

# Study of the expanded clay sand uses in surface and underground mine construction

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**Abstract.** The possibility of using expanded clay sand in surface and underground mine construction is considered in the article. As a result of the research, the material properties were studied, its uses were determined. The research has experimentally proven that expanded clay sand can be used as a base for concretes and mortars, which are suitable for mine construction by their properties. In the course of the research, samples of various compositions were made; the structure of the material is shown. Samples were tested to determine several physical and mechanical properties. Based on the experimental data, it was concluded that expanded clay sand can be used for mine construction projects, providing strength and heat performance of structures.

## 1 Introduction

In the Kemerovo region - Kuzbass, an industrialized coal region, there is a large volume of surface and underground mine construction [1-2], which requires a large number of different materials. The need for concrete and mortars for mine construction is significant and it requires the use of a large volume of expanded clay sand [3-5]. Expanded clay sand can be used in surface and underground mine construction.

In our country, a fairly large volume of expanded clay gravel is produced [6-8]. Expanded clay pebble is a round grain with internal pores and a dense external crust. The grain composition of the product obtained after calcination is not stable and includes particles of sizes from 0.14 to 70 mm.

Expanded clay with a grain size of more than 5 mm is called pebble, and expanded clay with a particle size of 0 to 10 mm is referred to as sand. The content of sand in the total mass of the product varies within wide ranges. It is not always fully in demand for haydite concrete production. Excess sand is generated in many industrial processes.

Expanded clay sand which is not used for haydite concrete production must be disposed of.

Environmental issues in the Kemerovo region - Kuzbass are especially acute, since there is a high load on the environment from coal mining enterprises and other industries. Many works of scientists are devoted to nature protection, pollution and environmental monitoring issues [9-12]. The production of materials using wastes from various industries

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can reduce the production of new building materials and reduce the volume of waste, which will have a positive effect on the environment of the region. The use of waste for the production of building materials is one of the research areas of KuzSTU, to which the works [13-17] are devoted.

The use of expanded clay sand instead of natural one will reduce the amount of added natural sand and the cost of solutions while ensuring the required product quality.

The aim of the work is to study the uses of expanded clay sand in mine construction.

## 2 Research methods

The possibility of several uses of expanded clay sand is considered in the work. The use of fine-grained expanded clay sand for construction purposes was studied. The main properties of sand - density and grain size composition - were studied.

Strength properties were studied on test samples of various compositions. The ratio of cement to sand varied from 1:2 to 1:5. The results obtained were compared with the results of similar samples with natural sand.

The possibility of using coarse expanded clay sand for construction purposes, namely in the production of blocks, which will include this sand, was studied. The properties of sand were studied and test samples with different ratios of cement to sand were tested for strength. The results obtained were compared with the results of similar tests of the samples with natural sand.

The possibility of using expanded clay sand to provide and improve the thermal performance of structures was studied. The thermal properties of the working mixtures with expanded clay sand and the use of such sand as a heater were studied.

The results obtained were compared with the results of testing control samples with natural sand.

The grain size composition of expanded clay sand was analyzed by screening with the standard screen set according to the State Standard GOST method.

To determine the strength, a test cube were made from mortar mixtures of various compositions, kept under normal conditions for 14 and 28 days and tested for compression. The tests were carried out by destructive and non-destructive methods.

## 3 Results and discussion

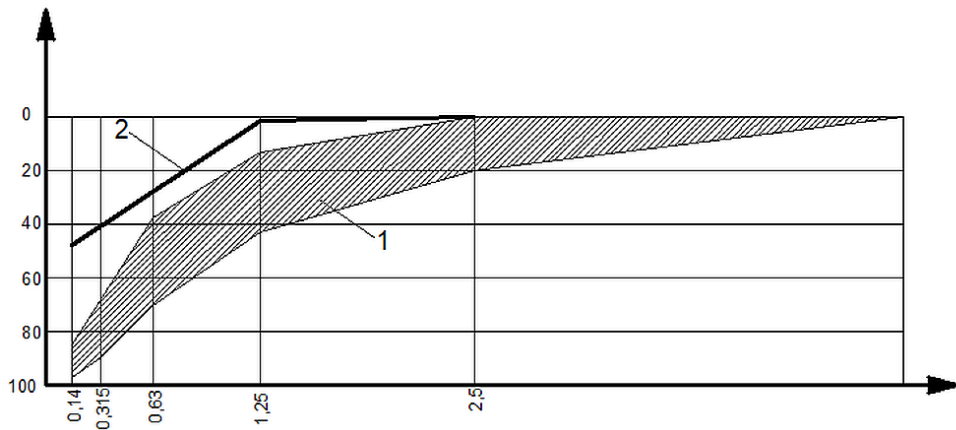
Expanded clay sand of two compositions was used for the research: fine-grained and coarse-grained. The main properties of the materials were determined in the laboratory.

