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Features of Spatial Planning Solutions for Low-Rise Residential Buildings with a Passive Solar Heating System

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Abstract: This article describes design solutions for low-rise residential buildings with a passive solar heating system. Studying the influence of the thermal stability of a building with a passive solar heating system on the temperature regime of premises and creating a functional model of energy-efficient low-rise residential buildings for the rural conditions of the Republic of Uzbekistan.

Keywords: thermal insulation, thermal insulation materials, enclosing structure, freezing, waterproofing, formwork, thermal energy, efficiency.

Introduction. One of the promising and economically profitable directions of using renewable sources is the use of radiant solar energy for heating buildings without the use of special expensive solar equipment. They are commonly called passive solar heating systems. Thanks to a special architectural and planning solution, the capture and accumulation of solar energy occurs in the structures of the heated building itself. In many countries, passive solar heating technologies are included in national energy saving programs as one of the main energy-saving areas in construction [1].

As can be seen from the analysis of the development of various solar heating systems, theoretical studies, and the results of multiple pilot construction, obvious advantages of passive systems have been identified. They, in relation to active systems, are effective in saving energy for heating, since they operate at a lower temperature regime [4].

In this connection, since the 80s of the last century, preference has been given to passive systems. Disadvantages of active systems, in particular, the high cost of special solar equipment, the complexity of their operation, especially if solar installations are located on the roof. Their inactivity during the non-heating period and the problem associated with the removal of excess heat in the summer are a serious obstacle to their wide practical application.

The results of many years of research, experimental construction of solar houses and, most importantly, a radical change in approaches to architectural design and structural solutions of the building have shown clear advantages of passive solar heating systems. Cheapness, ease of operation and, most importantly, the absence of the need for expensive imported solar equipment are their main advantages [2,6].

Due to the intermittent receipt of solar radiation in clear weather with a maximum at noon and its alternation with semi-clear and cloudy days, it becomes urgent to address the issue of compliance with the requirements of norms on the amplitude of temperature fluctuations and other parameters of the microclimate of premises [9].

To achieve this goal, the following research tasks have been identified: an analysis of the efficiency of solar heating and the quality of the created temperature regime was carried out;

determined solar technical requirements for the design of buildings with a passive solar heating system; full-scale studies of the temperature regime of the heliohouse were carried out from the point of view of ensuring the calculated thermal stability, ensuring the required temperature regime in the room; functional models of possible options for volumetric-spatial and structural solutions for solar houses have been developed; a feasibility study was completed for the construction of low-rise residential buildings with a passive solar heating system.

In Uzbekistan, in the 70s of the last century, the institutes "Uzgiproplodovoshvinprom" and "Uzgiproselstroy" developed and built two low-rise heliodome in the village of Ulugbek, Tashkent region. The first building ("Uzgiproplodovoshvinprom") with an active system due to a leak in the construction of the solar roof and other serious defects in the design and construction, the solar heating system has not been turned on since the construction of the building. Over time, the helio roof was replaced with a conventional roof. The second heliodom development of "Uzgiproselstroy" was equipped with a passive system. Conducted in 1980. Studies have shown that under various operating conditions at an average outdoor temperature of +3.50 C in the rooms, the temperature fluctuated between 9-160 C with an amplitude of 70C. As can be seen, the sustained temperature range and temperature fluctuations are very different from the normalized values and are not acceptable for civil engineering [5].

On the territory of Uzbekistan, one-storey houses with a passive system were built as an experiment in Termez and Samarkand. The research results also do not allow them to be fully used for heating specific civilian facilities. They also have temperatures ranging from 10-200C, which is clearly unacceptable.

The obvious "stillborn" was the UNDP project on solar heating of the building on Chekhov Street in Tashkent. Ignoring the basic provisions of solar technology, in particular, the use of solar water heaters with single glass for winter heating, which (as is known from studies Institute of Physics and Technology Republic of Uzbekistan in the 70s) will not give the water temperature required for an active system parameter. In fact, the collector, instead of heating the water from 500 C to the required parameter, cooled it by several degrees [7,11].

One of the first "successful" solar heating solutions was recognized by the Douglas Balcomb heliod in Santa Fe USA 36 grad. USA.

