

Analysis Of Compositions Of Ceramsite Ash-Slag-Concrete For Monolithic Building Construction

A. V. Uglyanitsa, N. V. Gilyazidinova, N. Y. Rudkovskaya, T. N. Santalova

*Kuzbass State Technical University named after T. F. Gorbachev,
Kemerovo, Vesennyya St., 28*

Abstract

This paper describes selection of compositions of constructional and constructional-heat-insulating ceramsite ash-slag-concrete of classes B5-B15 with the frost resistance grade F35-F75 for monolithic building construction; the technique of production and placing of concrete in the structure. For these scientific studies ceramsite combined with ash slug waste from combustion of the Kuzbass coal was used. As the result of placing concrete into a vertical formwork the wall structures get a smooth surface, homogeneous concrete structure over the entire thickness, strength and thermo technical characteristics allowing using concrete for production of the external and internal walls of the heated buildings. The basis for development of this subject was also the issues related to pollution of the environment of the Siberian region. The economic potential of the use of ceramsite ash-slag concrete consists in reduction of the product cost due to the use of cheaper materials, increase in the performance by reducing the labor intensity of erection of external walls of buildings and excluding additional actions for heat insulation. Implementation of the research findings will allow minimizing the negative man-made impact on the environment due to waste disposal and release of lands for more efficient use thereof.

Keywords: Ceramsite, ash-slag mixture, ceramsite ash-slag concrete, monolithic building construction, frost resistance, strength.

1. INTRODUCTION

Today monolithic concrete for production of which natural fillers are used is widely applied in construction [1, 2, 3]. Heavy weight concrete is used primarily by erection of internal walls and external ones are made from small piece materials with heat insulation. Such construction requires significant material consumption and special

techniques for heat insulation of facades and removal of thermal bridges. In 2013, within the frameworks of the Federal target program “Scientific and scientific-pedagogical staff of the innovative Russia’ for the years 2009-2013 employees of the Kuzbass State Technical University named after T. F. Gorbachev performed research activities on the subject ‘Technology of construction of monolithic buildings from ceramsite ash-slag concrete’. The findings of this work show that one may construct both the internal and external support structures of buildings from the same material – lightweight ceramsite ash-slag concrete requiring no heat insulation and additional façade finishing.

Today a lot of wastes accumulated on the Kuzbass territory find a slightly use by production of slag blocks at the same time the dump areas increase steadily [4, 5, 6, 7]. This is why the proposed technology of construction of monolithic buildings from ceramsite ash-slag concrete solves the following problems:

- removal of dumps that pollute the environment;
- replacement of natural materials through relatively inexpensive wastes of the fuel and metallurgical industry;
- improvement of the concrete performance in terms of strength, frost resistance, resistance to aggressive environments, etc.;
- production of bearing and enclosing structures featuring high strength, heat- and soundproof specifications.

During performance of the research work the tasks aimed at achieving the goal set were solved:

- to establish the regularities of impact of the concrete composition on the structural strength and durability [8];
- to design the optimal composition of the concrete mix with the specified specifications ensuring the quality of the structural surface [9];
- to select the most appropriate kind of formwork for construction of monolithic structures.

