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# STRENGTH CHARACTERISTICS CHANGE FOR FINE-GRAINED FIBER-TEXTILE CONCRETES WITH PLASTICIZERS

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**Abstract**

The quality of used building materials, products and structures makes a direct impact on the quality of constructed buildings and structures. Blocks and concrete wall stones became increasingly popular in building material market. Combining good performance, environmental friendliness and the availability of raw materials, they are widely used in progressive construction for the construction of multi-storey buildings, as well as in low-rise construction, the development of which is aimed at the realization of the national project "Affordable housing for Russian citizens". The study of strength characteristics of aggregate concrete wall stones made by vibration pressing with different plasticizing additives.

**Key words**: wall materials, wall material, strength, plasticizing additives, vibrocompression, mini-cone, dosage, fine fiber-textile concrete.

**Introduction**

Currently, the construction industry and utility development in Russia is directed and governed by economic, energy and environmental crises. In these circumstances, lightweight, cost-effective, energy-efficient, eco-friendly, non-flammable, durable construction materials, products and structures should be widely used, which will allow to design all types of buildings and structures from them, meeting the same requirements [1].

Nowadays wall materials are environmentally friendly, durable and reliable and safe materials that allow to erect buildings and facilities of the highest quality. The most popular and demanded materials are ceramic and silicate bricks, all kinds of blocks - aerated concrete, silicate and expanded clay, as well as small building blocks. These wall materials are often chosen for civil and industrial construction [2-3].

Nowadays in Russia and in the city of Belgorod a great popularity is gained by expanded clay, foam concrete and aerated concrete blocks. Their properties allow the use of these materials for the construction of both residential, industrial and commercial premises [4-5]. They allow to reduce the time of construction and installation works several times, to make significant savings in auxiliary materials cost and expenditure for caulking and a house structure strengthening [6].

The analysis of different country experience in energy saving problem solution shows that one of the most effective ways of its solution is to reduce heat loss through the enveloping of building structures. A building energy efficiency improvement involves the minimizing of energy consumption during the production and the use of building materials. In this regard the lightweight construction and construction-insulating concrete, characterized by high thermal resistances is claimed within the entire territory of Russian Federation [7].

The following hypothesis was put forward during the studies: the selection of an effective plasticizer will allow to get expanded clay masonry blocks, manufactured by vibration pressing with improved strength characteristics.

**Methods.** Compressive strength tests in respect of stones were determined in accordance with GOST 10180-2012 at the laboratory using the hydraulic press PMM-125. In order to carry out the monitoring according to the requirements of normative documents the blocks of SKTS 1R100 and SKTS2R100 samples were selected.

The following raw materials were used in the article:

1) Cement - PTS500DO (CEM I 42,5 N according to GOST 30515) of CJSC "Belgorod cement" ($\rho_i$ = 3120 kg/m$^3$ ρn = 1200 kg/m$^3$) (GOST 10178-85 Portland cement and slag Portland cement specifications).

2) Quartz sand from Kursk quarry ($M_k$ = 1.8), the moisture content of 3%, the bulk density makes 1350 kg/m$^3$. The quartz sand residue on the sieve № 063 up to 10% by weight, the content of the sand grains with the size of more than 10 mm does not exceed 0.5% by weight, and the grains larger than 5 mm - no more than 10% and the grains smaller than 0.16 mm - no more than 20% by weight. The content of dust and clay impurities in sand makes no more than 5%, and in lumps of clay the corresponding content makes no more than 0.5%. Sand is resistant to the chemical impact of cement alkali. The content of natural radionuclides in a fine aggregate makes no more than 370 Bq/kg.

3) Crushed granite fr. 5-10 mm from Novopavlovsk quarry with the density of 1345 kg/m$^3$, the moisture content of 1,2%, M-I200 ($\rho_i$ = 2670 kg/m$^3$ ρn = 1350 kg/m$^3$). A full residue on a sieve of 2.5 mm and 1.25 up to

100% by weight. The content of plate (bedplate) grains and needle grains makes 35-50%. The content of weak grains makes up to 5%. The content of clay lumps makes up to 0.25%. The content of dust and clay particles makes up to 1%. The brand of rubble by frost resistance is F 150. The content of natural radionuclides makes no more than 740 Bq/kg.

