

PAPER • OPEN ACCESS

## The Energy-Efficient Facade Systems for Civic Buildings

To cite this article: M.M. Kosukhin and A M. Kosukhin 2018 *IOP Conf. Ser.: Mater. Sci. Eng.* **463** 042037

View the [article online](#) for updates and enhancements.



**IOP | ebooks™**

Bringing you innovative digital publishing with leading voices to create your essential collection of books in STEM research.

Start exploring the [collection](#) - download the first chapter of every title for free.

# The Energy-Efficient Facade Systems for Civic Buildings\*

M.M. Kosukhin<sup>1, a</sup>, A M. Kosukhin<sup>2, b</sup>

<sup>1</sup>Engineering and Construction Institute, Department of Building and Urban Development, Belgorod State Technological University n.a. V.G. Shukhov, Kostyukova Street, 46, Belgorod, 308012, Russia

E-mail: mkosuhin@mail.ru

**Abstract.** It has been demonstrated that nowadays the housing stock doesn't meet the up-to-date requirements of heat engineering, energy saving and energy performance of buildings. To create the necessary indoor climate of living accommodations and to provide the comfortable living environment most of civic buildings, built at different times, are in need of the large-scale modernization. The main part in solving this problem belongs to capital repairs. For its satisfactory implementation an integrated approach to repairs and construction works technologies with the use of up-to-date energy-efficient technologies and materials is needed. A special part in solving this problem is played by designing and installing the heat-insulating facade systems. Some peculiarities of making such systems with account of the service conditions and the used materials have been described. It has been pointed out that the efficient heat insulation of enclosing structures should be preceded with the professional engineering survey of structures and with providing the scientifically-grounded recommendations, based on present-day scientific achievements in this sphere and on the knowledge of physical and chemical processes and phenomena, taking place in enclosing structures under the influence of internal and external operational environment. To ensure the economical and operational efficiency of selecting and installing heat insulation it's necessary to learn to manage these processes at the stages of design and facade works performance.

## 1. Introduction

The main component of housing and utility complex of the country is civic buildings, presented by the housing stock and social infrastructure facilities. Nowadays, in order to create the comfortable living environment, comply with the requirements of increasing the energy-saving, energy-performance and operating reliability parameters and improve the architectural expressiveness, the civic buildings must meet specific requirements. Carrying-out these requirements is the issue of national importance in the sphere of construction sector and housing and utility complex of the country [1].

The up-to-date requirements to the functional properties of facades have also changed. For example, the usage of conventional building materials in a single-layered form can't provide the heat-transfer resistance value, specified by the requirements of regulatory documents and legal acts for facades installation. The prescribed value can be achieved only at the multi-layered application of enclosing structures with the usage of efficient heat-insulating materials. To solve this problem a large number of various heat-insulating facade systems and materials have appeared at the building materials market [2]. But the errors, the overoptimistic approach and sometimes lack of professionalism at facades installation, as well as the subjective attitude to solving the problems, didn't



bring the expected results [3]. In this regard, the purpose of this work is improving the technology of making heat-insulating plaster systems at the capital repairs of civic buildings by completing it with several details, based on analyzing the results of a number of engineering surveys of operated residential buildings, carried out before and after the capital repairs.

## 2. The main part

The civic buildings, which are under construction at present, mostly comply with the requirements of energy performance. As for the buildings, built at different times, most of them don't meet the modern heat engineering requirements [4]. Bringing them to the regulatory heat-engineering standards requires carrying out capital repairs and reconstruction of buildings, and, first of all, the buildings constructed according to the old heat engineering standards. The desired result in this process can be achieved only by updating the repairs and construction industry itself, based on the findings of the professional engineering survey of civic buildings [5]. To solve this problem an integrated approach to building and repair works technology is needed, using the up-to-date energy-saving technologies and different from the traditional, conventional ways of organizing construction and repair operations [6].