The grain size composition of sand was determined by screening with the standard screen set. The results are presented in Table 1.

**Table 1.** Properties of expanded clay sand

Expanded clay sand	Density, g/m <sup>3</sup>		Total screenings, %						Fineness modulus, M <sub>fin</sub>
	true	packed	A <sub>0.14</sub>	A <sub>0.315</sub>	A <sub>0.63</sub>	A <sub>1.25</sub>	A <sub>2.5</sub>	A <sub>5</sub>	
fine-grained	2.6	-	50	25	2	0	0	0	-
coarse-grained	2.6	0.86	99	25	21	18	16	7	2.37

The particle size distribution was analyzed by comparing the fine-grained sand screen curve with the range of sands acceptable for the use in concrete in accordance with regulatory requirements. The result of the study is shown in Fig. 1.

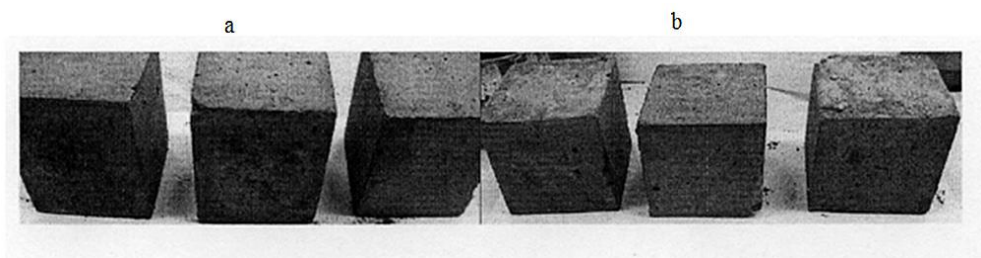


**Fig. 1.** Grain size curve: 1 - range of sands acceptable for the use in concrete; 2 - fine-grained sand screen curve

It can be seen from the graph that fine-grained sand does not fall into the range of sands acceptable for the use in concrete. This can possibly be corrected by adding coarse-grained sand to fine-grained sand. Then the curve can fall within the range of sands acceptable for the use in concrete, or get as close as possible to it, but this will require additional research and costs.

M400 Portland cement (class B32.5) was used to manufacture the samples. The samples were cubes with dimensions of  $7 \times 7 \times 7$  cm (Fig. 2). Figure 2 shows that the samples have a one-piece structure.

Strength tests were carried out by crushing the samples with a press and determining the force under which the sample was destroyed



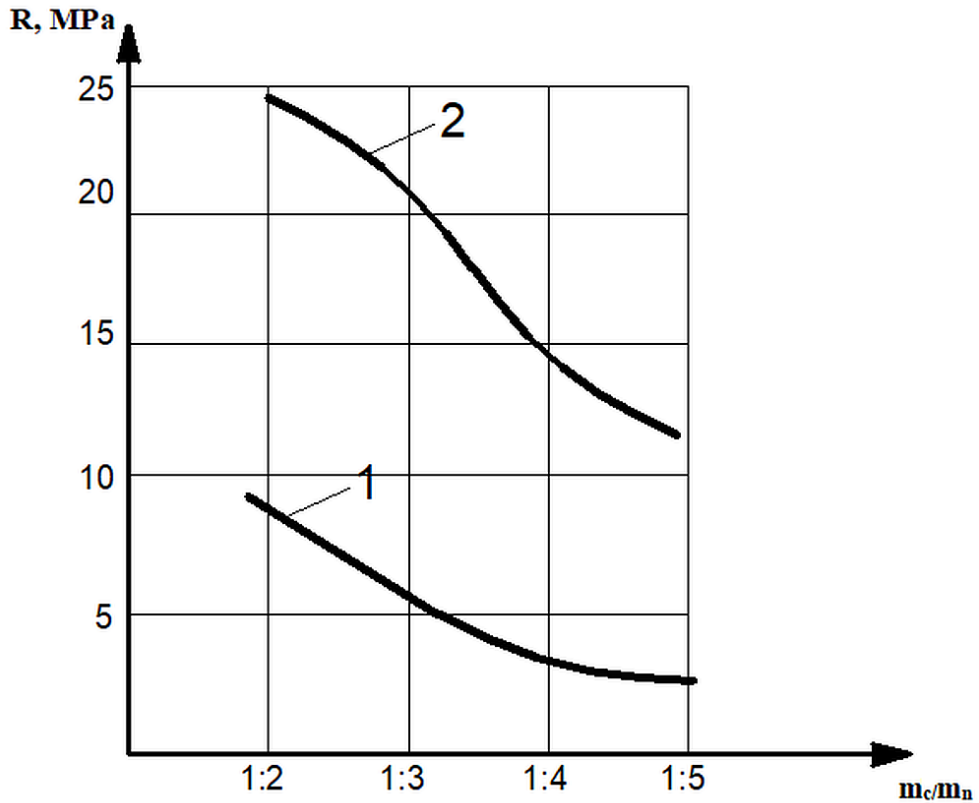
**Fig. 2.** Samples with fine-grained expanded clay sand: a - ratio of cement to sand is 1:2; b - ratio of cement to sand is 1:4

