

Energy-Saving Regimes Examination During New Generation Building Structures Insolation

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Abstract. High energy efficiency achievement isn't possible without secondary and renewable resources using. One of the universally available alternative energy supply sources is solar radiation as it can be utilized in most Russian Federation regions with sufficient radiance duration. Along with it, active radiation converting systems into both thermal and electric energy imply significant financial investments that under unfavorable climatic conditions and negative weather factors, disrupting equipment functioning, can be recompensed during more than a decade. Solar energy passive utilization requires significantly less expenditure on necessary facilities, as building structures are used for the organization. The processes of external energy exposure of external panels with protective glazing influence on rooms' microclimate have not been thoroughly examined. Typical daily variation in heat fluxes into such a type of solar panels that include different thermal properties building materials requires more extensive examination, including experimental ones. The results of thermal regimes measurements, generated during the cold period of the year into a structure that includes a layer of concrete, protected with an outer-walled double-glazed unit, air layers, and thermal insulation fixed on the inside of the outer panel are presented in the article. Results showed that, in case of relatively low solar radiation intensity, a panel is able to accumulate and give energy to the room, providing a positive daily balance. Achieved results, including ones obtained at temperatures below -15 °C, allow us to recommend solar panels of passive type using for a large part of the Russian Federation.

1. Introduction

One of the main requirements for designed buildings is full compliance with energy efficiency class A. Generally, it is achieved due to thermal insulation with low thermal conductivity for external panels and by engineering systems automation. Given often used methods lead to resources consumption reduction by buildings less than 50%, that is caused by objective technological limitations of reduction methods. Higher savings can be achieved with additional use of secondary and renewable energy sources. However, experiences of alternative systems implantation have shown, the payback period can last several years, and in case of equipment with an expired warranty period failure, savings will be spent on repairs and faulty devices replacement. Therefore, in process of energy conservation issues solving, it's necessary to give priority to low-cost methods of passive utilization as solar radiation absorption by wall panels and following heat transfer to room air to maintain the required microclimate according to sanitary and hygienic standards.



Passive solar heating systems' optimal design, providing their year-round exploitation, allows to reduce thermal energy consumption, in case of additional costs for buildings external panels construction, depending on climatic construction area, from 15 to 35%. For range of possible energy extraction determination during solar panels exploitation, it is necessary to study external panels thermal regimes with given class integrated devices.

2. Literature review

The thermophysical foundations of solar energy, including steady-state regimes, have been thoroughly studied and tested in practice [1]. But buildings and devices for radiation utilizing exploitation is carried out during daily outside air temperature fluctuation and solar radiation flow that causes non-stationary heat transfer into building envelopes. The process of heat transfer is complicated by multi-layer structures using, the main purpose of which is to provide reliable protection against excessive losses under adverse conditions.

Permanent heat flows changing into external panels, including materials that are different in terms of thermophysical properties, are sufficiently studied experimentally [2], but additional glazing and air layers' organization significantly change temperature indicators, even in a storage layer. In addition, such panels allow to organize ventilated and unventilated facade systems [3-8], that physico-mathematical description is often difficult taking into account accepted classical external panels heat transfer theory. The result of experimental solar panels studies allows to estimate the most reliable possibilities of solar energy passive utilization and thermotechnical properties of storage building materials, as well as influence of their massiveness on the ongoing processes.

3. Methods of research

For experimental research realization, measuring method according to State Standard 25380-2014 for heat flows density passing through external panels determination, was used.

Given requirements document regulates thermophysical properties of external panels determination for various purposes in operation mode [9]. The method of heat flow density determining is based on measuring the temperature drop on an "additional wall" (plate) installed on building's external panel. This temperature difference, fixed by thermocouples located even on "additional walls", and connected in series with generated signal, is proportional to heat flow density. Therefore, the "additional wall" and the applied thermocouples create conditions for heat flow conversion into thermoelectromotive force (thermo-EMF). Heat flow density is measured by specialized instrument scale ITP MG-4.03 «Potok», that includes heat flow converter, or calculated from the results of thermo-EMF measurement by transducers.

In order to achieve real exploitation conditions for the investigated element of solar passive heating, a 174 mm chamber of SIP panels simulating a residential one-story building was pre-mounted (Fig. 1). On the southern facade, absorbing solar radiation and heat-transfer accumulating material was placed behind the installed single-chamber double-glazed unit. An infrared electric heater was installed to maintain the temperature of indoor air at low solar radiation intensity or in case of its absence. Constant temperature of internal air was maintained by a mechanical thermostat TDC-1. The envisaged entrance vestibule (Figure 2) for the room where the solar panel is installed reduces heat losses through outer door and reduces negative runoff effect on experiment integrity.