4) Expanded clay gravel (ρn = 550-600 kg/m3) "ZHBK-1 plant".

5) Additives (Murasan BWA 19, plasticizer C-3, Vibropor ZH 35 RB, technical lignosulfonate "LST", Relamiks, LMG, SB-3).

6) Water according to GOST 23732-2011 "Technical conditions. Water for concretes and mortars".

The cement slurry flowability was determined using a mini cone in order to determine a constant value of water-cement ratio, which made W/C = 0.35. The optimum dosage of studied additives was determined graphically according to a curve inflection at the maximum value mini cone breaking. Mini-cone method also evaluated the reduction of water demand for the cement paste with the studied additives during the obtaining of equally movable mixtures. Using the same method they determined the maximum possible reduction of water amount without the reduction of cement paste mobility as compared to the control sample ($d_0$ = 60 mm). The maximum possible amount of water was determined empirically - the graph of mini-cone breaking dependence on the percentage of mixing water reduction was developed [8-9].

**Main part**. The solution of an urgent problem of the XXI-st century, namely energy saving in the building material industry is possible through the use of industrial waste. The addressing of the priority national project implementation on waste management is possible due to large-scale use of fine-grained concretes on the basis of composite binders and technogenic sands of the Belgorod region. Recent advances of fiber concrete technology embodies textile-concrete most fully - a composite building material, in which a dispersed or a steel or textile reinforcement of polymeric, carbon or glass fiber is laid in a fine-grained concrete matrix, which leads to masonry efficiency increase. Recently, textile concrete is one of the most advanced types of concrete. This is an environmentally friendly material that does not require any significant energy costs in production. This composite material comprises such affordable components as cement, water, sand, fiber and chemical additives. The replacement of traditional natural sand by man-made one will significantly reduce the environmental pressure on the Belgorod region environment. Thus, the increase of aggregate concrete masonry efficiency is possible not only through the use of plasticizers, but also through the use of fine-grained fiber-textile concretes [10].

The walls of public buildings should be strong and sustainable; they should have a long life, corresponding to a building class; they should correspond to a building fire resistance degree; they must meet many requirements for resistance, thermal insulation, ecology, technology issue in construction process, the weight for the calculation of base pressure, they should have a beautiful appearance, be suitable for their purpose, meet the cost, be energy-saving element of a building; they should have heat resistance according to the thermo-technical standards and provide the necessary temperature and humidity comfort in buildings; they should have sufficient sound insulation properties; they should be constructed according to the modern methods of wall structure construction [4,7].

The analysis of wall material properties presented nowadays at the construction market are shown in Table 1.

The concept of a modern building creating with an efficient use of energy is quite topical at the moment. During the design of residential houses an economic factor should be determining one in comparison with others. A significant reduction of construction cost, the provision of the necessary structural safety, durability, material capacity and energy intensity reduction can be achieved by the use of optimal design solutions [11, 16].

**Table 1:** Comparative specification of wall materials.

| **Specification** | **Ceramic brick** | **Wood** | **Aerated concrete** | **Silicate brick** | **Expanded-clay concrete blocks** | **Wall insulation** |
|---|---|---|---|---|---|---|
| Density, $kg/m^3$ | 1000-1600 | 500-700 | 400-600 | 1300-1900 | 800-1400 | 1200-1400 |
| Thermal conductivity, $W/m^oS$ | 0,52-0,64 | 0,18-0,23 | 0,11-0,15 | 0,76-0,81 | 0,21-0,58<br>0,4-0,8 | 0,10 |
| Strength, $kgs/cm^2$ | 100-200 | 385-440 | 25-45 | 75-300 | 35-75 | 92 |
| Water absorption, % wt. | 18 | 30 | 25 | 16 | 8 | 12,7 |
| Frost resistance, cycles | 100 | 70 | 25 | 15-50 | 50 | 100 |
| Solution flow per $1m^2$ of masonry, $m^3$ | 0,36 | – | 0,011 | 0,51 | 0,11 | 0,009 |
| Wall thickness at the same heat conduction, m | 1,55 | 0,49 | 0,375 | 2,20 | 0,6 | 0,4 |
| The time required for the placing of 1 $m^2$ of wall, person / hour | 3,88 | 0,98 | 0,83 | 5,5 | 1,44 | 0,75 |

The reduction of energy consumption during a building operation is possible only during the application of protecting structures on the basis of efficient thermal insulation materials, which certainly include expanded clay wall materials. Their use as the part of wall structures can improve their durability, environmental friendliness in comparison with various layered walls [12-15].