The results of testing are presented in Table 2.

**Table 2.** Properties of the test samples

Cement to sand ratio	Density, g/m <sup>3</sup>	
	Fine-grained expanded clay sand	Natural sand
1:2	1429	2024
1:3	1408	2069
1:4	1382	2094
1:5	1370	2143

Studies have found that with an increase in the proportion of sand in the composition of the solution, its strength decreases. The effect of the sand content in the mixture on the strength is shown in Fig. 3



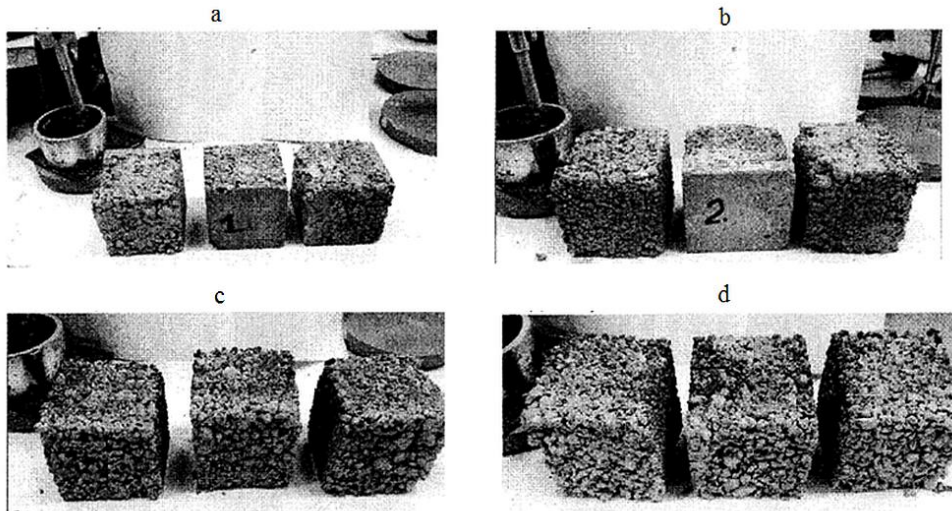
**Fig. 3.** Compressive strength versus concrete composition: 1 - with fine-grained expanded clay sand; 2 - with natural sand

The mixture compositions with coarse-grained expanded clay sand are presented in table. 3.

**Table 3.** The mixture compositions

Cement to sand ratio	Sand, kg	Cement, kg	Water, kg
1:2	1	0.5	0.3
1:3	1.2	0.4	0.3
1:4	1.2	0.3	0.2
1:5	1.25	0.25	0.17

The appearance of the test cubes is shown in Fig. 4. The figure shows that with a change in the proportion of expanded clay sand, the structure of materials changes and at a ratio of 1:5 it becomes coarse pored.



**Fig. 4.** Samples with coarse-grained expanded clay sand: a - ratio of cement to sand is 1:2; b - ratio of cement to sand is 1:3; c - ratio of cement to sand is 1:4; d - ratio of cement to sand is 1:5.

The results of testing samples with coarse-grained expanded clay sand for compression are presented in Table 4.

