Research Journal of Applied Sciences 9 (12): 1073-1077, 2014
ISSN: 1815-932X

Ceramsite Concrete Durability: Prediction and Reality

[1]P.S. Abramova, [1]A.E. Mestnikov, [2]V.S. Lesovik,
[2]M.S. Ageeva, [2]G.A. Lesovik and [2]N.V. Kalashnikov
[1]Northeast Federal University of a Name of M.K. Ammosov,
Belinskay Street 58, 677000 Yakutsk, Russia
[2]Belgorod State Technological University Named after V.G. Shukhov, Belgorod, Russia

Abstract: The study presents the results of ceramsite concrete studies with respect to sharply continental climate of the North. At that the particular importance for concrete durability prediction is the evaluation of frost resistance within particular operation conditions. To evaluate the thermal strains, the solidity and frost resistance at sign variable and subzero temperatures, the method of dilatometric studies is used. It is determined that the improved frost resistance of fused ceramsite concrete in harsh environments contributes to the selection of concrete components with similar coefficient values of linear thermal expansion and the introduction of complex supplement.

Key words: Ceramsite concrete, sharply continental climate, frost resistance, durability, dilatometric studies

INTRODUCTION

During the Soviet period the factories of panel building construction with the use of ceramsite concrete were built in the developed northern cities (Vorkuta, Naryan-Mar, Norilsk, Igarka, Yakutsk, Magadan in sea ports "Gates-of the Arctic"-Tiksi and Pevek then at Mirny, Neryungri cities, etc.). Almost half of a century experience concerning large-panel houses construction in the Far North allowed to achieve a lot in the technological and technical terms (Gridchin *et al*., 2008; Veshnyakova *et al*., 2012). A lot of papers are devoted to the produced concrete quality improvement (Lesovik *et al*., 2007a, b, 2009a, b; Lesovik, 2004). The industrial approach at proper quality allows to achieve high rates of construction and commissioning in respect of residential apartment buildings which are competitive within market economy terms. The durability of concrete and reinforced concrete at cryogenic exposure is one of the most important tasks in building science (Lesovik *et al*., 2011a, 2009, 2012, 2010; Lesovik, 2013; Lesovik *et al*., 2009; Lesovik *et al*., 2012; Gridchin *et al*., 2004). Its complexity is conditioned by the variety of factors that affect the durability of concrete and reinforced concrete and is not always quantifiable and controlled (Lesovik *et al*., 2011, 2014; Lesovik, 2004, 2003; Lesovik and Klyuev, 2011). The evaluation of frost resistance in particular operation conditions is of particular importance for concrete durability prediction.

CLIMATE CONDITIONS

The Republic of Sakha (Yakutia) according to its harsh climatic parameters differs significantly from the subarctic states of the Northern Hemisphere. An extreme climate (-71°C+38°C) in conjunction with the permafrost platform, the number of uncomfortable days up to 300 or more per year allows to state that the region is located in a high risk area for human habitation and the natural ground for cryogenic tests of building materials and structures.

When designing an integrated account of climatic and other environmental influences on the constructions of buildings and structures is necessary. The peculiarity of the Central Yakutia is its sharp continental climate which is manifested in significant temperature fluctuations at small amounts of precipitation.

The climate data analysis for the city of Yakutsk and the field observations (Lesovik *et al*., 2007) revealed the intensity and a greater frequency of ambient air temperature fluctuations up to 103°C for a season, up to 40°C for a month and up to 20°C during a day. The cyclical fluctuations in the average per year are calculated as with the transition through 0°C (61-68 cycles) so as separately within the negative (90 cycles) and positive (51) temperatures.