According to the performed analysis of modern wall structures and heat engineering calculation of specific schemes for civil building walls of the city of Belgorod during further operation we will considered ordinary ceramsite concrete masonry units such as SCTS 1P and SCTS 2P of the grade 100. At that let's select original materials and the composition of concrete for their production with an effective additive (Fig. 1).

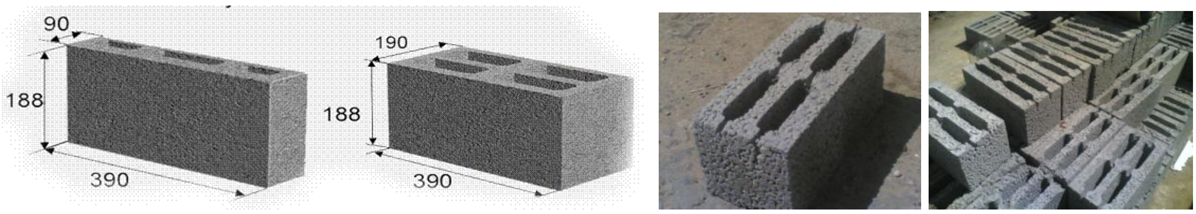


**Fig. 1.** Wall expanded-clay concrete bricks.

The development of modern high-quality expanded-clay concrete bricks for walls, the study of their strength characteristics with different plasticizing additives and the selection of an efficient wall construction with their application for the use in modern building within the trend of energy and resource saving, is the actual trend in modern construction [2, 17]. The material for lightweight aggregate concrete blocks is an expanded clay gravel, cement, fine sand and water.

Lightweight aggregate blocks (Figure 1) have a number of advantages over ceramic and silicate bricks: the proportion is 2.5 times lower than the masonry, which allows to reduce the load on the foundation; cement content of a lightweight aggregate laying is considerably lower than in a brick one, which leads to the reduction of building costs; one lightweight aggregate blocks replaces seven bricks by volume, which allows to reduce construction time; according to its environmental properties lightweight aggregate blocks are in one line with ceramic brick, as only natural, environmentally friendly raw material is used for their production; the insulating properties of lightweight aggregate concrete blocks make them preferable during their use in a warm and a cold climate. The disadvantages of expanded-clay concrete blocks as compared to heavy concrete and brick is the following one: they have high porosity and friability, which reduces their physical-mechanical characteristics such as strength, frost resistance and density.

During the manufacture of lightweight aggregate concrete stones Portland cement PTS500DO (CEM I 42,5 N according to GOST 30515) of CJSC "Belgorod cement" was used as a binder ($\rho_i$ = 3120 kg/m$^3$ $\rho_n$ = 1200 kg/m$^3$).

Cement brand was determined by bending strength limit of bar samples 40*40*160 mm, and the compression of their halves made of the solution 1:3 with standard monofractional sand. Flexural strength limit was not less than 5.9 MPa at the compression of no less than 49 MPa. The mass fraction of sulfuric acid anhydride does not exceed 3.5% by weight according to GOST. The fineness of cement grinding cement at the sieving of cement sample through the sieve with the mesh number 008 in accordance with GOST 6613 makes at least 85% of a sample weight. The start of setting began at least 45 minutes after mixing, and the end of the setting began no later than 10 hours after mixing.

Originally they studied a mineral and a content composition of a binder that meets the requirements of GOST 31108-2003. The radiograph of cement is shown on Fig. 2.