2. ANALYSIS OF CLAYDITE GRAVEL

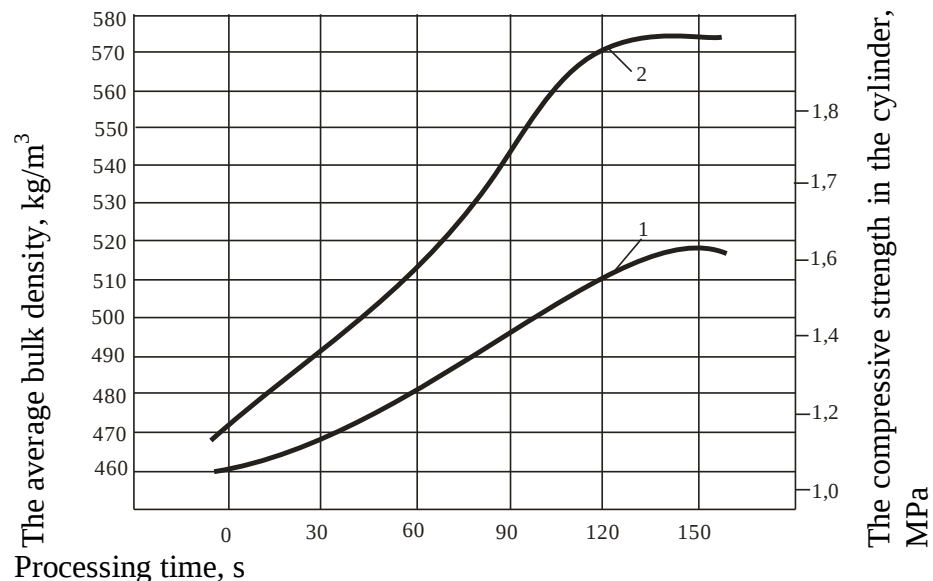
By performance of the laboratory experimental tests in order to establish the trend of impact of the concrete composition on the structural strength and durability as the binder the Portland cement of the grade 400-500 (the actual activity by curing varied in different batches from 30 to 46 MPa) was used. The fineness determined by the rest on the sieve 008 made 0,9%; such cement belongs to the fine-grained binders. Ceramsite was used as a coarse aggregate for the light-weight concrete. Presence of fine particles in the ceramsite gravel makes 0,5% which stays within the standard maximum according to GOST 9757-90 [10]. Frost resistance of the ceramsite gravel by testing according to GOST 9758-86 [11] was determined by the weight loss after 15 cycles of alternating freezing and thawing and makes 12% which exceeds the performance standard (8%). Therefore, according to the GOST requirements the ceramsite gravel may be used in structural and structural – heat-insulating light-

weight concretes only after testing concrete for frost resistance [12].

As part of testing of ceramsite gravel it was found out that ceramsite is not homogeneous by average density and grading [13]. Its bulk density varies from 400 to 800 kg/m³, thus, by assigning the specified average density one should rely on the maximal possible values of its bulk density. The ceramsite gravel under consideration does not contain fractions 0,14-5 corresponding to the fine aggregate for ceramsite concrete this is why it makes sense to use the turbulence mixer – activator for production of ceramsite concrete активатор. During the mixer operation the partial crushing of ceramsite with formation of fine fractions takes place as well as breaking of the external surface of the coarse aggregate and activation thereof which have a favorable effect on the physical-and-mechanical characteristics of the concrete. The results of testing the crushing modes are presented in the Fig. 1 (a, b).

As can be seen from the figures presented along with increase in duration of the ceramsite gravel crushing up to 120 s, the number of fractions of 20-40 mm in its composition is gradually reduced from 45% to 12%, at the same time the content of the 10-20 mm fraction is increased by 20% and up to 13% of sand fractions are formed in the mixture (5-0,14 mm). Further increase in the crushing duration (150 s) does not result significant changes of the aggregate composition. Therefore, it makes sense to provide for pre-treatment in the mixer during 120 s as part of the manufacturing process of ceramsite production.

a)



b)

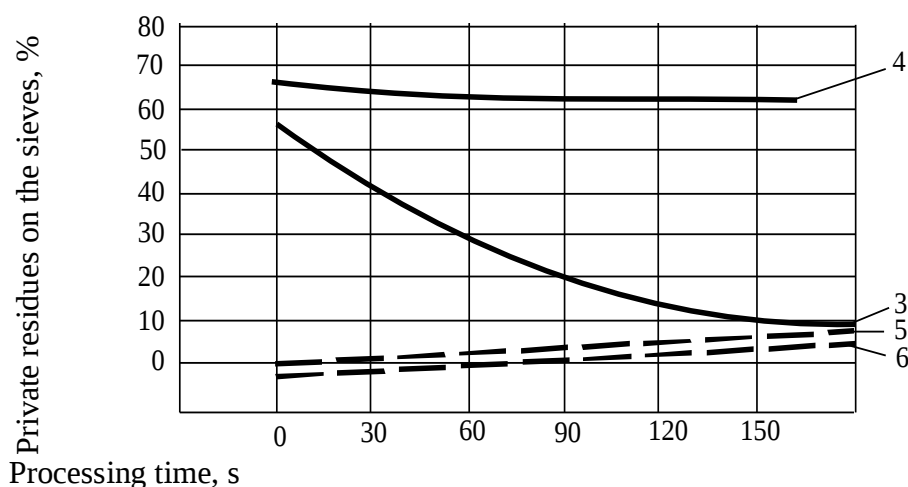


Fig. (1). – Changes in characteristics of ceramsite gravel depending on the duration of treatment in a turbulence mixer: a) dependence of strength on the compression in the cylinder and average density of ceramsite gravel on the crushing duration: 1 – compression strength, MPa; 2 – average bulk density, kg/m³; b) changes in the grain composition of ceramsite gravel: 3 – partial residuals on sieves (%) fractions 20-40; 4 – the same – 10-20; 5 – the same – 5-10; 6 – the same – less than 5.