The frost resistance of ceramsite concrete when exposed to sign changes and negative temperatures. During the first 2-3 years of building operation in extreme

Corresponding Author: Polina Semenovna Abramova, Northeast Federal University of a Name of M.K. Ammosov, Belinskay Street 58, 677000 Yakutsk, Russia

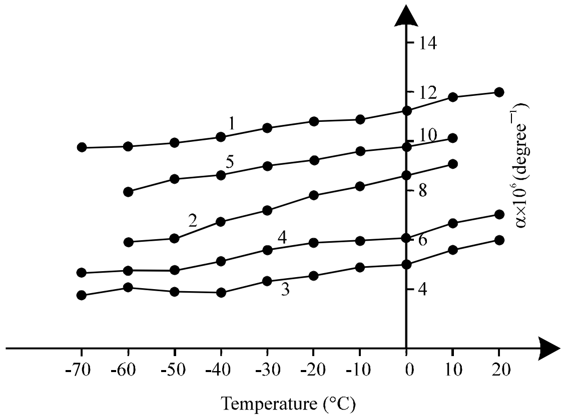

Fig. 1: CLTE dependence on the temperature: 1: cement stone; 2: quartz sand solution (fine-grained concrete); 3: Bestyakhceramsite; 4: Bestyakhceramsite solution (warm solution); 5: silicified medium-grained sandstone

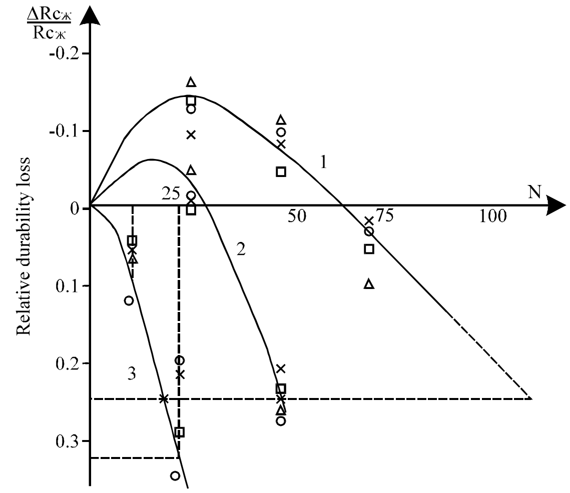

Fig. 2: Ceramsite concrete frost resistance dependence on test temperature; 1: $t_1 = -15°C$, $\Delta Rcж/Rcж = 9.88.10^{-5} N^2$; 2: $t_1 = -34°C$, $\Delta Rcж/Rcж = 2.48.10^{-4} N^2 - 7.4.10^{-3} N$; 3: $t_1 = -55°C$, $\Delta Rcж/Rcж = 4.17.10^{-4} N^2 + 5.84.10^{-3} N$

climatic conditions of Yakutsk the shrinkage deformations of lightweight concrete are manifested in wall structures as a grid of small cracks on the finishing layer of cement and sand mortar and concrete. Also other types of defects are possible.

In some cases with the establishment of a stationary temperature and humidity mode in the wall material the reduction of operational stability due to the difference in thermal strains of concrete components is possible. A good compatibility is assumed due to this factor of concrete and steel which is true at the moderate ranges of fluctuations and their small frequency. Thus, the coefficients of the Concrete Linear Thermal Expansion (CLTE) based on dense filler are taken on the average as $9^{-11}.10^{-6}$ 1/°C and the coefficients of the steel linear thermal expansion make $10^{-12}.10^{-6}$ 1/°C.

Figure 1 shows the CLTE values and the nature of their variation at low temperatures which were obtained by us for local materials by the dilatometric methods of concrete components research. The thermal compatibility of cement stone with dense filler made of sandstone is fairly high and it is significantly lower with Bestyakhceramsite. Therefore, with the repeated temperature fluctuations on the borders (in the contact zone) the significant internal stresses with the formation of microcracks are possible.

The presence of porous filler contributes to a more robust and frost-resistant microstructure of the contact zone and ceramsite concrete. The convincing proof of this is the results of ceramsite concrete samples frost resistance tests at the freezing temperature of -15°, -55° and -34°C shown in Fig. 2.