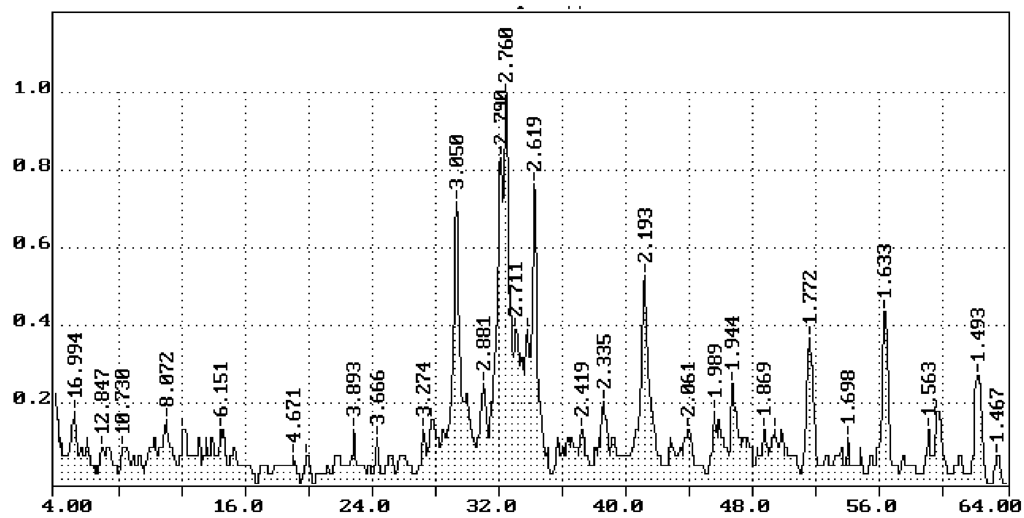


**Fig. 2.** X-ray analysis of Portland cement CEM I 42,5 H.

Chemical (determined in accordance with GOST 5382-91) and mineral composition of applied Portland cement is presented in Table 2 and 3.

**Table 2.** Chemical composition of Portland cements.

| Binder type | $SiO_2$, % | CaO, % | $Al_2O_3$, % | $Fe_2O_3$, % | CaO sv., % |
|---|---|---|---|---|---|
| CEM I 42,5 H | 22,49 | 67,22 | 4,77 | 4,40 | 0,20 |

**Table 3.** Mineral composition of Portland cements

| Binder type | $C_3S$, % | $C_2S$, % | $C_3A$, % | $C_4AF$, % | KH | P | N |
|---|---|---|---|---|---|---|---|
| CEM I 42,5 H | 65,4 | 18,1 | 4,1 | 12,4 | 0,91 | 1,11 | 2,36 |

They also used the expanded clay sand of M700 brand as a fine filler for lightweight aggregate concrete stone preparation for walls. These sands should not contain any foreign clogging impurities (Figure 3). Expanded clay sand (the screening of crushed expanded clay) - the filler for light concretes and mortars with a particle size from 0.14 to 5 mm is obtained by firing clay fines in rotary and shaft furnaces or by crushing some larger pieces of expanded clay and also by the sifting of waste during expanded clay production.

An expanded clay gravel produced by the crushing of expanded clay chunks was used as a large filler (Fig. 3).

**Fig. 3.** Expanded clay gravel, crushed stone and sand

During the selection of initial material characteristics the strength of a porous filler was determined, which is an important indicator of its quality through the compression of grains in a cylinder by a steel punch to a predetermined depth. The standard practice provides a free filling of expanded clay gravel into a cylinder and then its squeezing with an original volume reduction by 20%. Under the impact of load the compaction of gravel takes place first of all due to some displacement of grains and their more compact laying. The test results of expanded clay gravel are presented in Table 4.

In the course of this work the cement slurry flow rate was measured using a mini cone to determine a constant value of water-cement ratio, which made W/C = 0.35.

An original required value of water-cement ratio (W/C) was determined initially, equal to 0,35 (d0 = 60 mm). Thus, the set amount of water will be used to determine the optimal dosages of studied additives. 100g of cement + 35ml of water + 0.1; 0.2; 0.3; ... 0.4% of the cement weight (in terms of dry matter).

**Table 4.** Expanded clay gravel test results

| Filled up clay density (kg/cub. m) | Strength limit at a cylinder compression, MPa, no less than | Strength grade | Hole diameters of test sieves, mm and their residues, % | | |
|---|---|---|---|---|---|
| | | | 7,6 | 5 | дно |
| 544 | 3,5 | П150 | 49,4 | 39,9 | 4,7 |
| 550 | 3,5 | П150 | 47,9 | 37,9 | 4,2 |
| 540 | 3,5 | П150 | 46,8 | 38,6 | 4,5 |
| 548 | 3,5 | П150 | 50,1 | 40,3 | 4,6 |
| 550 | 3,5 | П150 | 49,8 | 39,8 | 4,5 |

