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Satbayev University

Х А Б А Р Л А Р Ы

ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК
РЕСПУБЛИКИ КАЗАХСТАН
Satbayev University

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OF THE REPUBLIC OF KAZAKHSTAN
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Қазақстан Республикасы Ұлттық ғылым академиясы "ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы" ғылыми журналының Web of Science-тің жаңаланған нұсқасы Emerging Sources Citation Index-те индекстелуге қабылданғанын хабарлайды. Бұл индекстелу барысында Clarivate Analytics компаниясы журналды одан әрі the Science Citation Index Expanded, the Social Sciences Citation Index және the Arts & Humanities Citation Index-ке қабылдау мәселесін қарастыруда. Webof Science зерттеушілер, авторлар, баспашылар мен мекемелерге контент тереңдігі мен сапасын ұсынады. ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы Emerging Sources Citation Index-ке енуі біздің қоғамдастық үшін ең өзекті және беделді геология және техникалық ғылымдар бойынша контентке адалдығымызды білдіреді.

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MICROCLIMATE IN THE BUILDINGS FROM VOLUME BLOCKS

Abstract. Providing the necessary parameters of the microclimate is one of the necessary conditions in the modern construction. For these purposes, there is a set of measures and microclimate support systems applicable in all types of the structural design of buildings. But the features of houses form the modular blocks allow us to move away from standard solutions and use energy-efficient construction technologies, namely, walls with a ventilated interlayer. This design allows us to provide the necessary air exchange in the premises while providing the necessary inlet air temperature. Walls with a ventilated interlayer complement the central ventilation systems or even make it possible to abandon their use. In this article the issue of using walls with ventilated interlayers in the modular blocks, with the use of additional heating of the incoming air in the cold season by using film infrared heaters was considered. The question of the integration of this design with the system of "smart home" was also considered, which will lead to the possibility of creating an energy-efficient building by ensuring cellular regulation of the microclimate parameters. The result of the research is the data required for an approximate calculation of walls with ventilated interlayers and infrared film heating systems, and the possibilities of creating active buildings were also considered. To ensure the energy efficiency of the building, it is proposed to control air exchange and temperature. The control will be carried out directly as follows: in the ventilated walls, at the holes, sensors are installed that will control the speed and temperature of the supply air; a radiant heating film and a recuperator plate that heats the supply air are mounted in the inner heating layer of the wall panel. If the plate temperature is insufficient, the heating film is switched on, which increases the temperature of the supply air masses to the desired temperature.
Key words: volume block, building automation, ventilated wall, infrared heating film, heat engineering.

Introduction. Industrialization is one of the important events in construction. After all, construction, like other industrial processes, has a high energy and material intensity, i.e. it requires a large number of raw materials and energy to create the final product. They are spent on: the extraction of this raw material and its processing, production processes. At the same time in construction, there are several types of these processes.

Production of building materials, i.e. the creation of raw materials necessary for the construction of buildings and structures, and their engineering systems. As you know, the method of activation of binding systems [1-4] increases the strength properties of concrete. The composition of aerated concrete [5-9] affects the mechanical properties of aerated concrete products. In this case, there is a high level of industrialization, because modern materials are manufactured at specialized factories.

Construction. This point implies processes for the construction of buildings and structures, and the level of industrialization of these processes ranges from low, in which most processes are carried out on the construction site, to the high, i.e. installation of sections (parts) of the building that are manufactured at the factory.

Building operation - the processes associated with the creation of the necessary microclimate in a building or a structure.

The high level of industrialization in construction is ensured by transferring most of the processes to factory conditions by introducing a block type of construction, consisting in dividing a building into modular blocks and sections, manufactured in factories and house-building factories. The only processes carried out outside the workshop: transportation of blocks to the construction site and their installation.

When a building is divided into volumetric blocks, they are unified, i.e. blocks have standard sizes. This unification allows us to create experimental samples that use lightweight materials or non-standard types of joints, the production of which directly on the construction site is impossible.