The passive recycling system installed on the southern facade can include various building materials with appropriate properties, and for tests duration it consisted of a single-compartment double-glazed unit, air interlayers communicating with room internal air through provided slots, a layer of accumulating material, thermal insulation fixed on a gypsum sheet, provided as walls interior decoration.

At the indicated layers of the investigated structure in the direction from the room to outside air, the influence of mineral wool 50 mm thick, air layer 20 mm thick, accumulating concrete in 100 mm and outer air layer 20 mm thick, protected from the environment by a translucent fence, were taken into account. Thermophysical parameters of listed materials are given in Table 1.

Table 1. Materials parameters used for a passive solar energy utilization panel

Building material or medium	Density, kg / m³	Heat capacity, kJ / (kg · °C)	thermal conductivity, W / (m · °C)
Mineral wool	158	0,84	0,037
Concrete	2200	0,84	1,55
Air	1,166	1	0,0258

On the inner and outer surfaces, according to given method, sensors were mounted, fixing temperature and heat flow. The results were recorded every hour in device memory. The measurements were made automatically by ITP MG-4.03 «Potok».

**Fig. 1.** General view of test chamber

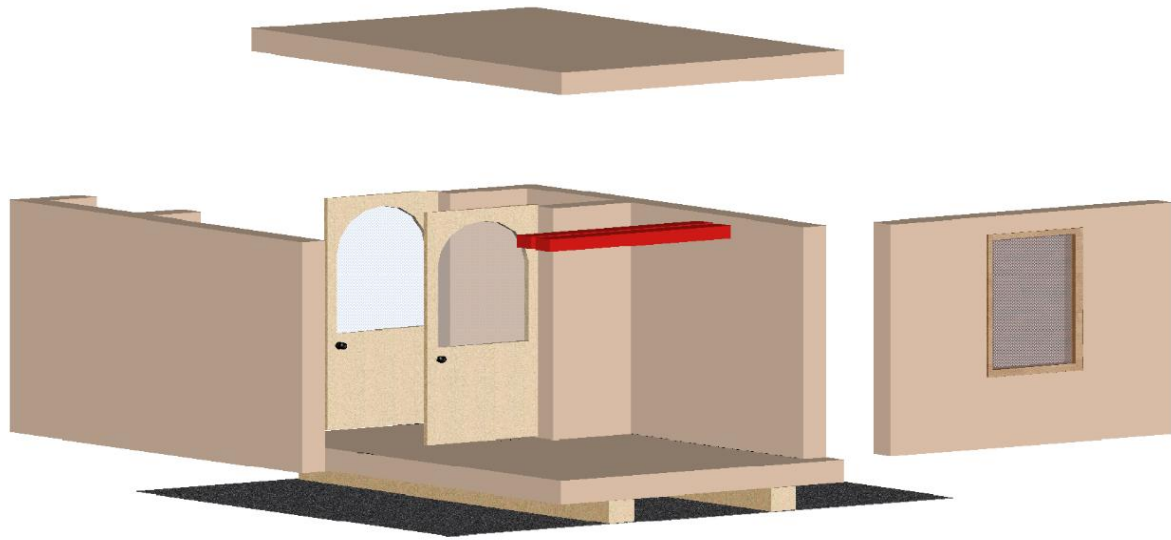


Fig. 2. 3D model of experimental chamber's main elements, imitating a residential building

4. Results

Tests of solar panel, consisting of the above mentioned materials, were carried out from January 11 to January 31, 2018 at the training ground of Voronezh State Technical University. For most of the measurements carried out, the temperature was higher than the average monthly values for outdoor air. On an insignificant time interval, the temperature has reached monthly averages. Therefore, given in Table. 2 and in Fig. 3, experiment results were obtained at high atmospheric pressure, established with cold air masses arrival, that ensured clear daytime weather. Obtained empirical values of heat flows confirmed results of the previous mathematical modeling [10, 11] (Fig. 3). The observed deviations of the measured heat flow from the calculated values are caused mainly by the change in solar radiation, in process of statistical simulation average statistical actinometric data were used [12].

Table 2. Average values of heat flow on January 14, 2018 into solar panel with a series of measurements by ITP MG-4.03 «Potok»

Indicators	Heat flows at characteristic points of the solar panel, W / m2			Average heat flow qsr, W / m2	Air temperature, °C	
	q ₁	q ₂	q ₃		external	internal
Measured	32,5	34,4	35,2	34,04	-12,3	19,4
Numerical simulation	34	35,5	36	35,17	-12	19

The results in Fig. 3 show a slight discrepancy with the numerical simulation data, which is within 15%.