The introduction of additives in a concrete mixture improves technological, mechanical and rheological properties of concrete. That is, the properties of concrete and mortar mixes are improved from the date of manufacture, transportation to the laying into a boxing. The periods and the mechanisms of artificial conglomerate hardening are regulated optimally, their structure and final characteristics are improved. Therefore, a great attention is paid to the use of chemical additives in concrete technology. While working on structure formation processes, especially at at an initial (coagulation) stage, super plasticizers modify the rheological properties of a cement system, help to reduce its water demand, which further influences the the parameters of a crystal structure. Thus, it can be assumed that the mechanism of superplasticizer action is in a physical adsorption of macromolecules on the active centers of a binder, leading to solid phase particle internal friction and its dispersion reduction. Subsequently, after the appearance and the accumulation of calcium hydroxide in a system a chemical reaction of the functional groups of superplasticizers with calcium hydroxide takes place, leading to the neutralization of molecules and their disposal from the surface of cement grains.

The optimum dosage of studied plasticizers was determined according to the plasticizing ability determination methods. The graphs were developed according to the obtained results concerning the amount of additive dependence on a mini-cone breaking diameter and minimum dosages were determined, at which the maximum plasticizing effect is achieved, that is, when the curve reaches saturation (Figure 4).

As you can see, all curves are S shaped. In low dose areas plasticization is demonstrated weakly, then the spread increases sharply with dosage increase and becomes almost constant one at further increase of studied additive dosages. The same S shapes are typical of other superplasticizers and manifest the same during the testing according to a large cone method. The test additives are superplasticizers. The plastifying activity, which is determined as a superplasticizer dosage needed to achieve the maximum effect of dilution makes 0.35, 0.45, 0.3, 0 , 45, 0.4, 0.4% and 0.8% from the weight of cement for SB-3, C-3, LMG, LST, Murasan, Vibropor and Relamix respectively (Figure 4). This optimal dosage is determined by the concentration of a superplasticizer, at which the inflection of a curve is observed and the obtaining of a mini cone maximum spread is observed.

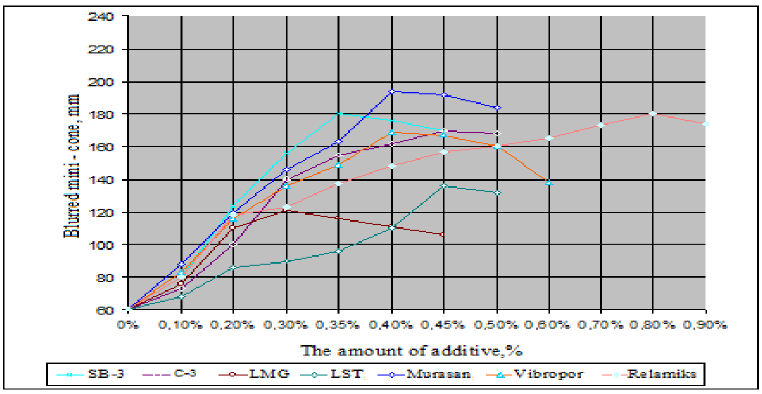


**Fig. 4.** Dependence of cement paste mini-cone spread on the amount of additives.

Using the method of mini-cone it is also convenient to assess the reduction of water demand for a cement paste with the additives during the preparation of equally movable mixtures. Figure 5 shows the dependence of the cement paste with optimal dosages of superplasticizer mobility on water reduction. The mobility of a control sample without additives made 60 mm. The maximum possible amount of water was determined empirically - the graph of a mini-cone breaking dependence on mixing water percentage reduction (Figure 5) was developed for this purpose.

When they use superplasticizers the water demand decrease takes place to 35%. Consequently, using superplasticizers for a concrete mix mobility increase, it can be noted that SB-3, Murasan, Vibropor and Relamix additives are more effective than the known additive S-3. Thus, in the future the experimental studies of strength characteristics for lightweight aggregate concrete stones for walls made by vibrocompression, will be conducted directly with SB-3, S-3, LMG, Murasan, Vibropor and Relamix supplements.

