Foam concrete with porous mineral and organic additives

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Abstract. The article presents results of studies of structural heat insulating foam concrete with porous mineral and organic additives. By mixing additives with the concrete the speed of the initial structure formation increases. The additives of ash loss and thermal-modified peat TMT 600 provide a stable increase of strength by compression and bending of foam concrete. In the dried foam concrete with the addition of TMT and ash loss thermal conductivity decreases by 20% and 7% respectively. The regularities of changes in the thermal conductivity at various moisture of foam concrete have been investigated.

1. Introduction

In the main areas of economic and social development of Russia including construction industry a lot of attention is paid to the acceleration of scientific and technical progress. Energy saving and resource conservation through the development and implementation of energy efficient building materials for building envelopes are especially important [1].

In the construction sector significant part of energy consumption includes the energy cost of building materials production, their transportation, construction of objects, and further operation of buildings [2]. For heat-efficient house it is necessary to find materials and products of the new generation to apply in building envelopes and in bearing structures. The criteria for the effectiveness of such materials should be their high thermal properties, enhanced reliability and durability, ease of technology solutions, the low level of production costs in the manufacture of products. Therefore development and improvement of the production of heat insulating foam concrete of a higher level of quality and steady properties is crucial problem to be solved. The application of natural hardening foam in buildings will improve the energy efficiency of building due to its higher thermal resistance of the walls and by decreasing energy intensity of building envelopes [3].

In order to improve the competitive ability of natural hardening foam, that is, the improvement of its quality and the reduction of its cost, it is necessary to focus on reduction of thermal conductivity of concrete as much as possible at the stage of the selection of raw materials, the design of composition and preparation of raw material mixture, forming of the products by providing the required compressive and flexural strength. Preparation of foam concrete with low thermal conductivity and density is achieved by mixing the cement paste with porous foam or the introduction of fine-grained additives, as well as by the acceleration of setting time of cement which will fix the structure in the same condition in which it was formed in the process of mixing and molding. Solving the problem of stabilization of foam concrete mixture with porous mineral and organic additives will provide a new competitive and efficient heat insulating material based on cement binder.

The purpose of research performed was to develop concrete compositions and processing methods of manufacturing of structural heat insulating non-autoclave foam with low thermal conductivity and improved levels of quality through the use of porous mineral and organic additives.

The main goal of this paper is to investigate the influence of porous mineral and organic additives on the technological properties, structure of foam concrete mix, as well as the technical and operational characteristics of the hardened foam.

2. Materials and methods

For studies of foam the following raw materials were used: Portland cement from Topkinsky plant M500 D0 (GOST 30515-97), CEM I 4,5 B (GOST 31108-2003), quartz sand with Mach -1.44 (GOST 8736-93), ash loss CHP-5, Novosibirsk (GOST 25818-91), thermal-modified peat additive TMT600 developed by the staff of the Departments of Chemistry and Building Materials and Technologies of Tomsk State University of Architecture and Building [4]. Thermal-modified peat additive comprises thermally steady organic mineral complexes providing reinforcing and structure forming effect in the cement stone. Thermal-modified peat additive is chemically active and promotes the formation of new compounds in the structuring process of cement paste that leads to an increase in strength of cement stone. As the mixing water tap water was used that corresponds to the requirements of GOST 23732-2011. According to the results of preliminary studies [5] for the preparation of higher quality foam it can be recommended to use synthetic foaming agent Benoteh PB-C, satisfying the requirements of GOST 24211-2003 and technical condition 2481-010-58771162-2007. Foaming agent Benoteh PB-C has a high foaming ability, foam stability and steady properties when incorporated into cement slurry and increases the speed of structure formation.

Laboratory studies of foam were carried out in the laboratories of the Department Building Materials and Technologies in TSUAB. Preparation of foam concrete mix was carried out by one-step process in the laboratory using foam concrete mixer PBS with the volume of 10 liters. Foaming agent was injected into the foam concrete mixer with the mixing water. Plastic strength of foam concrete mix was determined by using conical Rebinder plastometer. Molded foam samples were kept up in wet conditions until the standard test. Testing and evaluation of the quality of foam was conducted in accordance with GOST 25485-89 d. The average foam density was determined in accordance with GOST 12730.1-78. Foam test in determining the compressive strength and flexural strength was carried out on a hydraulic press by loading to failure in accordance with GOST 10180-2012, and thermal conductivity - in accordance with GOST 7076-99.

