

Optimization of fractional composition of Volga River sand for improvement of characteristics of mortars and concrete

A Y Zhigulina and S A Mizuryaev

Samara State Technical University, 194, Molodogvardeyskaya str., Samara, 443001, Russia

E-mail: auzhigulina@mail.ru

Abstract. The article is devoted to the use of fine sands to produce high-quality mortars and concrete. The problem of improving the quality (rheological and strength characteristics) of mortars and concrete without increasing cement consumption is being solved. The results of the study of the fractional composition of typical fine river Volga sand are presented. The results of the studies show that the method of fractional selection can significantly improve the rheology and strength of mortars and concrete with the effective use of screenings. Optimization of fine sands should not only consist in their enlargement due to the removal of fine fractions, but also in the selection of the optimal fractional composition.

1. Introduction

Currently, concrete and reinforced concrete are the main building materials. The characteristics of concrete largely depend on the materials used in their manufacture. A competent choice of materials for concrete, taking into account the characteristics and properties of concrete, as well as the properties of the starting materials, is of fundamental importance. It is known that concrete is an artificial material obtained by hardening a rationally selected mixture of binder, coarse and fine aggregates, and water [1, 2].

The concrete structure can conditionally be divided into a “frame” consisting of coarse aggregate, and a “matrix” - mortar part, including hydrated cement, fine aggregate and water.

2. Materials and methods

In concrete and mortar, all starting materials have a significant impact on their technological and operational characteristics. Small aggregate, which is most often used natural sands, is no exception. Ordinary natural sand is a loose mixture of particles with a particle size of 0.16 - 5 mm. Sand is formed as a result of the natural destruction of massive rocks. According to the mineralogical composition, natural sands can be divided into quartz, feldspar, limestone, dolomite and others. The most widely used in concrete and mortar are quartz sands.

The main problem of using natural sand as a fine aggregate in concrete and mortar is their fine grain size. Fine-grained sands have a high specific surface area, which leads to a deterioration in the rheology of concrete and mortars. The strength of concrete on such sands is low and to increase it requires an increased consumption of cement. The ratio of particles of various sizes (fractions) in the sand is also very important for obtaining high-quality concrete. Sand of monofraction composition has a high



intergranular porosity (up to 50-60 %). To obtain high-quality concrete on such sand, increased cement consumption is required. The smaller the volume of voids, the less cement is required to produce concrete. Therefore, sand for concrete should consist of grains of various sizes in a certain ratio (have a polyfractional composition) so that the volume of voids in concrete is minimal [3-7].

According to the standards adopted in Russia, the grain composition of sand is determined by sifting a certain amount of dry sand through a set of sieves with a hole diameter (from top to bottom) 10; 5; 2.5; 0.63; 0.315 and 0.16 mm. The residues formed on each sieve are weighed (partial residues) and their percentage of the total amount is calculated.

Total residues and particle size modulus are also calculated. The total residue is the sum of the private residues on all sieves with a large hole size plus the residue on this sieve.

3. Results

In the Volga region, ordinary Volga river sand is highly demanded as a fine aggregate. According to the mineralogical composition, these sands are quartz (Figure 1 and 2).



Figure 1. Ordinary Volga river sand



Figure 2. Ordinary Volga river sand under a microscope (scale 1 mm.)

Its tests showed the inconsistency of its grain composition with optimal values. In particular, trials of three samples showed the following (table 1 and 2).

Table 1. Partial and total sieve residues

Fraction (sieve)	Partial residues, a %			Total residues, A%		
	№1	№2	№3	№1	№2	3
2.5	0.41	0.20	0.51	0.41	0.20	0.51
1.25	0.20	0.20	0.20	0.61	0.41	0.71
0.63	1.43	1.53	1.53	2.05	1.93	2.24
0.315	54.71	54.12	60.82	56.76	56.05	63.06
0.16	43.24	43.95	36.94	100.00	100.00	100.00

Table 2. Fineness modulus of the test samples

Sample	Fineness modulus
№1	1.598
№2	1.586
№3	1.665
Average value	1.62

The results showed that the test sand refers to:

- by the total residue on a sieve of 0.63 (= 2.05) - to "very small";
- fineness modulus (= 1.62) - to "small".

It was decided that the optimization of the grain composition of the sand should consist in increasing its size due to the complete or partial removal of some fine fractions.

The following fractions were successively removed from the test sand and samples were made:

- sample No. 1-2 - removed a fraction of less than 0.16 mm;
- sample No. 1-2 - removed fraction less than 0.315 mm;
- sample 1-3 - fraction less than 0.63 mm removed.

The optimized grain composition of the studied samples is presented in table 3.

Table 3. Optimized grain composition of test samples

Fractions	Samples, residues, %							
	№ 1 (original)		1-1 (> 0.16)		1-2 (> 0.315)		1-3 (> 0.63)	
	Partial residues	Total residues	Partial residues	Total residues	Partial residues	Total residues	Partial residues	Total residues
2.5	0.41	0.41	0.72	0.72	20	20	66.67	66.67
1.25	0.20	0.61	0.36	1.08	10	30	33.33	100.00
0.63	1.43	2.05	2.53	3.61	70	100	0	0
0.315	54.71	56.76	96.39	100.00	0	0	0	0
0.16	43.24	100.00	0	0	0	0	0	0

For a preliminary assessment of the sand optimization results by successive removal of its fine fractions, a graphical analysis was used. The distribution curves of the total residues were superimposed on the graph of the distribution of sand over the total residues. The graph has three zones - the region of large sands, the region of fine sands and the region of optimum-sized sands. The results are shown in Figure 3.