In the building, the winter garden performs the function of a solar collector, the heat accumulator is a pebble nozzle under the building. Architecture, in addition to solar engineering requirements, minimizes heat loss and provides the necessary thermal stability of the building. The uniqueness of the project lies in the fact that the author has conducted meticulous experiments for many years using 86 different measuring sensors and obtained a complete picture of the thermal processes of solar heating. It is this successfully designed and built in 1976. Douglas Balcomb's heliodome gave a powerful impetus to the widespread development of such houses in the USA. There are now hundreds of thousands of them and their number is growing rapidly.

An analysis of the world experience in the construction of solar houses shows that if the solar heating system is applied to an ordinary house, the result is unequivocally negative.

Solar architecture is not just a "beautiful" way to place a collector on the roof of a building. Helioarchitecture is formed at the junction of three sciences architecture + solar engineering + construction thermophysics.

In our opinion, the fundamental moment of solar heating is, by a special architectural and constructive solution, giving the building the necessary thermal stability, maintaining the necessary temperature regime in the room with intermittent heating by the sun. Here, by heat resistance, we mean the rate of cooling of the premises after the termination of its heating in degrees/day.

The purpose of these studies is to determine the optimal angle of inclination of the solar receiver and the sector of its permissible orientation in relation to passive solar heating systems. To determine the limits of possible deviation from these solar engineering requirements in specific situations of architectural design. A lot of research has been devoted to the question of the orientation of solar installations [10].

To specify the solar engineering requirements for a building with a passive system, we calculated the total solar radiation on the surface with a different angle of inclination

If we assume that the solar receiver is mounted on a rotary mechanism and monitors the trajectory of the sun, then 26% more solar heat enters its working surface per day than vertically located, and only 12% more heat than obliquely located at an angle of 60 degrees

Vertical arrangement of solar installations is recommended, although the angle of 60 degrees is optimal for the conditions of Uzbekistan [5].

The orientation should be south, the permissible deviation from the south is +-15 degrees. In situations where a large deviation is required, preference, from the point of view of warning against summer overheating, should be given to an offset to the eastern points. For example, the heliodome in Burchmull is oriented with an eastward shift of 40 degrees. here we have introduced an adjustment to the size of the winter garden serving as a heliopriemnik [10].

The main parameter determining the quality of the created microclimate, with intermittent solar heating, is the thermal stability of the building. According to research on real objects by Brink Lalovich and according to the conclusions of Douglas Balcomb and our research at an experimental facility in Tashkent, for natural and climatic conditions close to those of Uzbekistan, the heat resistance parameter should be within 1.5-2.50 S/day. In further research, we will stick to these limits. Of course, bearing in mind that with further research, as theoretical and research experience accumulates, these figures will be clarified [6].

Working hypothesis. However, for practical use in mass construction, including low-rise construction of any heating systems, including passive solar heating systems, it is necessary to comply with certain conditions for ensuring the microclimate of residential premises. The main disadvantage that prevents the mass use of passive systems is the difficult control of thermal processes, the consequence of which is an unacceptably high amplitude of fluctuations in indoor air temperature for residential premises. In intermittent heating systems, for example, with furnace heating with a one or two-time furnace, fluctuations in air temperature are inevitable, but it is regulated within limits that do not affect the quality of the microclimate created. In furnace heating, according to the norms, the amplitude of temperature fluctuations is allowed to be no more than 3° [3].

Calculation method. The article uses methods of scientific observation, abstract-logical, comparative and system analysis.

Mathematical modeling of the temperature regime of buildings heated, changing during the day, by the energy of solar radiation is considered as the process of heating and cooling an enclosed space with intermittent heating.

As is known, in houses with conventional water heating systems, the thermal balance of the building is compiled for stationary conditions, due to the use of continuous heating systems capable of constantly maintaining the necessary temperature in the room. Daily fluctuations in outdoor air temperature due to the massiveness of the enclosing structures practically did not affect the temperature regime of the room [8,13].

When modeling the thermal processes of heliodomes, it is necessary to take into account the intermittency of solar heating in the daily cycle and take into account the probabilistic indicators of clear sunny weather alternating with semi-cloudy and cloudy days. So, in clear weather, the maximum intensity of solar radiation is observed at noon (12-00 hours solar time) and around noon. The minimum values of the sun's energy are observed at sunrise and sunset. In the geographical conditions of the Republic of Uzbekistan, the duration of sunshine in winter is 8-10 hours [9].

