High-strength fibrous concrete of Russian Far East natural materials

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Abstract. Fiber-reinforced concrete is designed on composite binder. At 1.6% of reinforcing steel anchoring fiber maximum physical and mechanical properties (R_{compr} = 100.9 MPa) can be obtained. It was found that the combined effect of mechanical and chemical activation (the presence of limestone particles) increases the pozzolanic activity of acidic ashes. It has a catalytic effect on the reaction activity of the surface of ash and sand during machining in vario-planetary mill. Furthermore, the addition of limestone increases the alkalinity of the concrete, which leads to the formation of greater hydration products of cement per unit of time. Theoretical and experimental results can be recommended for expanded implementation of the construction in various regions of the Russian Federation, taking into account the availability of raw materials.

1. Introduction
In the production of concrete with improved properties it is necessary to pay special attention to the selection of aggregates (quality, size, surface configuration) which play an important role in the preparation of concrete with high physical-mechanical properties [1,2]. Increasing the size of aggregates entails correspondingly increase of stress concentrations in the concrete. Small aggregates also provide more homogeneous structure. The larger aggregate, the more concrete is prone to cracking, but at the same time a more rigid framework is formed, which is important to reduce the strain of the concrete under load.

In Primorye, it is advisable to use local raw materials, which are characterized by high activity silica-containing phases of man-made sand (in particular, elimination of crushed granite), obtained from crushing rocks.

Fine-grained structure, in addition to high homogeneity is also characterized by reduction of specific stress in the contact area and an increase of the integrated strength of adhesion between cement stone and aggregate.

Structure-forming role of filler is most developed with increasing surface of interaction, these conditions are realized in the fine-grained concrete with screenings of crushing of granite rubble of field Wrangel based on composite binders that due to the high surface intensify and accelerate the process of structure formation of concrete strength and seal structure.

To study the effect of composition on the binding properties of fine-grained concrete samples of concrete slump were produced in the range of 10-12 cm in the developed binder, which were further investigated for various technological parameters, standardized during construction.
2. Selection of the composition of high-strength fine-grained concrete

The author's analysis of the literature proves the possibility of producing dispersion-reinforced cellular concrete construction with high-performance. However, it is necessary to take into account that the implementation of the potential of fiber-reinforced concrete is only possible at creating the optimum structure of the material, the formation of which is determined by the following parameters:

- type and the quality of raw materials [3];
- technology of preparation of concrete mixtures [4];
- quantitative relationship between the components of fiber-reinforced concrete mixture.

The main factors determining the efficiency of designing of concrete and its construction and technical features are:

- obtaining the desired properties (strength, workability, and etc.) at the lowest possible consumption of costly and energy-intensive components;
- reducing the complexity of operations related to the selection of optimum compositions;
- verification of quality of control samples and testing at the factory.

The properties of fine-grained concrete are characterized by the same factors as the conventional heavy concrete, but the lack of it coarse aggregate leads to increased water demand of concrete, and in equally full-strength concrete cement consumption increases by 20 ... 40%. To reduce the consumption of cement it is advisable to use high-quality fillers, plasticizers, mixtures, to produce a good seal.

In the manufacture of fine-grained concrete it is advisable to use natural and enriched sand, crushed and granulated slag and ash, waste industry, including screenings of crushed granite. The properties of fine-grained concrete are highly dependent on the properties of the binder component in the concrete and aggregate used, grain structure, surface quality and water demand which determine the basic physical and mechanical properties of concrete. When you receive a fine concrete aggregate of smaller size and higher surface area compared to conventional heavy concrete is used, the presence of these factors leads to an increase of cement consumption, which negatively affects the physical and mechanical characteristics of fine-grained concrete. With increasing flow rate cement concrete shrinkage also increases significantly, fracture toughness decreases, its creep increases also.

Calculation of the composition is produced in accordance with the recommendations on the selection of compounds and heavy fine-grained concrete (state standard 27006-86).

Baseline data for the design of the composition:

- the desired strength - 100 MPa;
- the mobility of the concrete mix slump - 10-12 cm;
- activity of the composite binder - 77.3 MPa;
- screening of crushed granite with water demand 7% and the true density of 2.6 kg / l and a bulk density of 1.37 kg / l;
- sand with true density of 2.63 kg / l.

\[
W / C = \frac{A_1 R_{CB}}{R_c - A_1 \cdot 0.5 R_{CB}},
\]

coefficient \( A_1 \) is accepted by the reference literature [5].

\[
W / C = \frac{0.43 \cdot 77.3}{100 - 0.43 \cdot 0.5 \cdot 77.3} = 0.40
\]

According to the schedule in reference [5] water flow turned to be 220 l / m³.

\[
\tilde{N}_{\tilde{A}} = \frac{220}{0.4} = 550 \text{ &/m³}
\]

Emptiness of dropping out of granite rubble:
\[ E_{gr} = 1 - \frac{1.37}{2.6} = 0.47 \]

According to the handbook [5] extendable coefficient \( \alpha = 1.5 \).

