, which has a significant effect on the processes of the structure of the binder, the rheological properties of the mixture, the physical and mechanical and other operational properties of concrete.

Experience in the preparation and laying of concretes shows that the use of a large aggregate with maximum size is not advisable, since this can lead to the formation of local leaks and caverns, and also complicates the packing and compacting of concrete. Therefore, it is expedient to use a filler with a maximum fineness of 25-40 mm. A significant influence on the properties of concrete is also provided by the shape of aggregate grains. Many researchers believe that the most appropriate application of aggregates of pellet form. The presence of flat and elongated impurities leads to a decrease in the density and uniformity of the concrete. At the setting stage, the inert surface of the aggregate is a substrate that facilitates the formation of crystalline embryos. In the future, their dimensions increase faster than crystals in intergranular space. This leads to an increase in the density of the contact layer of the cement stone, but at the same time increases the internal stresses and the detectiveness of the crystalline structure, since the recrystallization of neoplasms proceeds in confined conditions. In addition to size, shape and nature of the surface of aggregates, hydrophysical properties and activity of the surface of aggregates play a significant role in the formation of the structure and strength properties of concrete. Freshly crushed fillers due to ionization of the surface acquire physical and chemical activity, which contributes to the increase in strength of concrete.

As aggregates of fine-grained concrete, enriched screening of crushing of quartzite sandstones from the Razdolnenskoye field of Primorsky Krai (Russian Federation) were used. The results of the determination of the grain composition and the size modulus of screening are given in Table 5 and in Figure 2.

Table 5. Grain composition of quartzite sandwich screening.

| Sieve number | Remains on the sieves partial, $a$, Mass, g | Mass, % | total, $A_i$, Mass, % |
|--------------|------------------------------------------|---------|-----------------------|
| 5            | -                                        | -       | -                     |
| 2.5          | 320                                      | 32      | 32                    |
| 1.25         | 175                                      | 17.5    | 49.5                  |
| 0.63         | 275                                      | 27.5    | 77                    |
| 0.315        | 180                                      | 18      | 95                    |
| 0.16         | 20                                       | 2       | 97                    |
| Passage through a sieve | 20                                      | 3       | -                     |

Figure 2. Curves sifter aggregates in accordance with the requirements of GOST 26633-91. Curve 1 - the lower limit of the fineness of the sand (modulus of size 1.5); Curve 2 - the lower limit of the fineness of the sand (modulus of 2.0) for concrete of class B 15 and above; Curve 3 - the lower limit of the fineness of the sand (modulus of 2.5) for concrete of class B 25 and above; Curve 4 - the upper limit of the fineness of the sand (modulus of size 3.25). Curve 5 - screened screenings
\[ M_k = \frac{31 + 49.5 + 77 + 96 + 97}{100} = 3.50 \]

The value of the screening studied equal to 3.5 exceeds the upper limit of the size of sands.

In addition to plasticizing additives, to improve the plastic properties of concrete mixtures, it is recommended to increase the content of the finely dispersed component by adding fly ash. This additive does not adversely affect the strength and durability of the concrete. Investigation of the mechanism of interaction of superplasticizers and fly ash in composite binder was carried out earlier and as shown in [2-3, 14-16].

The use of carefully selected raw materials (production waste) makes it possible to create fine-grained concretes with high physical-mechanical and operational characteristics.

3. Conclusions
1. According to the obtained data it is possible to estimate the efficiency of grinding: grinding cement with a plasticizing additive in an amount of 0.5% of the mass of cement is more intensive; So the required specific surface area of 500 m² / kg is achieved after 3 hours of grinding, and not after 4 hours, as in the case of cement grinding without additives, in addition, the grain composition of the binder BLW-100 obtained in this case is characterized by a higher content of particles ranging from 5 to 20 μm, which ensures its higher activity.
2. According to physical and mechanical characteristics, quartzite sandstone can be used as aggregates in the preparation of fine-grained concrete.
3. Thus, the use of industrial waste in the construction industry, perhaps with careful selection of raw materials.

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