TECHNOGENIC SANDS AS EFFECTIVE FILLER FOR FINE-GRAINED FIBRE CONCRETE

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Abstract. In the article the use of technogenic raw materials (dropout of quartzite sandstone crushing) as filler for concrete is considered. Methods of research of the filler by the leading scientists of Russia are given. The physical and mechanical characteristics of the filler such as: size modulus, bulk density, real density, voidness, water demand, cement demand, are considered. Studies prove the possibility of effective use of dropout of quartzite sandstone crushing as filler for fibre concrete.

1. Introduction
As fine filler in concrete, as a rule, natural sands are used. The most important characteristic of sand is grain (granulometric) composition, which is characterized by the size modulus. In accordance with GOST 26633-91 in concrete, small, medium and large sands are usually used (M from 1.5 to 3.25). However, it is allowed to apply very fine sand with M=1.0-1.5.

In the CIS, deposits of fine-grained, including polymineral sands, are dominated. They have not found proper use in the technology of concrete and reinforced concrete products yet. There are regions in which there are no large reserves of certified sand necessary for the concrete production. These are Central Asian States, some regions of Kazakhstan, the Baltic States, about 90% of the territory of the Russian Federation. In this regard, the solution of the issue of developing cost-effective compositions and energy-saving technologies for the concrete production using local materials and industrial waste as a filler is relevant [1 – 12].

2. Materials and methods
One of the most important points in the study of microstructure using SEM is the preparation of samples. Due to the fact that the chamber of SEM samples is in a high vacuum, the samples must be completely dry before studying their microstructure. Among the special methods of drying, the method of vacuum frost (sublimation) drying is the most effective. The essence of the method is “instant” freezing of wet samples at a temperature of liquid nitrogen (-196°C). In this case, all pore moisture, failing to crystallize, goes to solid pseudo amorphous condition. Such transition is not accompanied by a volume expansion of the formed phase and does not cause any destruction of the sample microstructure. Then the frozen
samples are transferred to the vacuum chamber of the sublimation setting, where they are dried at the desired negative temperatures due to the sublimation of frozen moisture in a vacuum.

B.G. Skramtaev and Yu.M. Bazhenov offered the testing method of the filler directly in the concrete, which provides the most reliable technological characteristics of the filler: water demand, cement demand and sand strength factor.

To determine the water demand of the sand, $W_s$, $(W/C)_s$ of cement paste is set at first, in which it shows on the shaking table the blurring of the cone of about 170 mm, which approximately corresponds to its normal density. Then $(W/C)_s$ of mortar mixture 1 : 2 on the test sand is determined, in which it has the same blurring cone (170 mm) on the shaking table. Water demand of sand (%) is found by the formula:

$$W_s = \frac{[(W/C)_s - (W/C)_c]}{2} \cdot 100.$$  \hspace{1cm} (1)

The denominator represents the number of sand parts per one part of cement, as $W_s$ characterizes the water demand of the unit of fillers’ mass. The water demand of the sand shows how much water should be added with the implementation of sand in the cement paste to retain a mobility indicator.

At testing cement, standard Volsky sand is often used, that has a relatively stable composition and granulometry. The water demand of this sand is 4 %. Water demand of any sand can be determined by setting $(W/C)_s$ on the test and $(W/C)_{s,m}$ – on standard sand, which achieves the same mobility (stiffness) of the mixture. In this case:

$$W_s' = \frac{(W/C)_s - (W/C)_{s,m}}{2} \cdot 100 + 4.$$ \hspace{1cm} (2)

The cement demand was determined as follows: a mixture was prepared with a constant ratio of $C/W = 2.5$, and the amount of dropout was selected by achieving a blurring of the cone, determined on the shaking table, equal to 170 mm.

Cement demand was calculated by the formula:

$$V_{com} = \frac{V_{cem.paste}}{V_{sand}}$$ \hspace{1cm} (3)

where $V_{cem.paste}$ – volume of cement paste in the mixture; $V_{sand}$ – volume of sand in the mixture.