The experience of carrying-out capital repairs has shown that dealing with the fragmentary, random or local problems didn't help solving the global problem of reducing the excessive energy consumption of constructions. This resulted only in the extra costs for these works, and the ageing of the housing stock and its insufficient repairs resulted in the increase of the amounts of hazardous dwellings and dilapidated housing and decrease of the comfort level [7].

Due to the fact, that at carrying out capital repairs, apart from providing the required parameters of the indoor climate and service reliability, a special role is assigned to improving the energy performance and energy saving of the repaired buildings, the main object of implementing this task are the outer walls [8].

The enclosing structures, exposed to the action of the external and internal operational environment, are a complex thermodynamic system, subject to physical and chemical laws, processes and phenomena. So, its thermal-physical properties can be efficiently managed only on the basis of the scientific approach. This becomes especially important when it comes to using new building technologies, materials and heat-insulation systems [9].

For the clear insight into the need for heat-insulation of enclosing structures of residential buildings, one should understand the processes, which occur both inside and outside the structure under the action of various factors [10].

The durability of enclosing structures, especially their thermal-physical properties, are considerably influenced by the climatic conditions: atmospheric precipitations, daily and seasonal temperature fluctuations, wind loads, solar radiation, biocorrosion processes, as well as the processes and phenomena within the constructions, caused by these conditions. The influence of these factors results in the reduction of service reliability of both the enclosing structures themselves, and of the building in general. In the course of time, their thermophysical properties considerably deteriorate as well [11].

An exterior enclosing structure is a phase contact area of the interaction between the cold external and the warm internal operational environments. Both on the surfaces of this contact area and within it the new processes and phenomena take place, which considerably influence the quality of heat insulation, and, consequently, the indoor climate and the service reliability and durability of the building [12].

The atmospheric precipitations (rain, snow, fog) cause the dampening of exterior structures. Getting on the surface of the enclosing structures, the water penetrates through the capillary open pores into the depth of the structure and can exist there in all three aggregate states: liquid, solid and gaseous (vaporous). Temperature drops cause the phase transition of water to the ice with the considerable increase of volume. This, in its turn, results in the formation of internal stresses in the material of the enclosing structure, which cause mechanical corrosion. At the rise of temperature the reverse phase transition of ice to water takes place. The internal stresses are released, leaving a network of microfractures from the previous freezing in the bulk of the structure. Then the process is

repeated, and each new cycle contributes to the deeper penetration of moisture, and consequently, to even stronger deterioration. The larger is the difference between the seasonal and daily temperature fluctuations, the more frequent and intensive these processes are (the frost deterioration mechanism). The permanent action of alternating load on the dampened wall results in its intensive destruction. It should be also kept in mind that the moisture is always present within an enclosing structure in this or that amount, and not only due to atmospheric precipitations (construction moisture, telluric moisture, hygroscopic moisture and service moisture). A special role in dampening the enclosing structures is played by the service moisture, which is often neglected. Nevertheless, water vapor is contained in the exhaled air; a large amount of it is generated due to household and industrial activity, indoor cleaning and operation of water supply and sanitation systems. The excess pressure forces the water vapor to move outside. Part of the moisture leaves the indoor space through natural and forced ventilation systems, and part of it penetrates the enclosing structures and tries to get outside from there [13,14]. The water vapor is condensed on the cold surfaces and becomes the condensed moisture. The place of such phase transition is called the dew point. The adverse effects of the outer walls dampening can be caused not only by negative temperatures. The action of solar heat and sunlight on the damped enclosing structure create the favorable environment for the development of mould, rot, fungi and other microorganisms inside the structure and on its surface. This impairs the sanitary parameters of the indoor climate and has an adverse effect on the health of inhabitants. It follows thence that the outer structures of civic buildings should meet a number of requirements. They should be low-cost at building and maintenance, strong and durable, should perform their functional purposes, providing the necessary energy performance of the building and the required indoor climate, as well as the architectural expressiveness [15].