3. Results and discussion

Experimental evaluation of the influence of porous mineral and organic additives on the intensity of interactions between structural elements that occur immediately after mixing of the components was carried out according to the magnitude of the plastic strength of the concrete mix. Change of the plastic strength at an early stage of structure formation is an important technological characteristic of the concrete mix, allowing evaluating the formability (remolding effort) at a certain time interval of the cycle of manufacturing of products [6]. According to this criterion, it is possible to set the optimum time for removal of form of the molded products (prefabrication) or structures (monolithic construction), that, in practice will help to coordinate the timing when carrying out concrete works.

The results of determination of the plastic strength of foam concrete mix with thermally modified peat additive and ash loss are presented in Figure 1.

The results show that the higher rates of plastic strength are formed in the foam with porous mineral and organic additives in the initial setting periods of hardening. So after 45 minutes of hardening of the concrete mix with additives plastic strength is increased up to 56 % in comparison with foam concrete mixture without additives, and after 3 hours of hardening up to 65 %. Thus, the results of tests concluded the possibility of using additives TMT600 and ash loss to accelerate the initial structuring of foam concrete mix that can accelerate manufacturing process of products and increase the smoothness of foam structure by means of demixing reduction.

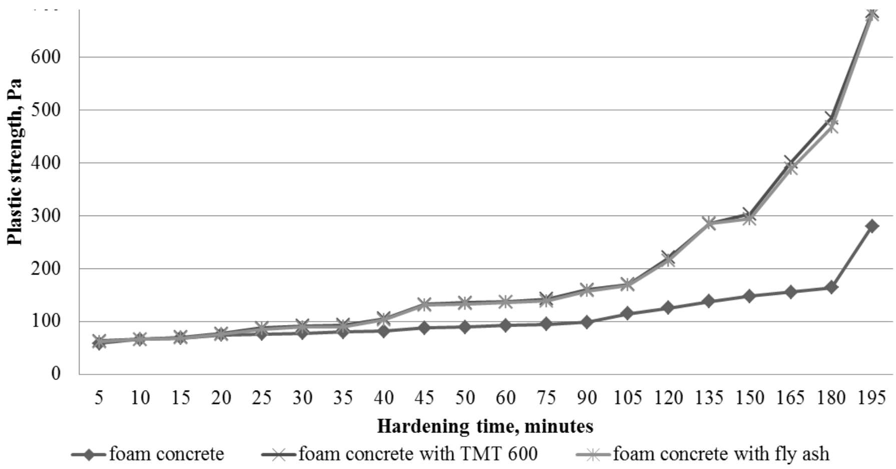

Figure 1. Plastic strength of concrete mixtures with additives.

Figures 2 and 3 show the results of a study of compressive strength and bending strength of branded foam at an average density of D700 with the addition of peat TMT600 and ash loss at the age of 14 and 28 days.

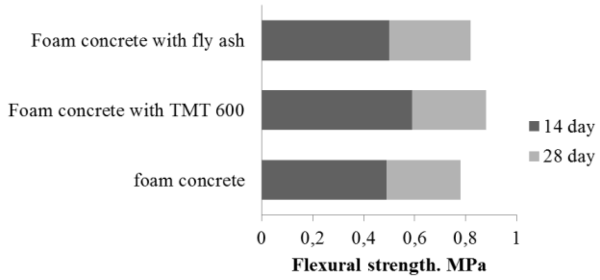

Figure 2. Kinetics of a set of bending strength of foam samples.

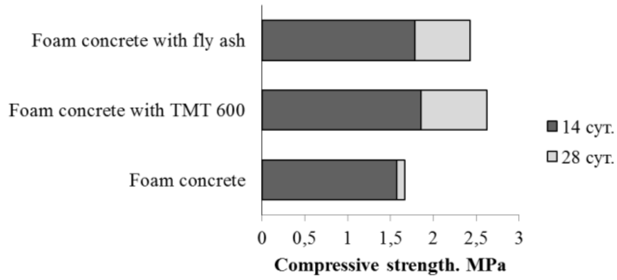

Figure 3. Kinetics of a set of compressive strength of samples of foam.

Analyzing the results (see Figures 2 and 3) one can see that when using ash loss in the age of 14 and 28 days the compressive and bending strength is raised up to 23 and 35 %, 10 and 12 %, respectively. In foam concrete with the addition of peat TMT 600 the compressive strength and bending strength is raised to 24 and 38 % and 15-20 % respectively.

