RETRACTED

Experimental determination of the thermal conductivity of building materials under operating conditions

Anastasiya Frolova[1*], *Ilya* Ledovskikh[2], *Kirill* Panin[2], and *Eldar* Ramazanov[2]

[1]Moscow State University of Civil Engineering, Yaroslavskoe shosse, 26, 129337 Moscow, Russia
[2]State budgetary educational institution of the city of Moscow "School No. 293 named after A.T. Tvardovsky", 129301, Moscow, st. Yaroslavskaya, 27, Russia

Abstract. This article is devoted to describing studies of measuring the operational thermal conductivity of various building materials. The experimental setup and test progress are described. The results are described and analyzed, and also compared with the values presented in regulatory documents. The new results and methodological developments obtained are of great practical significance in connection with the expansion of the use of building materials in the modern world.

1 Introduction

Correctly performed thermal engineering calculations of external enclosing structures depend on many factors [1, 2]. The normative document SP 50 [3] presents the thermophysical values of almost all currently known building materials at two values of material moisture content (5 and 10%). In thermal engineering calculations of external enclosing structures, it is customary to use these values. However, recently much attention has been paid to the fact that the actual thermal values during the operation of materials do not correspond to the calculated values [4-6]. In [7], the authors developed a mathematical model that describes the change in thermal conductivity of gas-filled polymer thermal insulation materials over time, which correlates with experimental data. And in subsequent studies [8] different methods are compared: NIISF and GOST R 56590-2016 [9]. International authors also show interest in determining the performance indicators of various building materials, describing their methods and approaches in works [10-13]. However, under operating conditions, it is quite difficult to determine the real thermophysical characteristics due to the need to destroy the existing external enclosing structure to obtain appropriate test samples. In this study, preliminary experiments were carried out to study samples kept indoors for a year and assess changes in the thermal conductivity coefficient from the standard values presented in SP50 [3].

* Corresponding author: FrolovaAA@mgsu.ru

2 Methods

For the experiment, we used the ITP-MG4 thermal conductivity meter, which is designed to measure the thermal conductivity and thermal conductivity resistance of building materials, as well as materials intended for thermal insulation of industrial equipment and pipelines, under stationary thermal conditions in accordance with GOST 7076-99 “Building materials and products. Method for determining thermal conductivity and thermal resistance under stationary thermal conditions" [14]. Structurally, ITP-MG4 “250” consists of two blocks: an electronic unit and a heater-converter, designed as a stationary installation.

The principle of operation of the device is based on the creation of a stationary heat flow passing through a flat sample of a certain thickness and directed perpendicular to the front faces of the sample, measuring the sample thickness, heat flow density and temperature of the opposite front faces. The stationarity of the heat flow is ensured by stabilizing the temperature on the faces to the specified values.

The stationary installation of the device consists of a heater and refrigerator control unit made on Peltier elements, a heat meter, platinum temperature sensors, a device for converting primary sensor signals, and a power source. The Peltier elements are cooled by a fan.

On the side walls of the unit there is a power switch, a grounding terminal, a fuse and sockets for connecting the cable of the electronic unit and the mains power cord, as well as a cam lock.

Power is supplied to the electronic unit from the unit via a connecting cable.

At the top of the installation there is a clamping screw equipped with a reading device for measuring the thickness of the sample and a torque device with a ratchet.

The samples are made in the form of a rectangular parallelepiped, the largest (front) faces of which have the shape of a square with a side of 250x250 mm.

The length and width of the sample in plan are measured with a ruler with an error of no more than 0.5 mm.

The thickness of the sample being measured should be from 5 to 60 mm.

All faces of the sample, except the two main ones, are well insulated.

The moisture content of building materials was determined using a moisture meter "Vlagomer-MG4-U", and thermal insulation materials using a "TOPIFY" type EMT01.

The following building materials were considered as the studied samples: foam block, polystyrene concrete, expanded polystyrene, mineral wool, extruded polystyrene foam and PIR board. These samples were kept in a heated room for at least 1 year.