The amount of filler:

\[ F = \frac{1000}{0.47 \cdot 1.5 + \frac{1}{2.6}} = 1623 \text{ g/m}^3 \]

Thus, an exemplary structure of the concrete mixture: composite binder - 550 kg/m\(^3\), a filler - 1623 kg/m\(^3\), water - 220 l/m\(^3\). The optimal composition will be selected by experimental verification.

3. Results

Research of physic-mechanical properties of fine-grained concrete showed that the use of the composite binder prepared by co-grinding of cement, fly ash and limestone, and hyperplasticizer allows to improve the characteristics of concrete, as compared to similar compositions made with other binding materials [6,7]. This fact is explained by more dense structure of cement stone of developed composite binder and lesser porosity due to the smaller amount of water in the concrete (Table 1).

| № composition | Material consumption per 1 m\(^3\) | Binder, kg | Screedsings crushing of granite, kg | Sand, kg | Slump | The compressive strength R, MPa | The elastic modulus, MPa |
|---------------|----------------------------------|------------|-----------------------------------|----------|-------|-------------------------------|-------------------------|
| 1             | 550                              | -          | -                                 | 220      | 107.5 | 86.3                          | 61.2                    |
| 2             | 278                              | 234        | 36                                | 330      | 83.7  | 59.5                          | 43.8                    |
| 3             | 265                              | 246        | 39                                | 334      | 84.2  | 60.3                          | 44.5                    |
| 4             | 252                              | 257        | 46                                | 337      | 76.3  | 55.2                          | 40.9                    |
| 5             | 239                              | 268        | 48                                | 343      | 75.2  | 55.0                          | 40.8                    |
| 6             | 225                              | 278        | 52                                | 348      | 75.0  | 54.9                          | 40.8                    |

The best physical and mechanical properties of the concrete compositions are '1 and '2: (they include cement - 48-51%, acidic ash - 43-45%, limestone - 4-9%).

It should be noted that with increasing amounts of ash and reducing amount of cement to ensure equal mobility formulations (slump = 10-12), it is necessary to increase the amount of mixture put into the concrete mixing water.

Despite a number of advantages, for example, with conventional heavy concrete, fine concrete has high shrinkage and modulus reduced by 20-25%.

Dispersion reinforcing of fine concrete with polymer and metal fibers opens great opportunities to improve the performance of the concrete.

In order to obtain high-density fiber-reinforced concrete the effect of the introduction of the concrete matrix of reinforcing fibers was studied. Composition number 2 from Table 1 was adopted as a basis for the concrete matrix.

To determine the optimal percentage of reinforcement of fine steel fiber concrete samples of the same composition with different steel fiber content (Table 2) were formed.
Table 2. The dependence of the strength of the fine steel fiber concrete reinforcement ratio

| № composition | Material consumption per 1 m³ | Reinforcement, % | R_{comp} MPa |
|---------------|-------------------------------|------------------|--------------|
| 2-1           | 550 330 1623 -               | 0                | 94.2         |
| 2-2           | 550 330 1623 23.97          | 1                | 96.1         |
| 2-3           | 550 330 1623 28.76          | 1.2              | 97.3         |
| 2-4           | 550 330 1623 33.56          | 1.4              | 99.8         |
| 2-5           | 550 330 1623 38.35          | 1.6              | 100.9        |
| 2-6           | 550 330 1623 43.15          | 1.8              | 99.5         |
| 2-7           | 550 330 1623 47.94          | 2                | 99.6         |

It was found that at the reinforcement of 1.4-1.6% by volume it is possible to obtain the maximum physical and mechanical properties. A further increase in the percentage of reinforcement is not advisable as it causes a decrease in strength and performance of steel fiber concrete.

For further optimization of structure, prevention of crack initiation, increase of strength and durability of the structure basalt fiber domestic production (Table 3) was used.

Table 3. The dependence of the strength of the fine basalt fiber concrete reinforcement ratio

| № composition | Material consumption per 1 m³ | Reinforcement, % | R_{comp} MPa |
|---------------|-------------------------------|------------------|--------------|
| 2-1           | 550 330 1623 -               | 0                | 94.2         |
| 2-2           | 550 330 1623 1              | 0.0004           | 95.6         |
| 2-3           | 550 330 1623 1.2            | 0.0005           | 95.9         |
| 2-4           | 550 330 1623 1.4            | 0.0006           | 96.3         |
| 2-5           | 550 330 1623 1.6            | 0.0007           | 97.1         |
| 2-6           | 550 330 1623 1.8            | 0.0008           | 98.2         |
| 2-7           | 550 330 1623 2.0            | 0.0009           | 98.1         |
| 2-8           | 550 330 1623 2.2            | 0.001            | 98.2         |

Comparing the experimental data on the tables 2 and 3 for further investigations we take steel fiber concrete according to number 5 (1.6% reinforcement).

4. Conclusion

Based on the abovementioned, it is obvious that it is possible to achieve high physical-mechanical properties of concrete, using local materials of the Russian Far East south. These features are implemented in the fine-grained concrete with screenings of crushing of granite rubble field Wrangel based on composite binders that due to the high surface intensify and accelerate the process of structure formation of a set of concrete strength and seal the structure.

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