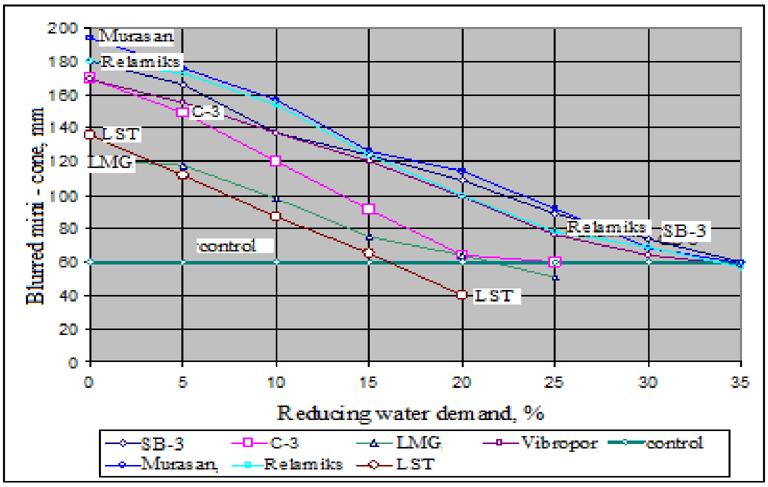


**Fig. 5.** Water demand reduction for cement paste with additives.

The quality of lightweight aggregate concrete wall stones and their work are determined by its properties (Table 5).

**Table 5.** Test results of SCTS-1 stones, brand M100

| Item # | Concrete age | Geometric dimensions, cm | Weight, kg | Press indicator, kN | Compressive strength , kgs/cm$^2$ |
|---|---|---|---|---|---|
| *with Murasan additive* | | | | | |
| 1 | project | 39,0x19,0x18,8 | 16,9 | 711,3 | 96 |
| 2 | | 39,0x19,0x18,8 | 17,1 | 700,3 | 95 |
| 3 | | 39,0x19,0x18,8 | 16,7 | 724,0 | 98 |
| 4 | | 39,0x19,0x18,6 | 16,6 | 702,6 | 95 |
| 5 | | 39,0x19,0x18,8 | 17,3 | 695,0 | 94 |
| 6 | | 39,0x19,0x19,0 | 17,0 | 699,2 | 94 |

| | | | | | |
|---|---|---|---|---|---|
| *with Vibropor additive* | | | | | |
| 1 | project | 39,0x19,0x18,8 | 16,7 | 700,3 | 95 |
| 2 | | 39,0x19,0x18,8 | 16,6 | 718,8 | 97 |
| 3 | | 39,0x19,0x18,8 | 16,5 | 700,3 | 95 |
| 4 | | 39,0x19,0x18,8 | 16,4 | 695,0 | 94 |
| 5 | | 39,0x19,0x18,8 | 16,7 | 695,0 | 94 |
| 6 | | 39,0x19,0x18,8 | 16,7 | 695,0 | 94 |
| *with Relamix additive* | | | | | |
| 1 | project | 39,0x19,0x18,8 | 16,7 | 700,3 | 95 |
| 2 | | 39,0x19,0x18,8 | 16,3 | 695,0 | 94 |
| 3 | | 39,0x19,0x18,8 | 16,5 | 689,1 | 93 |
| 4 | | 39,0x19,0x18,8 | 16,6 | 695,0 | 94 |
| 5 | | 39,0x19,0x18,8 | 16,7 | 681,7 | 92 |
| 6 | | 39,0x19,0x18,8 | 16,5 | 689,1 | 93 |
| *with LMG additive* | | | | | |
| 1 | project | 39,0x19,0x18,8 | 16,5 | 681,7 | 92 |
| 2 | | 39,0x19,0x18,8 | 16,5 | 674,3 | 91 |
| 3 | | 39,0x19,0x18,8 | 16,6 | 666,9 | 90 |
| 4 | | 39,0x19,0x18,8 | 16,6 | 681,7 | 92 |
| 5 | | 39,0x19,0x18,8 | 16,7 | 681,7 | 92 |
| 6 | | 39,0x19,0x18,8 | 16,6 | 666,9 | 90 |
| *with S-3 additive* | | | | | |
| 1 | project | 39,0x19,0x18,8 | 16,8 | 637,3 | 86 |
| 2 | | 39,0x19,0x18,8 | 16,9 | 644,7 | 87 |
| 3 | | 39,0x19,0x18,8 | 16,7 | 622,4 | 84 |
| 4 | | 39,0x19,0x18,8 | 16,7 | 622,4 | 84 |
| 5 | | 39,0x19,0x18,8 | 16,8 | 615,0 | 83 |
| 6 | | 39,0x19,0x18,8 | 16,6 | 607,6 | 82 |
| *with SB-3 additive* | | | | | |
| 1 | project | 39,0x19,0x18,8 | 16,6 | 700,3 | 95 |
| 2 | | 39,0x19,0x18,8 | 16,7 | 711,3 | 96 |
| 3 | | 39,0x19,0x18,8 | 16,8 | 718,8 | 97 |
| 4 | | 39,0x19,0x18,8 | 16,6 | 700,3 | 95 |
| 5 | | 39,0x19,0x18,8 | 16,6 | 711,3 | 96 |
| 6 | | 39,0x19,0x18,8 | 16,7 | 700,3 | 95 |