The bulk density of ceramsite after crushing increases by 3%, the compression strength – by 58%.

The number of fine fractions obtained by crushing of ceramsite gravel suffices for production of the light-weight concrete of dense structure. The necessity of introducing the missing quantity of the fine aggregate into its composition arises.

3. SELECTION OF COMPOSITION OF CERAMSITE ASH-SLAG CONCRETE

The following materials have been tested for use as the missing quantity of fine aggregate in the ceramsite concrete: ashes – dry discharge pick-up according to GOST 25818-91 [14], ash-slag mix of the hydraulic discharge of the Kemerovskaya State district power plant according to GOST 25592-91 [15] and the natural sand.

Specifications of the ash – pick-up of the dry discharge: bulk density – 1030 kg/m³; true density – 2100 kg/m³; loss on ignition – 2,25%; fineness by the rest on a sieve 008 – 1,3%. Ash grinding fineness - pick-up of the dry discharge is equivalent to the concrete fineness, loss on ignition – lower than permissible and the fly-ash is suitable for usage in a concrete.

Specifications of the ash-slag mixture: bulk density – 780 kg/m³; moisture – 17%; loss on ignition made - 4,8%. Fineness of grinding of the portion of mixture passed through the sieve 014 made 64% by the rest on the sieve 008.

Specifications of the natural sand: bulk density of sand – 1425 kg/m³; presence

of the clay particles – 21%. Total rest on the sieve 0,63 – 33%. This sand belongs to fine aggregates [16] and may be used for production of the high-strength concrete.

By selection of the concrete compositions the PA additives were used: the plasticizer LSTM-2 (modified lignosulfonates) according to GOST 24211-2008 [17]; super plasticizer S-3 according to GOST 24211-2008 [17]; gas-generating – PAK-3 according to GOST 5494-95 [18]; steel corrosion inhibitors – sodium nitrite (NN) according to GOST 19906-74 [19]; sodium tetraborate (TBN) according to GOST 24211-2008 [17].

By selection of the ceramsite ash-slag concrete composition the design objective was taken into account – production of cost-effective concrete with the average density grade D1100-D1300 of the strength classes B5-B15 and mobility 9-12 cm of slump of the standard cone by the time of placing. The concrete mix shall be placed into a vertical formwork forming a good face surface that does not require additional finishing. Concretes shall be designed for production of reinforced structures.

The total consumption of the fine and coarse aggregate for structural-heat-insulating concrete makes 1,55 m³. At the same time the portion of the sand (or ash-slag mix) in the aggregate mixture is determined based on the results of the tests during which it changed from 18 to 45%.

In order to define the effect of the fine and coarse aggregate on the concrete structure the pre-selection of the concrete components was performed experimentally by means of batch introduction of the fine aggregate (sand or ash-slag material).

The density and quality of the concrete surface were defined by eye based on the samples of cubes 150×150×150 mm and cylinders 100×400 mm.

Preparation of the concrete mix was performed by means of forced mixing with grinding of the ceramsite gravel.

As was found based on the results of experiments, the surface and strength of the coarse-pored no-sand concrete as well as no-sand concrete prepared in a turbulence mixer with pre-activation of the aggregate during 80 s do not meet requirements set to the strength, density, structure of the concrete and to the quality of its surface. Introduction into the ceramsite concrete composition of up to 20% of sand increases its compression resistance by 1,5 times as compared to the activated concrete, somewhat improves the sample appearance.

Substitution of sand through ash-slag material against the similar content and turbulence mixing with activation of the coarse aggregate during 120 s does not significantly improve the quality, structure and appearance of samples. The increase in the quantity of the ash-slag material up to 22% and the duration of mixing in a turbulence mixer ensures the increase in the strength by 2-2,2 times as compared to the no-sand activated concrete and satisfactory quality of its surface and structure.