To comply with these requirements a great variety of multilayered heat-insulating façade systems are available at the construction market nowadays. As it is known, during the new construction three types of insulating material arrangement are used: interior, inside the wall and exterior. As for heat insulating of already constructed and inhabited buildings during their capital repairs, a question arises from which side it would be the most efficient to apply the insulating material. The exterior insulation is the most appropriate for residential buildings, as it possesses a number of advantages: it uses the effect of heat accumulation by the load-bearing structures of the building; brings the «dew point» outside the load-bearing structure; doesn't reduce the volume of the habitable inner space. The most efficient and simple to manufacture is the external wall insulation system, which is also successfully used in new construction [16,17].

Depending on the kind of insulant protection in a multilayered enclosing structure, two types of heat-insulating façade systems are the most widely used nowadays: wet (plaster) ones – with the layer-by-layer protection of the insulating material with plaster coats, and the ventilated ones – with the use of structural curtain elements in the form of a protective-decorative screen, separated from the insulant with air space. Both types have their own structural peculiarities, advantages and disadvantages [18].

The plaster systems belong to the heat-insulation façade systems of the fastened type or to the «wet» facades systems and are divided into light and heavy ones. The installation of such facades helps reducing the heating expenses by 40-50%, reducing the heat losses through enclosing structures, improving the indoor comfort and reducing the risks of emergency situations.

Light plaster systems of façades heat-insulation are presented with a multilayered insulating-decorative structure, in which the insulant is fixed with an adhesive compound and mechanic fasteners on the outer surface of the enclosing structure. Then the heat insulating material is covered with a protective-decorative plaster layer, not more than 15 mm thick.

Though the technology of installing such systems is widely known and used, certain peculiarities should be noted, which are usually neglected during the performance of works. The insulated surface should be relatively smooth, dry and cleaned from dust and dirt. The special requirements are imposed on selecting an insulating material for such systems. For example, when choosing between the conventional mineral-wool boards or the lamellar boards, the latter should be preferred. While in the conventional boards the fibers are arranged in plane with the façade, in the lamellar boards they are

perpendicular to the insulated surface. This peculiarity allows bearing greater loads at the lower density of insulator, as the fibers work in tension.

After fastening the heat-insulating layer, it is covered with a levelling layer of building mortar with high adhesion and is kept so at least two days. After that the mortar is rendered once more and before the final setting a reinforcing glassweb is sunk into it, selected with account of its strength and resistance to acid or alkaline plaster environments.

The finish layer can be various in the used base, texture, color, technologies of rendering and decoration. In most cases rustic-textured coatings are used, made of mineral-based, silicate-based or silicon-based single-component plaster mortars. These bases have sufficient vapor permeability and are highly compatible with mineral-cotton heat insulation. The application of acryl finishing plasters and paints prevents implementing the vapor-permeable properties of rock-wool façades. So, they should be used with polystyrene foam insulants, which are also vapor-proof. In general, the «light wet method» heat-insulating systems allow achieving the high-quality heat insulation of buildings at relatively low costs and high decorative properties of a façade.

The heavy plaster façade systems consist of the successively rendered layers of insulating material and plaster composition; the load-bearing function in these systems is performed by reinforcement mesh. Unlike in the light plaster systems, the thickness of plaster layers, covering the heat-insulating layer, can be up to 50 mm. A distinctive feature of such systems is that the plate of insulating material is not glued to the surface of the outer wall, but fixed with special wall dowels [19].

It should be pointed out, that in heavy-plaster systems the whole load is carried by the mesh and wall dowels. So, they should be especially meticulously selected. The plaster can be rendered manually or by spraying, using special pumps. When sprayed, the plaster penetrates between the mesh and the insulating layer, filling tightly the space between them. So, the mesh becomes inside the plaster layer. The plaster has the frost-resistant composition and is rendered with two thick layers. The first layer forms the base. The second one is used for the external decoration, texturing and painting. An important advantage of heavy heat-insulating façade systems is no need for leveling of the façade surface, as compared to light plaster systems. This saves installation time and lowers the requirements to the qualification of workers, performing the installation operations.