**Table 4.** Sample test results

Ce- ment to sand ratio	Press				ONIX 2.5 device						
	R <sub>1</sub> , MPa	R <sub>2</sub> , MPa	R, MPa		R <sub>1</sub> , MPa	R <sub>2</sub> , MPa	R <sub>3</sub> , MPa	R <sub>4</sub> , MPa	R <sub>5</sub> , MPa	R, MPa	
			14 days	28 days						14 days	28 days
1:2	18.3	11.6	14.95	18.9	13.6	16.9	10.3	8.2	10.7	11.9	15.09
1:3	9.39	3.06	6.23	7.89	14.5	5.8	12.6	11.9	13.6	11.6	15
1:4	1.88	2.92	2.4	3.04	14.7	12.8	5.5	8.5	7.5	9.8	12.4
1:5	2.14	2.14	2.14	2.71	11	11.5	5.8	8.1	6.9	9.74	12.33

The grain size composition of fine-grained sand is presented in Table 5.

**Table 5.** Properties of fine-grained expanded clay sand

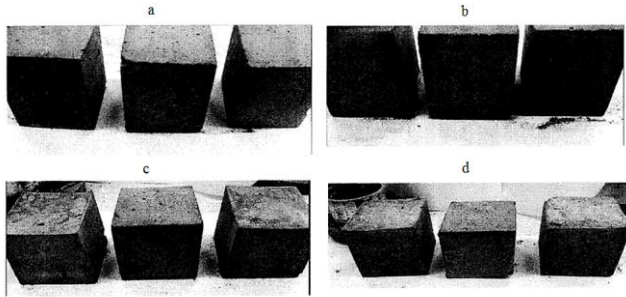
Sample weight	Grain size, mm						
	More than 5	2.5-5	1.25-2.5	0.63-1.25	0.315-0.63	0.14-0.315	Less than 0.14
2.06	-	-	-	0.46	0.34	0.52	1

The compositions of concrete with fine-grained expanded clay sand are presented in Table 6.

**Table 6.** The composition of concrete with fine-grained expanded clay sand

Cement to sand ratio	Sand, kg	Cement, kg	Water, kg
1:2	1.2	0.6	0.7
1:3	1.3	0.43	0.65
1:4	1.6	0.4	0.87
1:5	1.5	0.3	0.8

The appearance of the test cubes with fine-grained sand is shown in Fig. 5. It can be seen from the figure that the structure of the samples is dense.



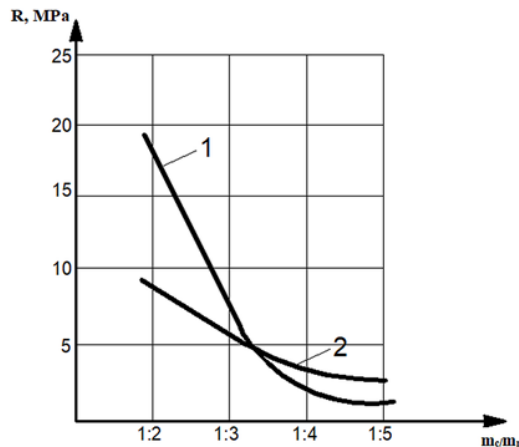
**Fig. 5.** Samples with coarse-grained expanded clay sand: a - ratio of cement to sand is 1:2; b - ratio of cement to sand is 1:3; c - ratio of cement to sand is 1:4; d - ratio of cement to sand is 1:5.

The results of testing samples with fine-grained expanded clay sand for compression are presented in Table 7.

**Table 7.** Concrete strength

Cement to sand ratio	Test method	
	Press	ONIX 2.5 device
1:2	8.315	11.14
1:3	5.71	9.06
1:4	3.97	8.02
1:5	3.18	6.58

The graph of the dependence of the compressive strength of concrete (press tests) on the ratio of cement to sand is shown in Fig. 6.



**Fig. 6.** Compressive strength of concrete (according to press data) versus the ratio of cement to sand: 1 - with coarse-grained expanded clay sand; 2 - with fine-grained expanded clay sand

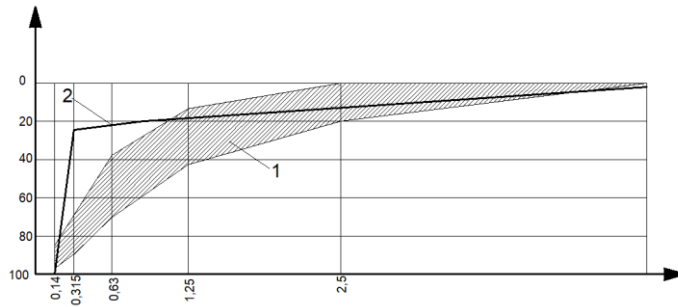
The graph shows that an increase in the proportion of sand of any kind leads to a decrease in the strength of concrete. At the same time, the comparative strength of coarse sand samples is significantly higher than that of fine sand samples.