At moderate subzero temperatures the reinforcement of a structure is observed up to 60 cycles at -15°C and up to 25 cycles at -34°C. And only during the freeze in a climatic chamber at -55°C the destruction takes place, leading to the loss of strength by 25% already at 23 test cycles.

The behavior of pre-stressed concrete with reinforced steel of different types may be judged by the results of the studies (Abramova, 1973) where it is noted that the thermal stresses started to develop due to the lower value of CLTE concrete than CLTE.

It was found that similar CLTE values of Bestyakhceramsite and the soluble part on ceramsite sand determines the obtaining of ceramsite concrete the structure of which is characteristic for frost resistant concretes. At the same time, the possibility of keeping CLTE components according to additive law allows to determine the material temperature deformations by calculation and there by optimize the ratio of concrete components according to CLTE values.

In order to study, the actual impact factors of severe climate on the material of the outer fencing the method of unilateral variable influence and low freezing temperatures was used. The effect of topcoat on the frost resistance of ceramsite concrete was studied as by the wall panel fragment so as by small test samples.

The method of research involves the testing of a wall fragment with the dimensions of 100×60×80 cm and sample cubes of 10×10×10 cm in a Special Cooling Automatic Device (SCAD). The SCAD test is performed as follows. The intermediate clip between warm and cold compartments is filled with a finishing layer is laid to the cold compartment of saturated samples with their full immersion in water for 24 h. The tests are carried out only in the air and from the outer side the samples are influenced alternatively for 4 h and subjected to the exposure of negative (up to -60°C) and then of positive temperatures (40°C) which makes one cycle. From the inner surface of a sample a constant positive temperature (20°C) is maintained.

During the test of ceramsite concrete fragments as well as control samples the measurements of air temperature in warm and cold SCAD compartments are performed as well as the temperatures on the sample surface, on the border of different material layers and inside the sample at different depths. The results of ceramsite concrete sample humidity change determination at typical sections are shown in Fig. 3.

Compositions of investigated ceramsite concrete, some of their physical and mechanical characteristics are given in Table 1.

The fragment of ceramsite concrete wall panel passed 75 cycles of testing. At the end of testing the tapping of finishing layer (2 cm thick made of cement-sand mortar with the composition of 1:2.5) is performed. There were no signs of solution layer destruction. According to the testing results of the finishing layer concerning its shift (Fig. 4) the best performance was shown by ceramsite concrete with complex additive at the amount of 0.2% from the cement weight, the introduction of which formed a good grip. During the test the change of strength is small even after 100 cycles (Fig. 4).

The adhesion strength of the film from an aqueous emulsion of organic silicon resin with ceramsite concrete was determined by the cross-cut of the film. A slight decrease in adhesion was observed in samples which passed 75 (one of the three series samples) and 100 cycles (two out of four samples). It was expressed with a partial detachment of the film at the notch.

The increase of ceramsite concrete hardiness of a fused structure in severe climatic conditions was stipulated by the selection of components close to SCAD values of the filler and the mortar part as well as the introduction of complex additive in ceramsite concrete at the amount of 0.2% from the cement weight. The method of unilateral freezing which is the thawing of wall panel fragments allowed to investigate the influence of the finishing layer on the frost resistance of ceramsite concrete.

Regardless of the exterior finish type the basic requirement in the North is the durability of constructive fencing material and finishing layer combination under varying and freezing temperatures. The uneven deformations of fencing materials and finishing layer in

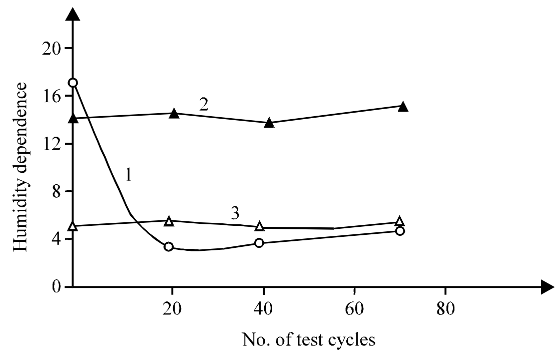

Fig. 3: The humidity dependence in the typical cross-sections of a panel fragment made of ceramsite concrete on the number of test cycles (1: outersurface; 2: innersurface; 3: the zone of transition from melted to frozen one)