The application of pumps and sprayers saves time considerably as well. The insulating material, which is not glued to the wall, securely covers the outer surface of the façade and, due to the anchors, remains movable against the wall. In case of its deformation vibrations at subsidence or temperature fluctuations, the heat-insulating layer together with the plaster layer stay put, preventing the crack formation or other damage of the façade surface.

These systems are much more durable in comparison with light plaster systems. Some manufacturers declare the guaranteed service life up to 50 years (the guaranteed service life of light systems is about 20 years). This made them especially popular in the Nordic countries [20,21]. In our country they have been just beginning to gain popularity. The heat insulation layer of the outer wall should be no less than 100 mm. The costs for heat insulation of outer walls consist of the cost of materials (heat insulation, plasters, mesh, wall dowels, decorative finishing) and the cost of works. According to the findings of the research, the difference in general costs at using the heat insulation 50 and 100 mm thick would be about 10%, and the difference in the efficiency would be about 1.5 times [22]. Increasing the thickness of heat insulation layer over 150 mm is economically unviable. The total cost would increase faster than the effect from heat economy. So, the optimal thickness of heat insulation at insulating the outer walls (when using heat insulation with thermal conductivity coefficient  $\lambda \leq 0,041 \text{ W/m}\cdot\text{°C}$ ) is 100...150 mm.

The advantages and disadvantages of the «wet-type» heat-insulating systems are widely known, so let us consider only some of them, significant at buildings maintenance, but not always taken into account at selecting the insulating systems. The principal difference of this type of heat insulation from another popular heat-insulating system by means of «ventilated facades» consists in the absence of air space, which creates air draught and contributes to the fast fire and smoke propagation if ignition occurs [23]. Such system of heat insulation is virtually not affected by wind pressure, due to the low

carried load on the walls. To prevent even the slightest moisture accumulation between the insulation and the wall and prevent the peeling of insulating system from the wall as a result of freeze-and-thaw process it's necessary to select the thickness of heat insulation layer correctly, so that the dew point were totally removed to the insulant. This would solve the problems of mould formation and freezing of walls. Removing the dew point to the insulant, the technology compliance and the correct execution of works is going to result in the high-quality heat insulation of walls and allow creating the comfortable indoor climate in the building during the prolonged period of heat insulation system's service life [24].

At reconstructing old housing stock the installation of heat insulation is the most efficient when used along with the glazing of balconies, installation of up-to-date windows, heat regulators and individual heating units etc. Combination of such measures can produce a considerable economic benefit with small payoff period.

### 3. Conclusion

So, all the above-mentioned allow us making a conclusion, that the improvement of civic buildings' energy performance at installing façades heat insulation can be achieved only at using scientific approach in solving these problems. This would allow the economically and technologically viable selection of the type of heat insulation depending on the climatic location of an object, materials and the installation technology. The heat insulation of facades of buildings with the subsequent painting or plastering is the most economically-efficient method and has no alternatives as compared to the other systems. The most important thing in solving these problems is to ensure, that instead of thermotechnical processes and phenomena influencing the operation of the outer enclosing structure, an efficiently designed structure would by itself regulate these processes.

*\*The article has been prepared within the framework of the Flagship University Development Program on the basis of BSTU named after V.G. Shukhov.*