Therefore, it may be concluded that the minimum quantity of the fine fraction ensuring satisfactory quality of the structure and external surface of the samples shall make no less than 22% from the total aggregate volume. It is recommended to introduce the plasticizers for high-strength concretes. Turbulent activation of ceramsite during 120 s with further mixing of the concrete mix in which the missing sand quantity is introduced ensure production of concrete with the desired strength characteristics and

satisfactory appearance.

By evaluation of the maximal reduced and optimal content of ceramsite gravel in the concrete mix relying on the physico-mechanical characteristics and quality of the relevant sample surface it was found that that the optimal characteristics of the strength and average density of the concrete samples are achieved by content of sand – up to 27%, ash-slag material – 28% net of the portion of sand produced by grinding of ceramsite in a turbulence mixer (8-10% of the ceramsite volume). The Figures 2, 3 present data on changes of the average density and compression strength of the light-weight concrete samples produced from different percentage of the fine aggregate – sand or ash-slag material.

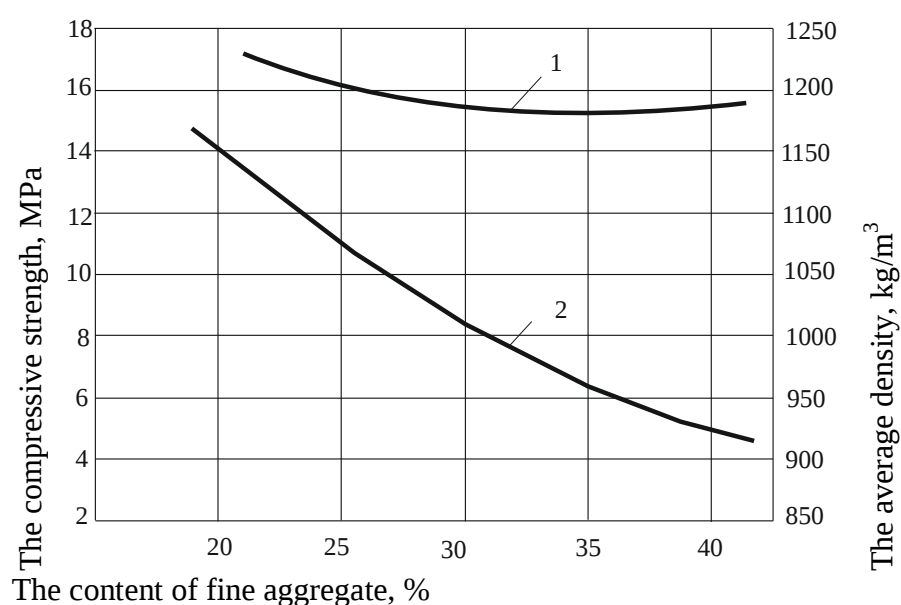


Fig. (2). – Changes in characteristics of ceramsite concrete with the fine aggregate from ash-slag material:

1. Changes in the average density of ceramsite concrete depending on content of the ash-slag material.
2. Changes in the compression strength of ceramsite concrete depending on content of the ash-slag material.

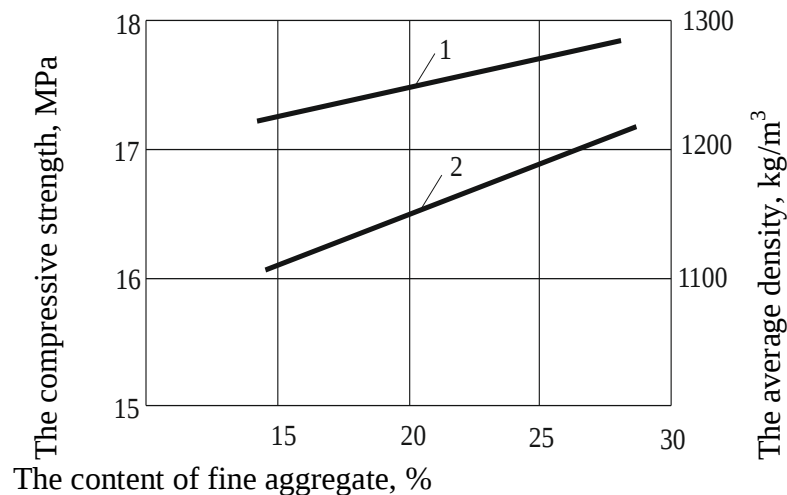


Fig. (3). – Changes in characteristics of ceramsite concrete with the fine aggregate from heavy sand:

1. Changes in the average density of ceramsite concrete depending on the sand content.
2. Changes in the compression strength of ceramsite concrete depending on the sand content.