Photos of the tests are shown in Fig. 1 and 2.

Fig. 1. Photo of mineral wool research

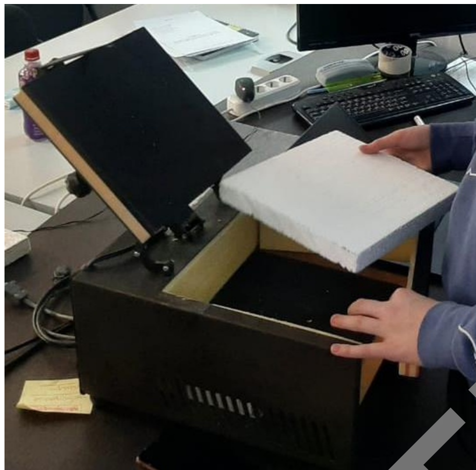

Fig. 2. Photo of foam block research

3 Results

As a result of testing several different samples of building and thermal insulation materials, the following thermophysical values were obtained, presented in Table 1.

Table 1. Experimental thermophysical values of the studied building materials

Materials	Humidity	ρ_{av}, kg/m^3	Temperature, K		Effective thermal conductivity λ, W/m*K
			Cold surface of the device	Hot surface of the device	
Foam block	5%	522,6	283	318	0,149
Polystyrene concrete	5%	247,3	283	318	0,105
Mineral wool	5%	40	283	318	0,039
Expanded polystyrene	5%	10,6	283	318	0,05
Extruded polystyrene foam	5%	27,73	283	318	0,034
PIR plate	5%	41,06	283	318	0,027

To interpret the obtained values, let us compare them with the values presented in the normative document SP50 [3] in Table 2.

Table 2. Standard thermophysical values of the studied building materials according to SP50[3]

Materials	Humidity		ρ_{av}, kg/m^3	Temperature, K		Effective thermal conductivity λ, W/m*K	
				Cold surface of the device	Hot surface of the device		
Foam block	11%	16%	500	283	318	0,22	0,28
Polystyrene concrete	4%	8%	250	283	318	0,085	0,09
Mineral wool	2%	5%	25-50	283	318	0,042	0,045
Expanded polystyrene	2%	10%	10-21	283	318	0,044	0,05
Extruded polystyrene foam	1%	2%	25-33	283	318	0,03	0,031
PIR plate	2%	5%	30-45	283	318	0,029	0,031

4 Discussion

Using the obtained values, it is possible to assess the degree of influence of the discrepancy between experimental data and standard data on the thermal insulation properties of the external building envelope using the example of an external wall. Let us consider various combinations of layers in a wall made of the building materials under study and, having calculated according to SP50 [3] the conditional heat transfer resistance, m$^{2}\cdot$°C/W, for these structures in two versions (normative values and experimental), we will construct a diagram of the obtained values (Fig. 3).

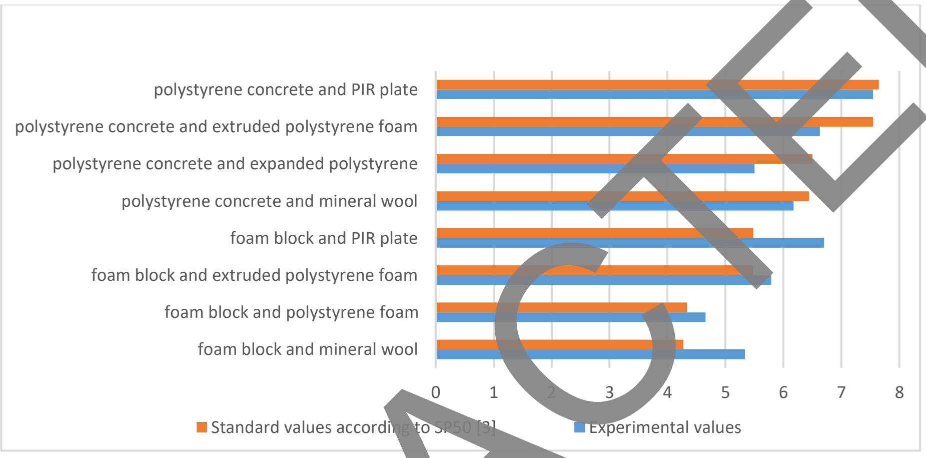

Fig. 3. Conditional heat transfer resistance, m$^{2}\cdot$°C/W, of external walls of various designs