The total coarse-grained sand screenings are presented in Table 8.

**Table 8.** Properties of coarse-grained expanded clay sand

True density, g/cm <sup>3</sup>	Packed density, g/cm <sup>3</sup>	Total screenings, %						Fineness modulus, M <sub>fin</sub>
		A <sub>0.14</sub>	A <sub>0.315</sub>	A <sub>0.63</sub>	A <sub>1.25</sub>	A <sub>2.5</sub>	A <sub>5</sub>	
2.6	0.86	99	25	21	18	16	7	2.37

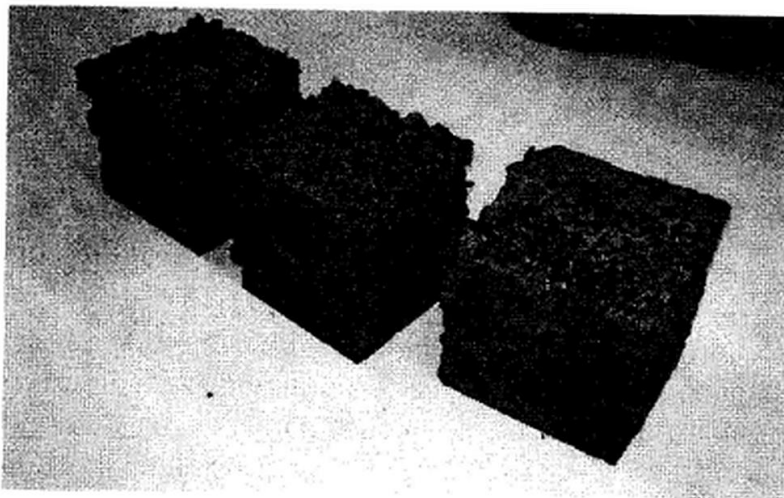
The analysis of the conformity of the grain size composition of coarse-grained sand to the requirements of regulatory documents is shown in Fig. 7.



**Fig. 7.** Grain size curves: 1 - range of sands acceptable for the use in concrete; 2 - coarse-grained sand screen curve

The graph shows that the coarse-grained sand screen curve does not fall within the acceptable range.

Samples are cubes of dimensions of 7×7×7 cm (Fig. 8).



**Fig. 8.** Photo of samples with coarse-grained expanded clay sand, the ratio of cement to sand is 1:2

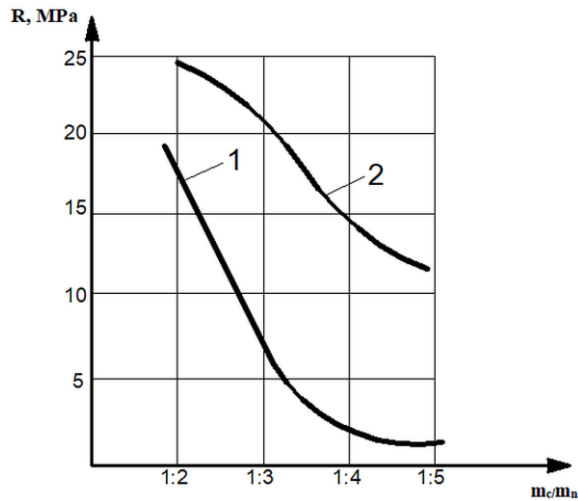
The figure shows that the structure of the samples is coarse.

The density of the samples of various compositions is presented in Table 9.

**Table 9.** Concrete density

Cement to sand ratio	Coarse-grained expanded clay sand	
	Coarse-grained expanded clay sand	Natural sand
1:2	1426	2024
1:3	1134	2069
1:4	1009	2094
1:5	988	2143

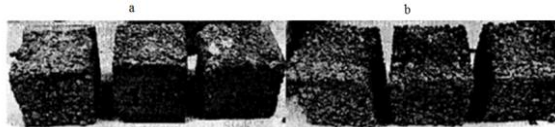
The graph of the dependence of the compressive strength on the composition is shown in Fig. 9.