Thus, it may be concluded on the basis of the tests performed that the minimum percentage of the fine fraction (net of the sand produced by ceramsite grinding) in the aggregate mix shall be no less than 22% and the maximum – not more than 39%. By selection of the working compositions one shall take into account the effect of the average bulk density of aggregates on change of the average concrete density that shall not exceed the specified values [20].

4. INVESTIGATION OF THE EXTRENAL SURFACE QUALITY

During this study we also investigated the effect of the following indicators on the quality of the sample vertical surface:

- material composition of the concrete including quantitative content of the finely dispersed and fine fractions;
- methods of concrete compaction in a vertical formwork;
- introduction into the concrete composition of micro-porous additives;
- the use of the formwork lubrications of different kind применение;
- plasticization of the concrete mix.

The qualitative characteristics were determined by eye by means of external examination of the sample cylinders with the diameter 100, height 400 mm and calculation of the percentage of pores with the diameter over 2 mm with respect to the total lateral area of the samples.

While studying the impact of the material concrete composition of the quality of the sample vertical surface it was found out that non-segregation and required

concrete density and, therefore, absence of large honeycombs on the sample surface are achieved by turbulent grinding of ceramsite gravel during 120 s and introduction into the composition of light-weight concrete mix not of no less than 22% of fine fractions (ash-slag material or sand), total consumption of the binder (concrete+aggregate 220 kg).

It was also found out that the quality of the external surface of the concrete samples made in a turbulence mixer is higher than in comparable forced mixed concrete. The increase in the concrete consumption against the quantitative reduction of sand or ceramsite in a concrete mix does not result in the significant improvement of the sample external surface. Substitution of the natural sand through ash-slag mix and quantitative changes in the composition of fine aggregate in the concrete mix composition also almost does not have an effect on improvement of the sample surface.

Thus, it may be concluded that the increase of the percentage in the concrete material composition of the dispersed fractions or ceramsite gravel over the pre-defined optimum almost does not have any impact on the reduction of porosity of the sample external surface. The turbulent grinding and mixing of the concrete mix components represent a necessary processing technology of improvement of the concrete quality.

The results of the studies of the effect of the concrete mix compaction methods on the quality of the sample vertical surface obtained during this research correspond to the conclusions of a number of scientific-research institutions and leading building construction enterprises of the country according to which by compaction of the concrete mix the air bubbles extracted by vibration are accumulated at the area of separation of the vertical formwork and the mix as the result of which honeycombs appear on the product surface. Processing of the concrete mix by high-performance poker vibrators allows outputting the air bubbles to the external surface and obtaining quite smooth product surfaces. However, Однако, it shall be taken into account that the use of poker vibrators instead of suspended ones results in certain increase in the concreting labor intensity; the most appropriate method is to subsequently perform the external and internal vibro compaction enabling concrete processing with the increased pitch and lesser duration of operation of internal vibrators though the final decision may be made only during actual concreting.

5. CALCULATION OF THE MINIMUM CONCRETE CONSUMPTION

The objective of the study also included preliminary definition of the minimum concrete consumption in a concrete mix on the basis of the psychical-mechanical specifications, average density, structure and quality of the sample external surface.

According to the SNiP 82-02-95 requirements [21] for monolithic reinforced structures from light-concrete the concrete consumption shall make no less than 200 kg/m³ and in case of use of ash-slag materials – no less than 180 kg/m³. For unreinforced structures the minimum values are not limited provided that concrete features the required frosts resistance according to the project.

As the result of the tests performed it was found out that the ceramsite concrete

with a fine aggregate from the natural sand at the cement consumption 220 kg/m^3 meets the strength and average density requirements set to materials of the upper floors and at 250 kg/m^3 – the lower floors. For the external base walls the cement consumption shall be increased approximately to 280 kg/m^3 . Concrete with the cement consumption from 180 kg/m^3 to 220 kg/m^3 in which the fly ash is used as the missing binder and fine aggregate featuring in the dry state the strength and average density specifications meeting the requirements set to external walls of the upper and lower floors. The strength and density characteristics of concrete with the similar composition in which the ash-slag mix of the wet discharge of the State district power plant is somewhat lower than the previous indicators, however, suffice to meet the requirements set to the concrete used for construction of the monolithic building walls.