4. Discussion

From the results of the graphical analysis it can be seen that none of the samples fully meets the requirements for the size of the aggregate.

By graphical analysis of the data obtained, it was found that the maximum "hit" in the region of the optimal grain composition has a mixed sample, consisting of 2 parts of sample No. 1-3 and 1 part of the fraction 0.315-0.63 mm, designated below as the sample No. 1-3-3-2. For further testing directly in solution, three samples were used:

- No. 1 - sand of the original composition;
- No. 1-1;
- No 1-3-2.

To determine the effect of optimized grain composition of sand on mortars, the following indicators were determined:

- rheology of the mortar (according to the cone spread on the shaking table and the value of the immersion of the StroyTSNIIIIL cone);
- strength in bending and compression.

The results of determining the rheology are shown in table 4.

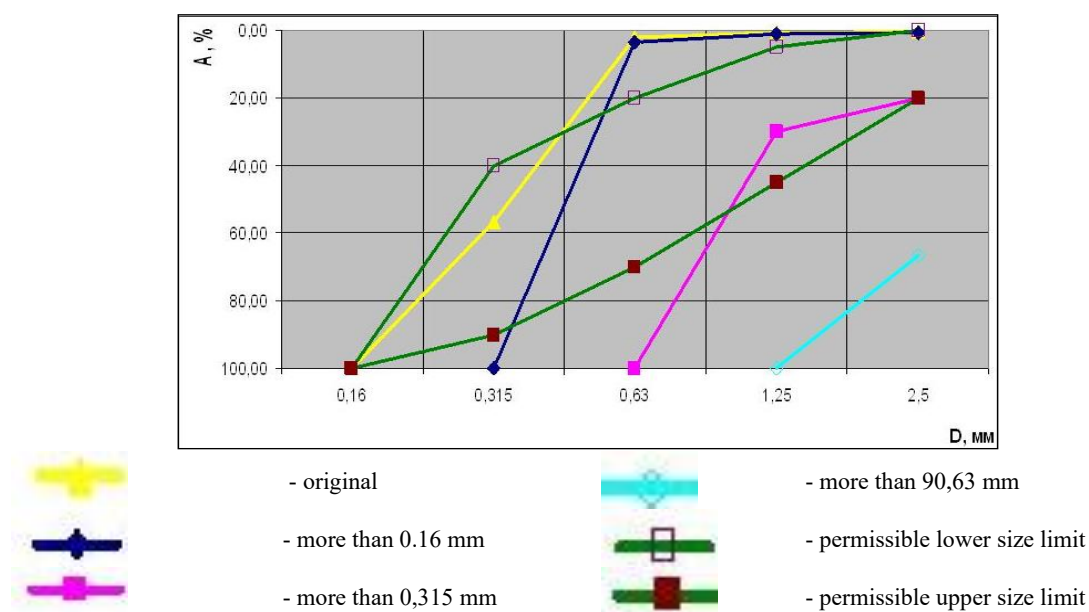


Figure 3. Graphs of suitability of sands by their grain composition

Table 4. The effect of grain composition on the spread and immersion of the cone

Samples	Cone spread, cm	Cone immersion, cm
№ 1 (original)	10.8	4.5
№ 1-1	11.3	6.4
№ 1-3-2	11.4	8.5

According to the above mentioned compositions with the same water-cement ratio, standard beams of 4 * 4 * 16 cm in size were made. The average values of the tensile strength of the beams during bending and compression are shown in table 5.

Table 5. Effect of grain composition on bending strength

Samples	Bending strength, MPa	Compression strength, MPa
№ 1 (original)	3.75	1.8
№ 1-1	3.82	1.9
№ 1-3-2	4.46	2.5

From the results of comparing the characteristics of concrete, it is seen that optimization of the grain composition of sand leads to an improvement in the strength of concrete based on it both in bending and in compression.

5. Conclusion

The optimization of the grain composition of fine sands clearly leads to an improvement in the characteristics of concrete and mortar obtained with their use. Both rheological and strength characteristics are improved.

The calculations show that the use of sand with an optimized composition while maintaining the rheological and strength characteristics of the concrete mixture will reduce cement consumption by 10 %.

Optimization of fine sands should not only consist in their enlargement due to the removal of fine fractions, but also in the selection of the optimal fractional composition.

References

- [1] Zhigulina A 2016 *City and town planning* **3 (43)** 47-49
- [2] Mizuryaev S, Zhigulina A, Mamonov A and Ivanova N 2011 *Construction Materials* **7** 12-13
- [3] Mizuryaev S, Chiknovorian A, Solopova G and Demidov R 2016 Some Aspects of the Development and Application of Silicate Expanded Aggregates in Lightweight Concrete Structures. *Procedia Engineering* **153**, pp. 599–603
- [4] Kudyakov A, Radina T and Ivanov M 2004 *Building Materials* **11** 12-13
- [5] Galitskov S, Mizuryaev S and Chiknovoryan A Heat resistant building envelopes made of lightweight concrete with the use of porous granular wastes 2017 *Technology. Resources. Proceedings of the International Scientific and Practical Conference* **3**
- [6] Lotoshnikova E, Usepyan L , Telegina V and Tsybenko E The issue of increasing the Products Durability Made of Fine-Grain Concrete *Materials Science Forum* **1**, available at: scientific.net/MSF.931.537
- [7] Bernard F and Gaffet E 2001 *Int. J. Self-Propag. High-Temp. Synth.* **10(2)** 109–132