Effective way to improve thermophysical properties of exterior walls of brick buildings during reconstruction

O V Burlachenko, O G Chesnokova, T F Cherednichenko

Institute of Architecture and Civil Engineering, Volgograd State Technical University, 1, Akademicheskaya St., Volgograd 400074, Russia

E-mail: tati_cher@mail.ru

Abstract. In the process of the operation of old buildings with single-layer external walls at negative temperatures problems can arise, which are related to freezing of the corners of the outer walls and deterioration of their thermophysical properties. The building corner freezing can lead to a premature destruction of the wall structure. The elimination of this situation is possible in the conditions of reconstruction. This article presents the results of calculating the change in the thermophysical properties of a brick wall, using various variants of the structural solution of the building angle. Using the local placement of materials with high thermal conductivity is an actual direction in studies on the energy efficiency of building materials and structures. The authors proposed a modern version of a possible solution to the problem described above, which confirms the practical significance of using the thermophysical properties of materials to protect certain unfavorable local sites. Due to the correct design decision, it is possible to achieve an increase in temperature on the inner surface of the wall in the corner of the room and to avoid its freezing.

1. Introduction

Energy-saving innovations in the construction of building walls are closely related to energy saving and sanitary and hygienic requirements. The desire to improve energy efficiency in the construction sector encourages scientists to expand research of high-performance thermal insulation materials, as well as methods of design and construction of separate elements of enclosing structures [1-4].

The practice of the construction of various buildings and constructions showed that at operation of existing brick buildings in Northern regions there are a number of problems with freezing of external walls corners and deterioration of their thermophysical properties. The corner becomes the place of mold formation. Freezing in the corner of the wall can lead to premature destruction of the wall structure [5]. The use of heavy and dense materials, such as concrete and metal, for the interior decoration of the wall angle makes it possible to partially reduce the negative impact of the cold climate on the thermal characteristics of the wall [5-8].

2. Relevance and scientific merit of the subject

The use of local distribution of thermal conductive inclusions is an actual direction in studies devoted to the energy efficiency of building materials and structures. The significance of the problem under consideration is undeniable for countries with cold winter temperatures. The relevance and scientific significance of the issue was considered in the following publications. [5-11]. In this article, the proposed variant of a possible solution to the problem described above, confirming the practical
significance of using the thermophysical properties of materials to protect certain unfavorable local sites.

3. Relevance and scientific merit of the subject
For the effective use of heat-shielding potential of building materials it is necessary such constructive execution of external walls at which they during the heating period will have the minimum coefficient of thermal conductivity. In recent decades, many new building materials and structural techniques have been developed. In this regard, it was possible to achieve high quality construction and reconstruction of buildings, to reduce material consumption, to improve energy efficiency and durability. [10,11].

The calculation of changes in the thermophysical properties of the wall at various design variants of its insulation from the inside was carried out by the finite element method (FEM) using the program COMSOL Multiphysics V4.3a [7, 10-15]. The solution of such problems in this program is actively used by Western scholars such as, Trabelsi A[1], Rus M [16], Janssen H.[17], N. Williams Portal [18].

In the study of thermal characteristics of the enclosing structure for comparative analysis, three options for the constructive solution of the wall were used. Option № 1: the design scheme is a single layer of existing brick wall (the building in terms of reconstruction) thickness of 510 mm. To combat the freezing of the corner in the wall in the winter area of polystyrene is used. (Figure 1, A).

Option № 2: the corner of the existing brick walls with a thickness of 510mm is protected by a concrete 150х212х150мм (Figure 1, B).

Option № 3: the corner of the existing brick walls with a thickness of 510mm is protected by a concrete 150х212х150мм. In addition, the design scheme added metal element (rebar diameter 20 mm), (Figure 1, (C).

Figure 1. The variants of the constructive solution of the wall: A - the settlement scheme of option no.1; In - the settlement scheme of option no.2. C – the design scheme of option no.3. Materials: 1-solid silicate brick, 2-polystyrene, 3-expanded clay concrete, 4-fittings with a diameter of 20mm.