For foam, used for the manufacture of building envelopes, thermal conductivity is of great importance. Products from foam are adapted to difficult climatic and economic conditions in Russia, namely, they have low thermal conductivity and high durability [7]. Thermal conductivity of porous materials, which are the foam concrete, is strongly influenced by the density of the material, type, size and location of pores and humidity [8]. Humidity has great influence on the value of the thermal conductivity. In Tomsk region, the average annual air humidity is in the range of 70-90 %.

Studies of the effect of moisture on the thermal conductivity of foam concrete have been conducted. To obtain foam with certain moisture, samples were kept in a desiccator over aqueous potassium hydroxide solution of various concentrations: 40 % potassium hydroxide solution (φ=70 %); potassium hydroxide solution 30 % (φ=80 %); potassium hydroxide solution 10 % (φ=93 %); water (φ=100 %) [9].

Thermal conductivity of foam concrete with additives TMT 600 and ash loss (Table 1) at 0 %, 20% and 7 % moisture is less respectively than the one without foam additives. This is due to the fact that the addition of TMT 600 and ash loss contribute to consolidation of cement stone structure in interporous partitions and provide increased micro porosity [10]. At 70 % moisture the thermal conductivity of foam with ash loss and 600 TMT is decreased to 30-32 % and at 90 % humidity to 25-

30 % compared with foamed concrete without additives.

Table 1. Thermal conductivity of foam concrete with the addition of peat and fly ash loss.

Thermal conductivity	Humidity, %			
	0 % W/mC	70 % W/mC	80 % W/mC	90 % W/mC
Foam concrete	0,14	0,2	0,23	0,24
Foam concrete with TMT 600	0,12	0,124	0,15	0,16
Foam concrete with fly ash	0,13	0,134	0,14	0,174

Using the obtained data the technological regulations of manufacturing of foam concrete mixes for prefabricated products have been developed.

4. Conclusion

Foam concrete with modifying mineral and organic additives have higher plastic strength by early structure formation, more homogeneous structure, compressive and bending rigidity and lower thermal conductivity in comparison with conventional foam concrete and can be recommended for use in the construction of thermal-efficient buildings.

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References

[1] Матросов Ю А 2008 *Энергосбережение в зданиях. Проблема и пути ее решения* (Москва: НИИСФ) 496

[2] Zuhua Zhang, John L Provis, Andrew Reid and Hao Wang 2014 Geopolymer foam concrete: An emerging material for sustainable construction *Constr Build Mater* **56** 113-127

[3] Kudiakov A I, Kopanitsa N O, Prischepa I A and Shangin S N 2013 Structurally insulating foam with the addition of peat thermo modified *Herald Trace* 172-177

[4] Копаница Н О, Кудяков А И, Саркисов Ю С и Касаткина А В 2010 Влияние термомодифицированного торфа на свойства цементных систем *Сборник трудов «Научные исследования, наносистемы и ресурсосберегающие технологии в промышленности строительных материалов»* (Белгород, Россия) 166-170

[5] Прищепа И А, Шаньгин С Н и Курмангалиев Р М 2012 Влияние модифицирующих добавок на свойства пенообразователей цементных композиций *Сборник научных трудов IX Международной конференции студентов и молодых ученых «Перспективы развития фундаментальных наук»* (Томск, Россия) 776-778

[6] Morgun L V, Krylov O I and Shevaldykin P V 2003 Evaluation of the effect of surfactant concentration on the kinetics of plastic foam and strength fiber foam concrete *Proc. Conf. Building materials and technologies in the III millennium* (Rostov-on-Don, Russia) 52-56

[7] Udachkin I B 2002 Key issues in the development of the production of foam *Journal of Building Materials* **3** 8-10

[8] Ramamurthy K, Nambiar E.K.K. and Ranjani G.I.S. 2009 A classification of studies on properties of foam concrete *Cement Concrete Comp* **31** 388-396

[9] Лурье Ю Ю 1967 *Справочник по аналитической химии* (Москва, Россия)

[10] Прищепа И А, Толченников М В и Прищепа Б А 2013 Влияние добавок на структурно-механические свойства пенобетона (ПМТС-2013) *Материалы Первой Всероссийской научной конференции молодых ученых с международным участием "Перспективные материалы в технике и строительстве"* (Томск, Россия) 383-386