But, bearing in mind the above, the engineering systems in block buildings do not differ from the usual ones: the same ventilation systems are used (natural, by means of windows and doors, or intake and exhaust systems) and heating. Although the block type of a building itself, using the systems that used in energy-efficient buildings, makes it possible to apply new schemes to ensure the necessary parameters of the indoor microclimate.

One type of efficient heating is a radiant heating system. The radiant heating is a system used in modern houses, consisting of panels or pipes laid in the floor or walls, creating infrared radiation that heats internal objects and air, and this system also increases the concentration of negative ions by 4 times. More than 90% of the radiation belongs to the far infrared range (5-20 microns). The water, gas or electricity is used as a heat-transfer material. The heating elements of this system can be installed in the walls, while the heat irradiation is from 160 to 200 W/m2.

Also, there are heating elements in the form of a film. These films are low-temperature heaters, up to 1 mm thick, with a surface heating temperature of 40-65.

Radiant heating systems provide electrical energy savings (about 40%) [10-12] provided by thermostatically controlled elements.

The ventilation is one of the systems that create normative parameters of the indoor microclimate, namely, providing the necessary quantity and quality of indoor air. The natural ventilation is carried out through doorways and window openings, vents in bathrooms and kitchens. The forced ventilation is a system consisting of a pump and pipes and can be inlet, exhaust or inlet and exhaust. But the greater the volume of the incoming air, the greater the load on the room heating system, in this case, the rate of heat loss due to ventilation is 45% of the total heat consumption.

Therefore, in energy-efficient buildings, mechanical ventilation systems with heat recovery systems are used, ensuring the inflow of the required air volume with the required temperature. These systems consist of a pump, a piping system, and a recuperator. In this case, in a block building, it becomes possible to abandon the piping system by using a system like a wall with ventilated devices. This system also works as mechanical ventilation with a heat exchanger, but there are no bulky pipelines. In this system, the outside air enters the room through the outer enclosing structures.

Research methodology. In order to study the possibility of using the above systems, let us consider the design of modern modular blocks.

The blocks are made of various materials and have different structural schemes. The most common scheme consists of ceiling, floor slabs and walls panels. Also, blocks of steel bearing frame, with hung external enclosing structures, are produced. Thus, the wall panels are not bearing. Therefore, it is possible to use walls with ventilated devices. The design consists of a ventilated layer, the inner and outer layers and insulation. In the outer and inner layers are inlet openings with control valves.

The meaning of the construction is to allow air to pass through the walls. The external air penetrates into the internal space through the holes in the inner and outer layers of the walls. To heat the supply air, the heat of the heated wall is used. There are also designs with multiple air movement. For example, to make a double movement of air masses, the walls of two ventilated interlayers are used, separated by a partition, which has high heat irradiation ability. The heating of this partition is carried out by the warm air of the interior space entering the interlayer. Thus, the incoming air is heated to the desired temperature before entering the room ys. The walls with multiple air movement have several air spaces. During the production of wall panels with windows, holes are located under the window opening.

In the warm season, when the air temperature is more than 21 °C, the heat of the incoming air can be used in the internal systems as an additional source of heat. But in the winter season, when the air temperature is below -25 °C, it is necessary to apply additional heating of the incoming air.

This construction can be considered a kind of modification of the inlet and exhaust system with a heat exc hanger, which differs from the latter in that the air flow is carried out naturally due to the difference in temperature between the internal and external air. To improve the performance of the system, the system of supply and exhaust ventilation can be used, which increases the flow of air into the room.

This system can be used in panel and block construction: the production of such panels requires precision and tightness, which can only be ensured through the factory conditions.

According to [11], the thickness of the insulation for the inner layer will be 40-55 mm, at the outside air temperature $t_н = -25 \ldots -33$°C, the outer layer - 60-65 mm, and the thickness of the channels should be more than 20 mm.

The channels in the thickness of the panel are formed with the help of pipes, void formers or embedded parts.

The precise calculation of this system is made on a computer. During the calculation, the temperatures of the inner and outer layers, the change in the air temperature along the height of the channels, the amount of heat passing through 1 m^2 of the inner layer per 1 hour are determined.