The structure and quality of the external sample surface at the cement consumption specified in this paragraph are satisfactory; therefore, they may be accepted for further tests as the minimum permissible ones.

6. CHOOSING THE FORMWORK

One of the important tasks by working on the problem set is choosing the most appropriate formwork by construction of structures from ceramsite ash-slag concrete with regard to the surface quality. Наиболее экономичной и менее трудоемкой признана разборно-переставная опалубка. The most cost-efficient and less labor-consuming is the collapsible formwork. There have been performed tests on analysis of the ceramsite concrete surfaces formed with the use of a formwork from different materials. The most widely used materials have been considered: plywood, metal, wooden boards. The quality of the surface has been estimated by eye.

During observations it was found out that the surface formed by a plywood form is non uniform: there are intercommunicating honeycombs, roughness, steps. A surface formed by a timber formwork is more uniform; however, there are single honeycombs as well as coarser roughness observed. The smoothest surface was observed on a ceramsite concrete surface formed by a metal formwork, here no roughness, honeycombs or steps were observed.

Thus, the most appropriate formwork to be used by construction of monolithic structures from ceramsite ash-slag concrete is the metal formwork.

Besides, taking into account the differences of the ceramsite ash-slag concrete from the heavy concrete in order to get a satisfactory surface vibro compaction of the mix shall be performed - along with the suspended vibrators – using the internal vibrators with a flexible shaft.

7. CHOOSING LUBRICATION FOR THE FORMWORK

Within the frameworks of this research work we performed testing of the impact of different lubrications on the quality of the sample surface.

It is known that a number of requirements is set to lubrications for steel forms the main of which are: adhesion to metal to keep it attached to the vertical formwork

surfaces and reduced adhesion to concrete to facilitate demolding without damaging it; possibility of the motorized production and application of lubrication, decreasing the probability of formation of spots and air-bubble voids on the concrete surface adjacent to the formwork; the lubrication shall not cause the metal corrosion and shall exclude reduction of strength and density of the surface concrete layer. Taking into account that construction of buildings with the use of a steel formwork is planned for the winter period the lubrication shall not freeze at negative temperatures.

Thus, it shall be supposed that for continuous monolithic building construction it is the most efficient method to use emulsol – lubrication that is centrally delivered by industry. During the winter period it shall be plasticized by means of introducing additives (fluid combustive and lubricating materials) or heated; on the surface of the concrete samples that were in contact with the form lubricated with emulsol no spots are formed, emulsol may be applied to the formwork mechanically, the use thereof does not cause metal corrosion.

8. SUMMARY

Based on the results of the experimental laboratory tests the following process solutions have been designed:

- the consumption of cement of any grade in a concrete with a fine aggregate from the ash-slag mix shall be no less than 220 kg/m^3 and in case of use of the fly ashes – no less than 200 kg/m^3 ;
- by preparation of the ceramsite ash-slag concrete mix for production of the ceramsite sand and activation of the ceramsite grains the turbulence mixer with cyclic operation and required batch volume shall be used;
- the procedure of charging materials into a turbulence mixer: coarse aggregate and 30% of the estimated water amount (aggregate activation and grinding thereof for 120 s) + remaining water + fine aggregate + cement (mixing for 150-180 s). The additives are introduced with the second portion of the tempering water;
- the concrete mix shall be transported to the site by concrete mixer trucks which allow preventing segregation thereof. For the ceramsite ash-slag mix the duration of transportation from the place of production to the pouring site shall not exceed 30 minutes;
- the mobility by discharging from the mixer shall not exceed OK 9-12 cm;
- by discharging the concrete mix from the hopper into the slab formwork the distance between the lower hopper edge and the surface on which concrete is placed shall not exceed 1,0 m. The concrete mix shall be placed in horizontal layers 1,5-2,0 m wide of the same thickness (15-30 cm) without gaps with successive directing the placing to the same side in all layers. It is allowed to place the next layer of the concrete mix before setting of the concrete below;
- in order to avoid the segregation of the mix the height of the free dropping shall not exceed 1-1,8 m. By filling with concrete the formwork of the walls up to 3 m high it is desirable to deliver the mix through a concrete-pouring trunk;