The heat loss of a room or building as a whole over a period of time should be equal to the heat release over the same period of all fences together with air at temperature values.

$$q(t_{в} - t_{н})dz = -\mu W + t_{из} k_1 f_1 dz + W^1 dz, \ (1)$$

Where $t_{в}$ and $t_{Н}$ are the temperatures of indoor and outdoor air;

q - thermal characteristics of the room;

t - excessive temperature of the heating system;

f_1 and k_1 - heating surface and heat transfer coefficient of the heating system;

W - heat generation from fences and surroundings when their surface temperature decreases by 1o;

W^1 - constant heat release per 1 hour from other heat sources;

μ - coefficient that takes into account the lag in changes in the temperature of the surfaces of the fences from the air temperature of the room.

Solving a differential equation as a first - order equation gives us the following formula:

$$t = -(t_o - А - Б)e^{\frac{-q}{\mu W}z} + Be^{\frac{-k_1 f_1}{c}} + A \ (2)$$

$A = t_{н} + \frac{W^1}{q}$, $B = \frac{t_0^1 \ \ k_1 f_1}{q - \mu W \frac{k_1 f_1}{c}}$ and $t_{О}$ - initial room temperature.

The resulting formula describes the process of cooling the temperature in the room without taking into account the loss of energy for heating the ventilation air.

q_1 – thermal characteristics of the room, that is, the amount of heat lost by the room through the external fences within an hour at a temperature difference of 10 kkal/hour deg;

q_2 – heat expended per hour to heat ventilation air by 10 kkal/hour degrees;

$m = \frac{V}{v}$ – frequency of air changes per hour;

τ - duration of ventilation in hours;

W' – heat accumulated or given off by building structures when their surface temperature changes by 10, kkal/degree;

W'' - heat accumulated or given off by furniture and household appliances when their temperature changes by 10, in kkal/degree;

Q' – heat gain from direct solar heating kkal/hour;

Q'' – heat from a pebble battery in kkal/hour;

Q''' – heat from the backup heating system in kkal/hour.

Suppose that ventilation is carried out by unheated outdoor air, then the heat balance equation for the elementary period will be written as

$$q_1(t - t_н)d\tau + q_2(t - tн)d\tau + q_3(t - t_н) \cdot e^{-m\tau}d\tau + \mu W'dt + W''dt =$$
$$= Q'd\tau + Q''d\tau. \quad (3)$$

The composition of the third term of the equation includes an exponential function that takes into account the reduction of infiltration with an increase in the multiplicity of air changes per hour from organized ventilation.

Since in residential buildings with a passive solar heating system, due to the insignificant multiplicity of air exchange, compared with industrial facilities, the third term can be neglected, and the heat balance equation with active ventilation takes a simpler form:

$$q(t - t_н)d\tau + Wdt = Qd\tau, \quad (4)$$

where

$$q = q_1 + q_2, W = W' + W'' \text{ и } Q = Q' + Q''.$$

Integrating the heat balance equation (4), we obtain

$$t = t_0 e^{-\frac{q}{W}\tau} + (t_н + \frac{Q}{q})(1 - e^{-\frac{q}{W}\tau}) \quad (5)$$

Or

$$t = t_0 e^{-\frac{q}{W}\tau} + T(1 - e^{-\frac{q}{W}\tau}) \quad (6)$$

$$T = t_н + \frac{Q}{q} \quad (7)$$

This is the basic equation for determining the current temperature in rooms with solar heating, simple in form is complex in essence. It consists of variables: the heat input from the sun, the accumulated heat in the massive structures of the building and the heat accumulated in the pebble nozzle.