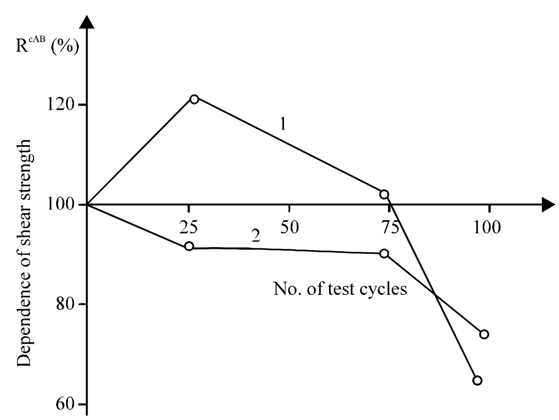

Fig. 4: The dependence of shear strength on the number of test cycles (1: ceramsite concrete composition 1; 2: ceramsite concrete composition 2)

Table 1: Composition and physical and mechanical properties of ceramsite concrete

Material consumption per m^3					Ceramsite concrete characteristic		
		Ceramsite (L)				Ultimate strength (kg/cm^2)	
Cement (kg)	Water (L)	0-5 (mm)	5-20 (mm)	Addition (%)	Density (kg/m^3)	At compression	At bending
232	260	493	964	-	1270	107	12.1
220	240	457	1102	0.2	1240	115	12.4

excess of the internal stresses of extreme tensile strength and bond strength will cause cracking or delamination of a finishing layer. Thus, the durability is determined by the conservation of solidity and the base material finishing. The solidity of these materials is violated by the defects which occur even during the formation of their structure which are increased by the influence of the environment. At high ambient temperature variations inherent for the areas with extreme continental climate, the difference in the dilatometric properties of filling concrete components and cementing material is manifested.

CONCLUSION

With significant fluctuations of ambient air, typical of Central Yakutia, it becomes necessary to take into account the thermal properties of the concrete conglomerate structural components as well as the protective and decorative layer material. Ceteris paribus the close CLTE values of these components contribute to the preservation of walling solidity. Conversely, the greater the CLTE difference or the thermal incompatibility, the higher the probability of internal cracking for finishing and concrete, reducing the frost resistance and overall fencing durability.

Taking into account the new developments in the cement system technology one may state that the 40-50 years ago the lightweight concrete trend was chosen correctly for the improvement of the cement stone pore structure using the complex plasticizer based additive and water repelling agent (air introduction agent) as well as accounting of temperature deformations for the North in respect of layered systems, i.e., the thermal compatibility of concrete components for protecting wall structures in particular.

There is the confidence that the trend towards the revival of ceramsite and ceramsite concrete in RF and the availability of effective domestic modifiers of new generation organic mineral type (Yudin, 2006) as well as the experience in the introduction of ceramsite concrete to build 24-storey building frames in Moscow of B35, B40 and even B60 classes and for reinforced concrete piles with a higher fracture toughness, impact and frost resistance than piles made from granite rubble will give rise to undeservedly forgotten single layer walls for frame buildings in the North made of lightweight concrete as the most comfortable for heat and sound insulation, durability and reliability.

Despite the skeptical statement on the impossibility of automation at the nano level of objects assembly from molecules within "Man-Computer-Manipulator" System, the progress for this trend have already been outlined and promise revolutionary changes in obtaining building materials with controlled structure and properties.

REFERENCES

Abramova, P.S., 1973. [The study of ceramsite concrete frost resistance for walling]. Ph.D. Thesis, MECI., Moscow.