- the concrete mix in vertical structures is compacted by the internal vibrators: the vibrator displacement pitch shall not exceed half as much as the radius of their operation; the depth of immersion of a vibrator into the concrete mix shall ensure the deepening thereof into the previously laid layer by 5-10 cm;
- the duration of vibrating at each position makes 20-30 s. The compaction is completed when the concrete mix ceases setting; the cement grout appears on its surface and the air bubbling stops;
- the external (surface) vibrators are used for compaction of the concrete mix in the floor structures. The duration of vibration at each place of the vibrator placement depends on the plasticity (mobility) of the concrete mix and makes no less than 45 s and not more than 90 s.
- the formwork shall be lubricated with emulsol. During the winter period emulsol shall be brought to the lubricating consistency by means of adding the diesel fuel oil, besides, lubrication shall be applied to a warm formwork and emulsol shall be heated to +15—+20 °C before use.

The results of the work may be recommended for construction of the external walls of monolithic buildings from ceramsite ash-slag concrete in the Siberian regions of Russia.

CONFLICT OF INTERESTS

The authors confirm that the data provided does not contain a conflict of interests.

ACKNOWLEDGEMENTS

The paper was prepared with the support of the Ministry of Education and Science of the Russian Federation.

REFERENCES

- [1] Concretes. Materials. Technologies. Equipment. – Moscow: Stroyinform; Rostov-on-Don: Phoenix, 2006.
- [2] Chumakov, L. D. The technology of concrete aggregates (workshop): Textbook for college students / L. D. Chumakov. – Moscow: ACB, 2006.
- [3] Bazhenov, Y. M. Concrete technology / Y. M. Bazhenov. – Moscow: ACB, 2007.
- [4] Dvorkin, L. I. Construction materials from the industrial wastes / L. I. Dvorkin. – Rostov-on-Don: Phoenix, 2007.
- [5] Uglyanitsa, A. V. and T. V. Khemelenko, K. D. Solonin. Slag-alkaline concrete –efficient building material International journal of applied engineering research. - Research India Publications, Volume 9, Number 22, 2014, pp. 16837-16842.

- [6] Gilyazidinova, N. V. and A. N. Ilyin. Use the slag concrete in building underground structures and mines. Modern scientific research and their practical application, Ukraine, 2014.
- [7] Alessandra Gianoncelli, Annalisa Zacco, Rudolf P. W. J. Struis, Laura Borgese, Laura E. Depero, Elza Bontempi. Fly Ash Pollutants, Treatment and Recycling. Pollutant Diseases, Remediation and Recycling. Environmental Chemistry for a Sustainable World Volume 4, 2013, pp. 103-213.
- [8] Gilyazidinova, N. V. and N. O. Tabert, M. I. Layb. Methods of increasing the concrete strength. Collection of research papers. SWorld. Ukraine, 2014.
- [9] Patent for the invention #2527974 d/d 15.07.2014. Composition of the ceramsite concrete mix. Russia 30.11.00-1.
- [10] GOST 9757-90. Gravel, chipping and stone artificial porous. Technical specifications.
- [11] GOST 9758-86. Aggregates porous, non-organic for construction works. Test methods.
- [12] Uglyanitsa, A. V. and Gilyazidinova, N. V., A. A. Zhikharev, A. A. Kargin. Study of reinforcement corrosion in expanded clay concrete. HRBS Journal, Volume 10, Issue 1. Cairo, Egypt, 2014. PP. 1687-1690.
- [13] J. Alexandre Bogas, Rita Nogueira. Tensile strength of structural expanded clay lightweight concrete subjected to different curing conditions. KSCE Journal of Civil Engineering. September 2014, Volume 18, Issue 6, pp. 1780-1791.
- [14] GOST 25818-91. Fly ashes of thermal power plants for concretes. Technical specifications.
- [15] GOST 25592-91. Ash-slag mixes of thermal power plants for concretes. Technical specifications.
- [16] GOST 8736-93*. Sand for construction works. Technical specifications.
- [17] GOST 24211-2008. Additives for concretes and mortars. General technical specifications.
- [18] GOST 5494-95. Aluminium powder. Technical specifications.
- [19] GOST 19906-74. Industrial sodium nitrite. Technical specifications.
- [20] J. Brozovsky, D. Benes, J. Zach. NDT of LWC with Expanded Clay. Nondestructive Testing of Materials and Structures. RILEM Book Series Volume 6, 2013, pp. 335-340.
- [21] SNiP 82-02-95. Federal (standard) itemized estimates of the cement consumption by production of concrete and reinforced concrete structures and products.