Conclusion. Based on the results of experimental and theoretical studies, the following conclusions were formulated:

the use of passive solar heating technology for low-rise residential buildings is the most promising area for real savings of fuel and energy resources in the Republic of Uzbekistan, since up to 80% of the energy of the total energy consumption of a building is spent for these purposes;

the reasons for excessive temperature fluctuations in solar houses exceeding the hygienic standards A_t=3.0 ^{0}C have been identified, the elimination of which in the design allows us to develop a new special technique for the formation of stable temperature conditions in rooms heated by intermittent solar energy;

based on mathematical modeling describing the nonlinear dependence of the course of temperature changes in the room on the specific consumption of thermal energy for heating, natural ventilation and heat-storing capabilities of massive building structures, a calculation equation for the course of temperature changes in the room was created in which it is most advisable to use passive solar heating technology to ensure the required microclimate of building premises and reduction of operational energy consumption;

numerical dependences of the thermal stability of the building on the absolute values of the ratio q/W of the exponential function indicator forming in the calculation equations the rate of temperature change during different periods of solar heating have been established.

REFERENCES:

1. Haggard, Ken, David A. Bainbridge, and Rachel Aljilani. Passive solar architecture pocket reference. Routledge, 2016.
2. Gorshkov, A. S. "Energy efficiency in construction: problems of standardizing and measures to decrease energy consumption of buildings." Inzhenerno-stroitel'ny zhurnal 1 (2010): 9-13.
3. Norov, Nusratillo, et al. "Use Of Solar Heating Systems AS An Element Of A Passive House." Academicia Globe 2.09 (2021): 38-43.
4. Norov, Nusiratjon, Yulduz Khudainazarova, and Akmal Bobakulov. "TECHNOLOGIES USED IN THE PROTECTION OF LOAD-BEARING STRUCTURES TO IMPROVE THE ENERGY EFFICIENCY OF BUILDINGS." International Bulletin of Applied Science and Technology 3.10 (2023): 616-620.
5. Норов, Нусиратжон, and Юлдуз Худайназарова. "Повышение энергоэффективности зданий с использованием современных конструкционных теплоизоляционных строительных материалов в условиях узбекистана." International Bulletin of Applied Science and Technology 3.9 (2023): 217-222.
6. Turgunaliyevich, Yusupov Usmonjon, and Mingyasharov Abdurakhim Horoz Ogli. "ENERGY EFFICIENCY OF INDUSTRIAL PREMISES OF INDUSTRIAL BUILDINGS." Вестник науки и образования 7-2 (110) (2021): 33-35.
7. Маракаев, Р. Ю., and Н. Н. Норов. "Узбекистон шароитида энергия самарали биноларни лойих, алаш/Укув кулланма." Ўқув-услубий қўлланма. Т., ТАҚИ (2009).
8. Зохидов, М. М., and Н. Н. Норов. "Энергоэкономичное здание." Жилищное строительство 5 (2003): 29-29.
9. Norov, Nusiratjon Nuraliyevich, and Yulduz Xudoynazarova. "TURAR-JOY BINOLARIDA ENERGIYA ISTE'MOLI HOLATI VA ENERGIYA TEJAMKORLIKNI TA'MINLASH MASALALARI." *GOLDEN BRAIN* 1.1 (2023): 157-159.
10. Nuraliyevich, Norov Nusratjon, and Khudaynazarova Yulduz Djumanazarovna. "Development of volume-planning and constructive solution of houses with solar heat supply." *European science review* 5-6 (2018): 313-315.
11. Авезова, Н. Р., etal. "Энергоэффективные здания." Гелиотехника 57.1 (2021): 53-65.
12. Nuralievich, Norov Nusratjon, et al. "DESIGN OF RESIDENTIAL BUILDINGS TAKING INTO ACCOUNT THE CONSEQUENCES OF CLIMATE CHANGE IN UZBEKISTAN." *Spectrum Journal of Innovation, Reforms and Development* 3 (2022): 204-208.
13. SCHIPACHEVA, ELENA. "ISSUESAND VIEWPOINTS OFSCIENTIFIC RESEARCH IN THE FIELD OF DESIGNING ENERGY EFFICIENT BUILDINGS IN UZBEKISTAN."
14. Норов, Н. Н., and У. Р. Абдуллаев. "ЭНЕРГОЭФФЕКТИВНЫХ ТЕХНОЛОГИЙ С СОЛНЕЧНЫМИ СИСТЕМАМИ ТЕПЛОСНАБЖЕНИЯ В СЕЛЬСКОМ КОМПЛЕКСЕ." Ta'lim fidoyilari 3.2 (2023): 48-50.