### 4. References

- [1] Kosukhin M.M. 2016 From the origin to the current state and development prospects of the housing and utilities sector in Russia *Bulletin of BSTU named after V.G.Shukhov* vol.12 pp. 48-54.
- [2] Menelyyuk A.I. 2008 *Modern facade systems*. K.: Osvita p. 340.
- [3] Ivanov G.S. 2009 Errors in norming a thermal protection level of enclosing structures *House construction* vol. 9 pp.11-13.
- [4] Korol E.A. 2001 The efficient enclosing structures with high thermal protection level *Industrial and civil construction* vol. 9 pp. 24-25.
- [5] GOST3 1937-2011 2011 *Buildings and constructions. Regulations of engineering survey and monitoring*. (M.: Standartinform).
- [6] Kosukhin M.M., Kosukhin A.M., Sokolovskaya D.M. 2017 The energy-saving technologies and methods in construction and housing and utilities infrastructure / Science and innovations in construction: collection of articles of the International research and practice conference: in 2 volumes *Belgorod: BSTU named after V.G.Shukhov* pp. 237-247.
- [7] Sozinov P. *Capital repairs remained without the professionals*. [Electronic resource]. URL: <https://ok-inform.ru/stroitelstvo/zhkkh/53919-kapitalnyj-remont-ostalsya-bez-professionalov.html> (reference date 12.10.17).
- [8] Gagarin V.G. 2009 *The economic analysis methods of improving the heat insulation level of enclosing structures of buildings* (AVOK. 1-3) pp. 50-53.
- [9] Biryukova T.P. 2005 The enclosing structures of walls with the use of up-to-date façade systems *Industrial and civil construction* vol. 1 pp. 50-51.
- [10] Akhmyarov T.A., Spiridonov A.V., Shubin I.L. 2014 Making the exterior enclosing structures with the increased heat insulation level *Energy saving* vol. 6.
- [11] Zabelskaya M. 2003 Façade systems: problems and their solutions *Budmeister* vol. 8 pp. 26-29.

- [12] Kosukhin M.M., Kosukhin A.M. 2017 The role of heat-transfer processes in improving the efficiency of thermal protection of civic buildings façade insulation *Bulletin of BSTU named after V.G.Shukhov* vol. 12 pp. 21-26.
- [13] CR 50. 13330.2012 2012 Buildings Heat Insulation. Revised edition of SNiP 23-02-2003. M. Gosstroy of Russia.
- [14] Shoykhet B.M. 2007 Structure and permeability of fibrous heat-insulating materials *Energy saving* vol. 7.
- [15] Vatin N.I., Gorshkov A.S., Nemova D.V. 2013 The energy efficiency of enclosing structures at capital repairs *Construction of unique buildings and structures* vol. 3(8).
- [16] Drizhuk D., Flenkin M. 2002 Problems of choosing a façade system *Construction technologies* vol. 6 pp. 34-37.
- [17] Glikin S.M. 2004 Designing and improvement of efficient enclosing structures *Industrial and civil construction* vol. 6 pp. 20-21.
- [18] Zhdanovsky B.V., Kuzhin M.F. 2012 Organizational and technological solutions of installing curtain façade systems at reconstructing residential and public buildings *Industrial and civil construction* vol. 1 pp. 62-64.
- [19] Kosukhin M.M., Kosukhin A.M., Bogacheva M.A., Komarova K.S. 2017 Improving the energy performance of civic buildings by using curtain façade systems of the fastened type / Power systems: collection of articles of the 2<sup>nd</sup> International research and practice conference. *Belgorod: BSTU named after V.G.Shukhov* pp. 461-470.
- [20] Kosukhin M.M., Semak A.V., Kosukhin A.M., Bogacheva M.A. 2016 Analysis of implementing the energy-saving technologies in EU countries / Science-intensive technologies and innovations: collection of articles of the International research and practice conference. *Belgorod: BSTU named after V.G.Shukhov* pp. 45-49.
- [21] Kasyuk S.T. 2012 Measures to provide the energy efficiency of residential and public buildings in Germany *Informational electronic journal «Energosovet»* vol. 1(20)).
- [22] Kosukhin M.M., Semak A.V., Kosukhin A.M. 2016 Evaluating the energy-saving potential on the basis of energy audit *Bulletin of BSTU named after V.G.Shukhov* vol. 12 pp. 89-94.
- [23] Gagarin V.G., Kozlov V.V., Lushin K.I. 2013 Air velocity in the air space of a curtain facade system at the natural ventilation *Housing construction* vol. 10 pp. 14-17.
- [24] Kosukhin M.M., Sharapov O.N., Bogacheva M.A., Kosukhin A.M. 2016 The problems of energy saving in conditons of stable functioning, modernization and development of housing stock *Bulletin of BSTU named after V.G.Shukhov* vol. 10 pp. 51-61.