For the manual calculation of the wall with one layer, the following method is used.

The temperature on the surface of the inner wall of the air gap τ_1, the temperature on the outer surface of the air gap τ_3 and the temperature change in the layer along the height $\Delta\tau_2$ is calculated by the formulas:

$$\tau_1 = \frac{B_3^2+25{,}5B_1+\left(200+50\frac{\lambda_в}{\delta_щ}-2B_3\right)\tau_3+4B_3\tau_2+2\tau_3^2}{2B_3+200+50\frac{\lambda_в}{\delta_щ}+2\tau_3} \tag{1}$$

where, B_1, B_3 – the coefficients, determined by the formulas:

$$B_3 = B_1\delta_щ/2\lambda_в \tag{2}$$

$$B_1 = \alpha_в(t_в - \tau_в) + \alpha_н(t_н - \tau_н) \tag{3}$$

$$\tau_3 = B_3 + \tau_1 - 2\sqrt{B_3(\tau_1 - \tau_2)} \tag{4}$$

$$\alpha_в = 1{,}66\sqrt{t_в - \tau_в} + 3{,}97 + 0{,}0245(t_в + \tau_в) \tag{5}$$

$$\alpha_н = 11{,}6\sqrt{\upsilon} + 3{,}97 + 0{,}0245(t_н + \tau_н) \tag{6}$$

where, $\delta_щ$ – the air interlayer thickness, m; $\lambda_в$ – the coefficient of the air thermal conductivity, W/(m · °C); $\alpha_в$ – the heat transfer coefficient of the inner surface of the interlayer, W/(m · °C); $t_н$ – the outside temperature, °C; $\tau_н$ – the outer surface temperature, °C; $t_в$ – the indoor air temperature, °C; $\tau_в$ – the inner surface temperature, °C; υ – the movement speed of air flows, m/s.

The amount of heat penetrating through 1 m^2 per 1 h through the inner layer of the enclosure Q_1 is determined by the formula:

$$Q_1 = \frac{\tau_в - \tau_1}{R_{тв}} \tag{7}$$

$$\tau_в = \frac{\tau_1 + t_в\alpha_в R_{тв}}{1+\alpha_в R_{тв}} \tag{8}$$

$$R_{тв} = \frac{\delta_1}{\lambda_1} + \frac{\delta_2}{\lambda_2} \tag{9}$$

where, $R_{тв}$ – heat transfer resistance of the inner layer, (m^2·°C)/W; δ_1, δ_2 – the thickness of the layers of materials of the inner layer, m; λ_1, λ_2 - the thermal conductivity of the layers of materials of the inner layer, W/(m·°C).

The amount of heat penetrating through 1 m^2 per 1 h through the outer layer of the enclosure Q_2 is determined by the formula:

$$Q_2 = \frac{\tau_3 - \tau_н}{R_{тн}} \tag{10}$$

$$\tau_н = \frac{\tau_3 + t_н \alpha_н R_{тн}}{1 + \alpha_н R_{тв}} \tag{11}$$

$$R_{тн} = \frac{\delta_4}{\lambda_4} + \frac{\delta_5}{\lambda_5} \tag{12}$$

where, δ_4, δ_5 – the thickness of the layers of materials of the outer layer, m; λ_4, λ_5 – the thermal conductivity of the layers of materials of the outer layer, W/(m·°C).

The amount of heat passing through 1 m2 of the outer surface per 1 h, $Q_н$is calculated by the formula:

$$Q_н = \alpha_н(\tau_н - t_н) \tag{13}$$

where, $\alpha_н$ – the heat transfer coefficient of the outer surface of the interlayer, W/(m^2·°C)

The change in the air temperature by the height of the layer is determined by the formula:

$$\Delta\tau_2 = \frac{H}{WCn}\left(\frac{\alpha_в(t_в - \tau_1)}{1 + \alpha_в\left(\frac{\delta_1}{\lambda_1} + \frac{\delta_2}{\lambda_2}\right)} - \frac{\alpha_н(\tau_3 - t_н)}{1 + \alpha_н\left(\frac{\delta_4}{\lambda_4} + \frac{\delta_5}{\lambda_5}\right)}\right) \tag{14}$$

where, H – the section height, m; W – the airflow, kg/(m^2·h); C – the specific heat capacity of air , 1010 J/(kg·K); n – the number of the discrete sections, pcs.