Gridchin, A.M., A.M. Harhardin, R.V. Lesovik and S.M. Shapovalov, 2004. Mineral concrete for crushed stone foundations. Build. Mater., 3: 74-75.

Gridchin, A.M., Y.M. Bazhenov, V.S. Lesovik, L.H. Zagorodnuk, A.S. Pushkarenko and A.V. Vasilenko, 2008. [Building Materials for Use in Extreme Conditions]. BGTU Publisher, Moscow, Russia, Pages: 595, (In Russian).

Lesovik, R.V. and S.V. Klyuev, 2011. Fiber reinforced fine grained concrete with the use of polypropylene fiber. Concrete and Reinforced Concrete, No. 3, pp: 7.

Lesovik, R.V., 2003. Fine-grained concrete for road construction. Bull. Higher Educ. Inst.: Constr., 11: 92-95.

Lesovik, R.V., 2004a. [Fine grade concretes with the use of man-made sands from Kursk magnetic anomaly for the construction of fortified road bases: Monograph]. BSTU Named After V.G. Shukhov, Belgorod, pp: 173.

Lesovik, R.V., 2004b. Complex use of wet magnetic separation tails for ferruginous quartzites. Mining J., 1: 76-77.

Lesovik, R.V., M.N. Kovtun and N.I. Alfimova, 2007a. Complex use of diamond processing waste. Ind. Civil Constr., 8: 30-31.

Lesovik, R.V., A.I. Topchiev, M.S. Ageev, M.N. Kovtun, N.I. Alfimova and A.P. Greenev, 2007b. Ways of fine-grained concrete improvement. Build. Mater. Equip. Technol. 21st Century, 7: 16-17.

Lesovik, R.V., E.S. Glagolev, S.V. Klyuev and V.A. Bogusevich, 2014. Deformation properties of fine-grained concrete. Build. Mater., 1-2: 113-116.

Lesovik, R.V., V.V. Strokova and M.S. Vorsina, 2004. The development of compacted concrete based on technogenic raw materials for road construction. Build. Mater., 9: 8-9.

Lesovik, V.S., 2013. Architectural geonics. Housing Construction No. 1, pp: 9-12.

Lesovik, V.S., V.V. Strokova, A.N. Krivenkova and E.I. Khodykin, 2009a. Composite binding material with the use of siliceous rocks. Bull. Belgorod State Technol. Univ., 1: 25-27.

Lesovik, V.S., F.E. Zhernovoi and E.S. Glagolev, 2009b. Use of natural perlite in mixed cements. Build. Mater., 6: 84-87.

Lesovik, V.S., M.S. Ageev, U.V. Denisova and A.V. Ivanov, 2011a. The use of composite binding materials for the durability of concrete paver increase. Bull. Belgorod State Technol. Univ., 4: 52-54.

Lesovik, V.S., M.S. Ageeva and A.V. Ivanov, 2011b. Granulated slag in the production of composite binding materials. Bull. Belgorod State Technol. Univ., 3: 29-32.

Lesovik, V.S., N.I. Alfimova, M.S. Sheichenko and Y.Y. Vishnevskaya, 2010. Highly efficient composite binders with the use of nanomodifiers. Bulletin of the Central Regional Branch of the Russian Academy of Architecture and Building Sciences, No. 1, pp: 90.

Lesovik, V.S., N.V. Chernyshev and V.G. Klimenko, 2012. Structure formation processes for gypsum containing composites taking into account the genesis of raw materials. Bull. Higher Educ. Inst. Build., 4: 3-11.

Veshnyakova, L.A., M.A. Frolova, A.M. Eisenstadt, V.S. Lesovik, O.N. Mikhailova and T.A. Makhova, 2012. Evaluation of raw material energy state for building materials production. Build. Mater., 10: 53-55.

Yudin, I.V., 2006. [The union of ceramsite and ceramsite concrete manufacturers is gaining its power]. Building Materials, No. 10.