From the obtained results it is clear that the experimental and theoretical conditional resistance of the outer wall differ from each other. The experimental conditional resistance of a wall with foam block is greater than the calculated conditional resistance. With a wall made of polystyrene concrete the picture is the opposite. This happens because the experimental value of the thermal conductivity of polystyrene concrete is higher than the calculated value and this compensates for the change in the thermal conductivity of the insulation in such a wall structure. Also, as can be seen from the results obtained, the difference between the experimental and calculated heat transfer resistances of the wall structure lies in a fairly large range from +20% to -20%.

5 Conclusion

Thermal conductivity coefficients of building materials under operating conditions, determined experimentally, differ from the calculated values presented in the normative document SP50 [3].

For correct thermotechnical calculations and calculation of the thermal load on the heating system of a building, it is necessary to take into account the operational thermophysical characteristics of building and thermal insulation materials in each specific region of the Russian Federation. To do this, it is necessary to continue the research and obtain performance values for a larger number of building materials and different climatic regions.

References

1. E. G. Malyavina, A. A. Frolova, E3S Web of Conferences, **263**, 04017 (2021) DOI:10.1051/e3sconf/202126304017
2. E. G. Malyavina, A. A. Frolova, IOP Conference Series: Materials Science and Engineering, **661(1)**, 012077 (2019) DOI: 10.1088/1757-899X/661/1/012077
3. SP 50. 13330.2012 2022 Thermal performance of the buildings (Moscow: Ministry Of Construction)
4. Yu.S. Vytchikov, M.E. Saparev, A.B. Kostuganov, Urban planning and architecture , **10(1)**, 30-35 (2020)
5. A.V. Kolesova, Scienceosphere, **1-1**, 322-325 (2023)
6. V.Z. Abdrakhimov, E.S. Abdrakhimova, Oil and Gas Technologies, **1(144)**, 13-17 (2023)
7. V.G. Gagarin, P.P. Pastushkov, Construction materials, **6**, 28-31 (2017)
8. P.P. Pastushkov, V.G. Gagarin, P.P., D.A. Ilyin, I.F. Nagaev, Construction materials, **6**, 30-34 (2022)
9. GOST R 56590-2016 Polyisocyanurate foam based thermal and sound insulation slabs. Specifications (Moscow: Ministry Of Construction)
10. K.M. Shaimerdenova, M. Stoev, G.K. Sekerbayeva, G.A. Bulkairova, D.A. Ospanova, A.S. Tussypbayeva, A. Rakhmankyzy, Eurasian Physical Technical Journal, **18(1)**, 70–74 (2021)
11. Jae-Hyeong Seo, Byoung-Hee You, Sang-Seuk Kwen, Dong-Yeon Lee, Moo-Yeon Lee, Entropy, **17(2)**, 903-913 (2015), https://doi.org/10.3390/e17020903
12. Tiwari, R.; Boháč, V.; Réh, R.; Lo Giudice, V.; Todaro, L.; Vretenár, V.; Štofanik, V.; Kristak, L. Tiwari, R.; Boháč, V.; Réh, R.; Lo Giudice, V.; Todaro, L.; Vretenár, V.; Štofanik, V.; Kristak, L. Developments in the Built Environment, **16**, 100228 (2023)
13. Franck Komi Gbekou; Rahma Belloum; Nawal Chennouf; Boudjemaa Agoudjil; Abderrahim Boudenne; Karim Benzarti, Building and Environment, **253**, 111294 (2024)
14. GOST 7076-99 «Construction materials and products. Method for determining thermal conductivity and thermal resistance under stationary thermal conditions» (Moscow: Ministry Of Construction)