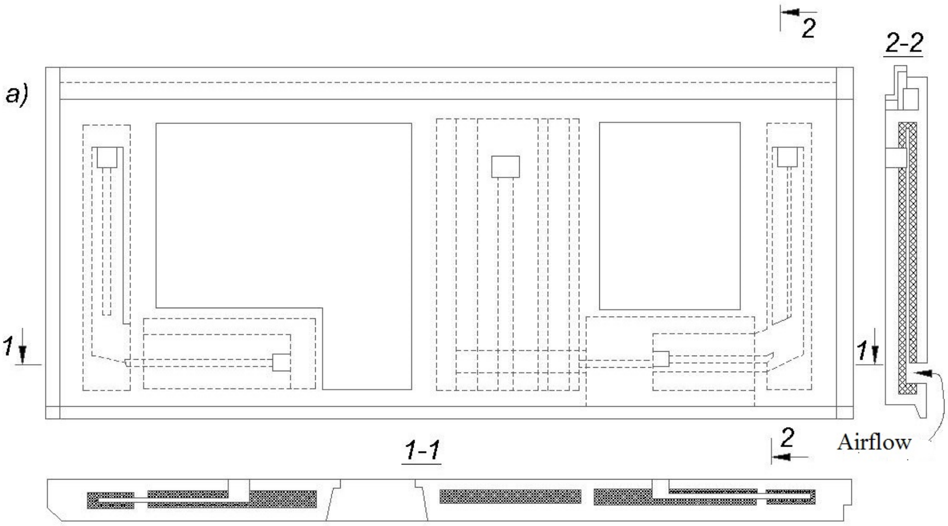
The airflow is determined by the formulas [2]. The amount of air W is calculated by the formula:

$$W = 3600\upsilon\delta h\gamma \tag{15}$$

where, υ – the air velocity in the interlayer, m/s; δ, h - accordingly, the thickness and height of the air interlayer, m; γ – air volume weight, kg/m^3.

During the designing a block building we have several possible positions of the walls with ventilated interlayers. In the first case, such walls are external, in the second case, such walls are internal (by which the contact of two blocks occurs).

Let us define the characteristics of the walls in the second case in the cold season. Let us accept climatic parameters for the city of Kyzylorda: $t_н = -24$°C, $t_н = 20$°C, airspeed 0,2 m/s. The construction of the wall panel looks like: $\delta_1 = 0{,}1\,м, \delta_2 = 0{,}8\,м, \delta_4 = 0{,}8, \delta_5 = 0{,}1$. The mineral wool plates with the thermal conductivity of 0,04 W/(m·°C) is taken as insulation.



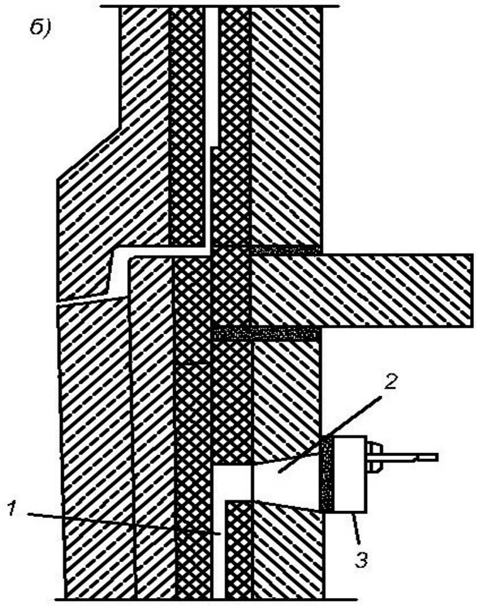
By using the iteration method, let us define the following values for the panels of external walls: $\tau_1 = -23{,}4$°C, $\tau_3 = -23{,}8$°C, $\tau_н = -24$°C, $\tau_в = -19{,}6$°C. The amount of heat penetrating into the interlayer through the inner layer of the panel is $Q_1 = 2{,}14\ \text{J/m}^2 \cdot \text{h}$.