3. Results and Discussion

The properties of technogenic sands, concrete mixtures and concretes based on them depend on many factors determined by the properties of the initial rocks, methods of their grinding and methods of enrichment of the resulting product. The strength, structure and composition of the rock have the most significant impact \[13 \text{–} 19\]. When comparing the properties of natural and technogenic sands, they pay attention to the main, fundamental differences of these materials. If the first are mainly quartz with a rounded shape of grains and a smooth surface, the second have significant differences in the composition and properties of the initial rocks, the shape of the grains and the roughness of their surface (Fig. 1. and 2).

The roughness of the fillers is closely related to the water absorption of the rock: the higher the roughness, the greater is the water absorption. By wettability of the filler surface it can be judged on its activity. The more active the filler surface is, the thicker the layer of water, attracted and held by it, is. At a low value of $C/W$, the greater thickness of the held water should reduce the delamination of the cement paste and thereby increase the adhesion in the solution or concrete. With a high $C/W$ value, it is impossible to form a thick cover of the liquid phase on the filler surface, as the ratio of the thickness of the liquid phase covers around the filler grains and cement will be determined by the ratio of their hydraulic activity. For high cement paste viscosity (due to the increased value of $C/W$) and sand with high water-holding capacity incomplete wetting of the filler surface and partial adhesion of the cement paste to the filler surface, which will significantly reduce the amount of adhesion between them, may occur, as a result. Therefore, to obtain high-quality concrete, it is better to use sand from well-wetted
rocks that hold little water on its surface.

![Natural sand grain](image1)

![KMA technogenic sand grain](image2)

**Figure 1.** Natural sand grain  
**Figure 2.** KMA technogenic sand grain

**Figure 3.** The dependence of water demand of dropout of quartzite sandstone crushing from the size of fractions

The determination of the cement demand was carried out as follows: while maintaining a constant ratio \(C/W=2.5\), the amount of filler was selected so that the consistency of the mixture corresponded to the diameter of its blurring on the shaking table of the LST is equal to 170 mm.

![Cement requirement vs. size of the dropout fraction](image3)

**Figure 4.** The dependence of cement demand of dropout of quartzite sandstone crushing on the size of fractions
Determination of the grain composition and size modulus of the dropout of quartzite sandstone crushing of Lebedinsky deposit of the Kursk Magnetic Anomaly was carried out by the method GOST 8735-88 “Sand for construction works. Test methods”.

The main physical and mechanical properties of traditional fillers are presented in table 1.

| N  | Name of the indicator       | Measure unit | Dropout of QSS |
|----|-----------------------------|-------------|---------------|
| 1  | Size modulus               | Ms          | 3.50          |
| 2  | Bulk density in uncompressed state | $P_{\text{bulk}}$, kg/m$^3$ | 1415         |
| 3  | Bulk density in compressed state | $P_{\text{bulk comp}}$, kg/m$^3$ | 1490         |
| 4  | Real density               | $P_{\text{real}}$, g/sm$^3$ | 2.71          |
| 5  | Voidness                   | $V_{\text{m, v.}}$, % | 47.8          |
| 6  | Water demand               | $W_{\text{drop}}$, % | 5.5           |
| 7  | Cement demand              | $C_{\text{demand}}$ | 0.530         |

4. Conclusion

Dropout of KMA quartzite sandstone crushing is characterized by a more diverse mineralogical composition (except for quartz, there is the presence of feldspars, mica, ore minerals). The form of grains (quartz and other minerals) is more developed: there are numerous chipped surfaces, sharpened and chipped places. This feature contributes to adhesion of particles during compression or vibration compaction into a solid monolith (on the principle of coupling). Finally, the minerals present in addition to quartz are able to participate independently in hydrothermal reactions with a binding agent, forming compounds and thereby contributing to the creation of the new formation structure. All this proves the possibility of using them as filler for fibre concrete.

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