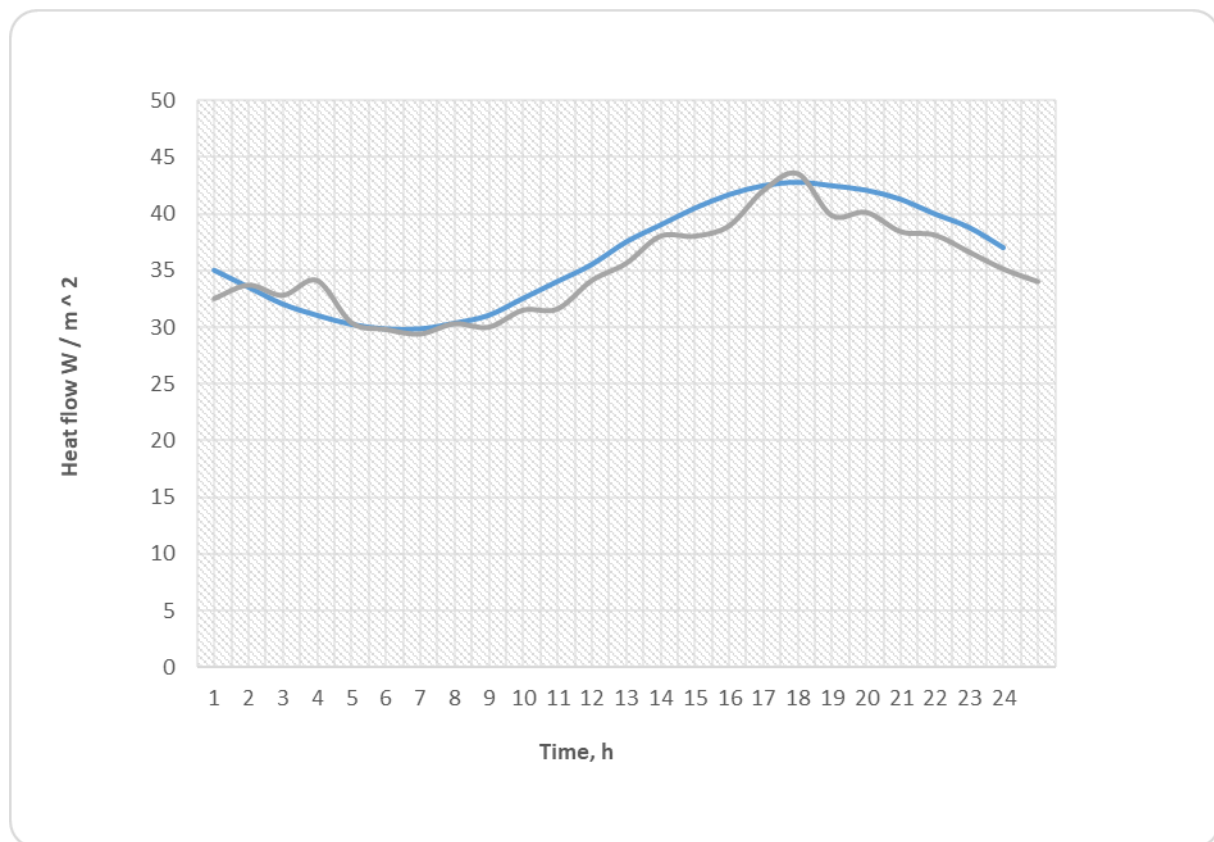


Fig. 3. Results of experimental research and mathematical modeling.

Conclusions

When solar panels are integrated into buildings' southern facade, a constant heat supply in a quasi-stationary mode to heated rooms is achieved not only in climatic zones with sufficiently long hours of sunshine and relatively high temperatures during the cold season, but also under more severe weather conditions.

The experimental studies of the proposed design of an energy-efficient external panel consisting of a single-chamber glass unit, a 100 mm thick storage concrete layer, air layers and mineral wool fixed on the inside have proved the effectiveness of the recycling method and confirmed the results of previous numerical simulation. In January, with daily outside air temperature of $t_n = -12.3\text{ }^{\circ}\text{C}$ in Voronezh ($51^{\circ} 40'19''\text{N}$), the minimum heat input from captured and converted solar radiation is 30 W / m^2 , and the maximum value of 43 W / m^2 is achieved in 18 hours. The average daily heat flow is 37.3 W / m^2 . Therefore, to achieve buildings' high energy efficiency, it is advisable to use passive solar panels, including by further increasing their efficiency through shielding devices that allow to regulate the process of utilization and innovative ingredients that increase building materials thermal characteristics [5, 14, 14].

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