The durability of LECA stones for walls is an integralcharacteristic, which depends on component properties, its composition, preparation conditions, curing, testing and operation. According to the results of aggregate concrete stone tests like SCTS-1 of M100 brand with M100 strength and test additives it was found that the proposed compositions allow to obtain the wall materials with desired strength characteristics (Table 5).

Within the developed market relations it is important to evaluate the application of additives in economic terms. The calculation of economic efficiency with the use of additives is performed. The following conclusions may be drawn as the result of performed calculations: the use of SB-3 and Murasan additive leads to a significant reduction of 1 $m^3$ of concrete cost, rather than the use of S-3, Vibropor ZH 35 RB, Lignosulfonate technical "LST", Relamix and LMG additives. This is achieved by the ability of these additives to save a greater amount of cement, and this additive allows to obtain the concrete with higher strength, frost resistance and durability.

Concrete compositions for the manufacture of wall stones are presented in Table 6.

**Table 6.** The composition of wall concrete stone wall like SKTS1R100.

| Name | Meas. Un. | amount, per $m^3$ of mixture | per 1 pcs |
|---|---|---|---|
| Wall stone SKTS1R100 | | | |
| BWA-19 additive | kg | | 0,0000 |
| Kursk sand | tn | 0,350 | 0,0040 |
| Cement 500 | tn | 0,380 | 0,0027 |
| Crushed expanded clay | tn | 0,5500 | 0,0055 |
| Water | $m^3$ | 0,1630 | 0,0014 |
| Wall stone SKTS2R100 | | | |
| BWA-19 additive | kg | | |
| Kursk sand | tn | 0,370 | 0,0021 |
| Cement 500 | tn | 0,400 | 0,0014 |
| Crushed expanded clay | tn | 0,5500 | 0,0029 |
| Water | $m^3$ | 0,2200 | 0,0007 |

According to the test results they determined that the proposed compositions allow to obtain the wall materials with desired strength characteristics.

The concrete blocks and stones for walls become increasingly popular at building material market of our region. They are made of aerated concretes, expanded clay, hard and fine-grained concretes, etc. The range of concrete wall stones includes solid and hollow articles with different emptiness. Combining good performances, environmental friendliness and the availability of raw materials, they are widely used in progressive construction for the erection of multi-storey buildings, as well as in low-rise construction, the development of which is aimed at the implementation of the national project "Affordable housing for Russian citizens". Concrete wall stones manufactured by vibrocompaction have excellent performances and compete successfully with such common construction material like silicate brick.

The following conclusion was made on the basis of numerous experimental data: the results of this study indicate the possibility of strength characteristics significant increase concerning lightweight aggregate concrete stones for walls through the use of superplasticizers in their composition.

**Summary**. Thus, modern energy - resource saving construction has special demands in respect of used construction materials. Often, the materials traditionally used in capital construction do not fully meet the increased requirements in terms of enveloping structure thermal efficiency, energy saving and construction work reduction. With the significant increase of energy prices, the need for the construction of buildings and structures, which fully meet modern heat engineering standards and requirements, is particularly relevant. A sharp increase of production volumes for wall materials of low thermal conductivity confirms once again the prospectivity of this area. Expanded clay masonry units are the absolute leaders among the thermal efficient wall materials. Small sized masonry blocks, panels and plates made from these materials are widely used in low-rise and in high-rise housing construction. Nowadays wall materials must be environmentally friendly, durable, reliable and safe that allow to build a house of the highest quality.

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