When using panels with two air interlayers with parallel air movement, the inlet mass is heated by 9.6.

In order to determine the required inlet air temperature, let us use [12]:

$$t_x' = t_n - \Delta t_2 \quad (16)$$

where, t_x' - the minimum premises temperature during assimilation of the premises heat, °C; t_n – the normalized air temperature, 20 °C;



Three-layer ventilated panel: a – with ribs; б – on connections; 1 – ventilation duct; 2 – air vents; 3 – valve

Δt_2 – the permissible variation of the air temperature,1 °C. $t_x' = 20 + 1 = 21$°C

Results and discussion. According to [13-20], this system will require additional heating, separately from the main heating system. To compensate for the losses, we can use radiant heating.

The scheme is as follows: the heating element is laid in the inner layer of the wall panel in the form of the heating film, which raises the temperature of the inner surface of the interlayer and inlet air. Since the duct area is rather small, the film costs are insignificant. For example, according to [19,20], the power per 1 m2 will be 110 watts.

This system is effective in the modular block housing. By production of blocks, especially with the frame scheme, it is possible to apply this system in wall panels. The efficiency is that during designing blocks, they are considered as autonomous cells, and, depending on the type of block (residential or technical premises), each cell requires its own microclimate parameters. By combining ventilated walls with a radiant heating system and a smart home system, it is possible to create a comfort regulation system in each cell of the building.

The smart home system (automation of microclimate control) is a complex of devices that make up the overall control system that controls the following parameters: heating, ventilation, fire alarms, lighting control, pumping stations (if heat pumps are used), emergency situations, power consumption, and others.

The system works as follows. Special sensors (temperature, speed of a movement of air masses) connected to the automatic control system are installed in the wall panels and in the room itself, with which the microclimate parameters are adjusted and controlled in all cells of the building. The interrelation of various systems is carried out according to standard, general protocols, and according to certain scenarios. The scenarios are the algorithms for the operation of these systems, i.e., they support the necessary parameters of the internal microclimate under the varying environmental conditions.

During designing the ventilated walls, we are faced with a dynamic system, the parameters of which periodically change. And in order to ensure energy conservation and increase the energy efficiency of the system, automation systems should be used.

The "Smart Home" implements a cellular climate control system, the purpose of which is to create the necessary temperature, airflow, air`s quality through special programs, and this system will ensure the building's energy efficiency.

Thus, the control of air exchange and temperature will be carried out as follows: in ventilated walls, sensors that control the speed and temperature of the inlet air are installed in the ventilated walls; in the inner, heating layer, the radiant heating film and recuperator plate are installed, that raises the temperature of the inlet air masses to the required temperature.

Conclusion. The districts with such "smart" block buildings are combined into "smart" districts. The system of this districts works the same way as in a “smart” house, while its area of influence is much greater: control of traffic, waste, power supply systems and other public services. The optimization of the district`s work affects the operation of buildings. Such a system increases the efficiency of using the city’s infrastructure through the mutual influence of every citizen and the city’s electronic system and the ability of the system to continuously learn.

Thus, the "smart home" is one of the main factors of energy-efficient construction, giving the building flexibility - the necessary quality of effective systems.

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КӨЛЕМДІ БЛОКТАРДАН ЖАСАЛҒАН ҒИМАРАТ МИКРОКЛИМАТЫ

Аннотация. Микроклимат параметрлерін қамтамасыз ету – заманауи құрылысқа қажетті шарттың бірі. Ғимараттардың құрылымдық схемаларының барлық түрінде қолданылатын шаралар жиынтығы және микроклиматты қолдау жүйелері бар. Бірақ көлемді блоктардан жасалған үй ерекшеліктері стандартты шешімдерді қолданбауға және энергия үнемдейтін құрылыс технологияларын, атап айтқанда, желдетілетін қабаты бар қабырғалар қолдануға мүмкіндік береді. Бұл дизайн ауа ағынының қажетті температурасын қамтамасыз ете отырып, бөлмелерде қажетті ауа алмасуды қамтамасыз етуге мүмкіндік береді. Желдетілетін қабаты бар қабырғалар орталық желдету жүйелерін толықтырады немесе тіпті оларды пайдаланудан бас тартуға мүмкіндік береді.