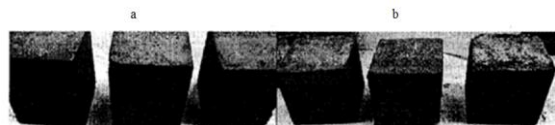
**Fig. 9.** Compressive strength versus composition: 1 - with coarse-grained expanded clay sand; 2 - with natural sand

The graph shows that the strength of the samples with natural sand is higher than that of the samples with expanded clay sand.

The samples were cubes with dimensions of 7×7×7 cm (Fig. 10, 11). The tests were carried out by crushing the samples with a press and determining the force at which the sample was broken. Compressive strength versus composition is shown in Fig. 12



**Fig. 10.** Samples with coarse-grained expanded clay sand: a - ratio of cement to sand is 1:2; b - ratio of cement to sand is 1:4

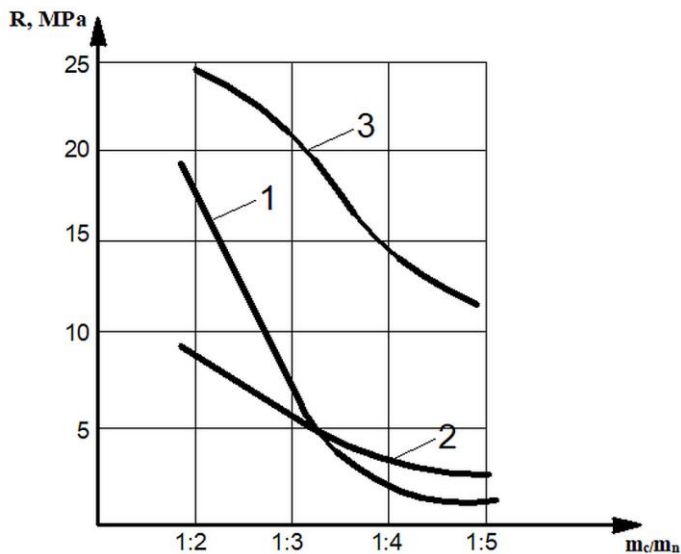




**Fig. 11.** Samples with fine-grained expanded clay sand: a - ratio of cement to sand is 1:2; b - ratio of cement to sand is 1:4

**Table 10.** Properties of the samples

Cement to sand ratio	Density, kg/m <sup>3</sup>		
	Coarse-grained expanded clay sand	Natural sand	Fine-grained expanded clay sand
1:2	1426	2024	1429
1:3	1134	2069	1408
1:4	1009	2094	1382
1:5	988	2143	1370



**Fig. 12.** Compressive strength of concrete versus composition: 1 - with coarse-grained expanded clay sand; 2 - with fine-grained expanded clay sand; 3 - with natural sand

The graph shows that the strength of the coarse-grained expanded clay sand samples with a composition of 1:2 is comparable to the strength of the natural sand samples. The strength of the fine-grained expanded clay sand samples is significantly lower than that of the compared sands.

An increase in the proportion of sand in all cases leads to a decrease in strength.

## 4 Conclusions

From the study it became evident that:

- the strength of the samples with expanded clay sand is somewhat lower than that of the samples with natural sand (see Fig. 3);
- the strength of the 1:2 composition with fine-grained sand is sufficient to use it for masonry mortar, or for finishing, because it makes the surface smooth (see Fig. 3). The measured densities show that the samples with expanded clay sand are lighter than those with natural sand. Therefore, their thermal conductivity is less.

Expanded clay sand, and in particular coarse-grained expanded clay sand, has a lower strength relative to that of natural sand. It became clear that the strength of the samples with expanded clay sand is somewhat lower than that of the samples with natural sand (see Fig.

9). The density of samples with expanded clay sand are much less than those of the samples with natural sand. Consequently, the thermal conductivity is lower, which means that the material can be used as a heater, or as structural and thermal insulation materials for auxiliary buildings.

– the strength of the samples with expanded clay sand is somewhat lower than that of the samples with natural sand (see Fig. 6). But the strength of the 1:2 ratio composition with fine-grain sand is sufficient to use it for masonry mortar, or for finishing, since it makes the surface smooth (see Fig. 4). Also, the measured densities show that samples with expanded clay sand (especially coarse-grained) are lighter than the samples with natural sand. Consequently, the thermal conductivity is less, which means that the material can be used as insulation, or as self-supporting walls of auxiliary buildings.

Thus, expanded clay sand can be used for surface and underground construction projects as an aggregate for masonry or finishing mortars for the manufacture of blocks and thermal insulation works.

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