Мақалада желдеткіш қабаттары бар қабырғаларды үлкен көлемдегі блоктарда пайдалану әрі жыл мезгілінде кіретін ауаны инфрақызыл жылытқыштармен қосымша жылытуды қолдану мәселесі қарастырылды. Бұл конструкцияны микроклимат параметрлерін жасушалық реттеуді қамтамасыз ету арқылы энергия үнемдейтін ғимарат құруға мүмкіндік беретін «ақылды үй» жүйесімен біріктіру мәселесі де қарастырылды. Зерттеу нәтижесі желдеткіш қабырғалармен және инфрақызыл пленкамен жылыту жүйелері бар қабырғаларды шамамен есептеу үшін қажетті деректер анықталды, сондай-ақ белсенді ғимараттарды құру мүмкіндіктері қарастырылды.

Ғимараттың энергия тиімділігін қамтамасыз ету үшін ауа ауыстыру және температураны бақылау ұсынылады. Бақылау тікелей келесі жолмен жүзеге асырылады: желдетілетін қабырғаларда, тесік орындарында, берілетін ауаның жылдамдығы мен температурасын басқаратын датчиктер анықталады; қабырға панелінің ішкі жылыту қабатында сәулелі қыздыру пленкасы және қоректендіретін ауа қыздыратын рекуператор табақшасы орнатылады. Егер пластина температурасы жеткіліксіз болса, қыздыру пленкасы қосылып, ауа массасының температурасын қажетті температураға дейін арттырады.

Түйін сөздер: көлемді блок, «ақылды үй», желдетілетін қабырғалар, инфрақызыл таспалы қыздырғыш, жылу техникасы.

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МИКРОКЛИМАТ В ЗДАНИЯХ ИЗ ОБЪЕМНЫХ БЛОКОВ

Аннотация. Обеспечение необходимых параметров микроклимата – одно из необходимых условий в современном строительстве. Для этих целей существует комплекс мер и систем обеспечения микроклимата,

применяемый во всех видах конструктивных схем зданий. Но особенности блочных домов позволяют нам отойти от стандартных решений и использовать технологии энергоэффективного строительства, а именно стены с вентилируемой прослойкой. Такая конструкция позволяет обеспечить необходимый воздухообмен в помещениях при обеспечении необходимой температуры приточного воздуха. Стены с вентилируемой прослойкой дополняют центральные системы вентиляции или даже дают возможность отказаться от их использования.

В данной статье был рассмотрен вопрос применения стен с вентилируемыми прослойками в объемных блоках с применением дополнительного обогрева приточного воздуха в холодное время года путем использования пленочных инфракрасных нагревателей. Также был рассмотрен вопрос интеграции данной конструкции с системой «умного дома», что приведет к возможности создания энергоэффективного здания, путем обеспечения поячеистого регулирования параметров микроклимата. Результатом исследования являются данные, необходимые для приблизительного расчета стен с вентилируемыми прослойками и системы инфракрасного пленочного нагрева, а также были рассмотрены возможности создания активных зданий.

Для обеспечения энергоэффективности здания предлагается контролировать воздухообмен и температуру. Контроль будет осуществляться следующим образом: в вентилируемых стенах в местах отверстий уславливаются датчики, которые будут контролировать скорость и температуру приточного воздуха, во внутренний, нагревающий слой панели стены монтируется пленка лучистого отопления и пластина рекуператора, осуществляющего нагрев приточного воздуха. При недостаточной температуре пластины в работу включается пленка отопления, повышающая температуру приточных воздушных масс до нужной температуры.

Ключевые слова: объемный блок, «умный дом», вентилируемые стены, инфракрасный пленочный нагреватель, теплотехника.

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