The characteristics of the materials used in the calculation are given in table 1.

| The name of the material       | The thermal conductivity, (W/(m*K)) | The density, (kg/m³) | The specific heat capacity, (J/(kg*K)) |
|-------------------------------|-----------------------------------|---------------------|--------------------------------------|
| 1                             | The solid silicate brick          | 0.76                | 2000                                 | 880                                    |
| 2                             | The foam polystyrene              | 0.041               | 40                                   | 1340                                   |
| 3                             | The claydite-concrete             | 0.67                | 1600                                 | 800                                    |
| 4                             | The steel                         | 44.5                | 7850                                 | 475                                    |

The following finite element mesh was obtained by calculations using the COMSOL Multiphysics program (Figure 2).
The distribution of temperature fields was determined from the solution of the differential equation:
\[
\text{div}(-\lambda \nabla T) = 0, \quad \text{where} \quad \nabla \cdot \frac{\partial}{\partial x} \mathbf{i} + \frac{\partial}{\partial y} \mathbf{j}
\]

The calculation took into account the following boundary conditions (BC):
\[
q = \frac{t_{\text{int}} - t_{\text{ext}}}{R_{\text{int}}} = \frac{t_{\text{int}} - \tau_{\text{int}}}{R_{\text{int}}} = \frac{t_{\text{ext}} - \tau_{\text{ext}}}{R_{\text{ext}}} = \text{const}
\]

where \( R_{\text{int}} \) – the resistance to heat transfer of the inner surface of the fencing; \( R_{\text{ext}} \) – the resistance to heat transfer of the outer surface of the fencing; \( R_0 \) – the general resistance to heat transfer of the enclosing structure; \( t_{\text{int}} \) - 20 °C – the temperature of the internal air; \( t_{\text{ext}} \) - 20 °C – the temperature of the outdoor air; \( \tau_{\text{int}} \) - the temperature of the inner surface of the enclosing structure; \( \tau_{\text{ext}} \) – the temperature of the external surface of the enclosing structure.

In addition, the following boundary conditions were specified in the calculation:
\( \alpha_{\text{int}} \) – the heat transfer coefficient is taken from the table 4 SP 50.13330.2012 "Thermal protection of buildings" equal to 8.7 W/ m²°C for a morning surface.
\( \alpha_{\text{ext}} \) – the heat transfer coefficient for the external surface equal to 23 W/ m²°C is adopted by the table 6 SP 50.13330.2012.

The problem is calculated in a stationary mode with the constant thermophysical properties of the materials of the construction layers. The stationary regime is considered as for the plane problem [9].

By calculations using the program COMSOL Multiphysics obtained the following results: the first calculation scheme (Figure 3, A), on the second settlement scheme (Figure 3, B) and on the third settlement scheme (Figure 3, C).
The design scheme of variant no.1 (Figure 3, A). On the line of contact of the element from expanded polystyrene with the bearing wall from a continuous silicate brick the temperature of 2.2 °C is obtained, which will lead to condensation and mold on this site at negative temperatures on the street, high humidity and insufficient multiplicity of air exchange in the room, that is, under adverse conditions.

The design scheme of variant no.2 (Figure 3, B). On the line of contact of the element from expanded clay concrete with a bearing wall from a continuous silicate brick temperature of 8.51°C that partially improves a situation is received.

The design scheme of variant no.3 (Figure 3, C). On the line of contact of the element from expanded clay concrete with an additional steel element (fittings with a diameter of 20 mm) with the bearing wall from a continuous silicate brick temperature of 9.45°C that also improves a situation is received.

Using the COMSOL Multiphysics program, the following temperature fields are shown in Figure 4.

![Temperature fields](image)

**Figure 4.** The distribution of the temperature fields: A – according to the design scheme of option no.1; B – according to the design scheme of option no.2; C – according to the design scheme of option no.3.

The temperature fields indicate the movement of the heat flux. For option no.3 (Figure 4, C), the best results are obtained - the minimum temperatures are shifted in the corner of the building to the outer surface.

4. Results obtained in experimental studies

As a result of the calculations described above, the option of improving the thermal properties of the exterior walls in the conditions of reconstruction of existing buildings can be used to solve the local problems such as the thermal protection of certain unfavorable areas. The presence of dense heat-conducting inclusions makes it possible to improve the thermal qualities of the outer walls in the corner zone, allows to increase the temperature in the unfavorable zone, which is especially relevant for regions with a cold winter climate. This article shows the practical significance of the selective approach to the local unfavorable zones. The results of experimental implementations in the field of the reconstruction of the existing housing stock confirmed the theoretical calculations obtained in the article. Metal constructions, embedded in the interior decoration of the walls become a heat-conducting inclusion, conducting heat through the wall. Thus, the dew point is moved to the outer surface of the cladding and increases the temperature of the inner surface of the wall.

5. Conclusions

The results of temperature calculations with nonlinear thermophysical properties showed that freezing and mold formation on the inner wall surface is possible in the existing single-layer brick walls [19].
The use of embedded steel elements inside the design of the finishing layer of expanded clay concrete gives a positive result [6,8,20]. It should be noted that a significant share in the change in the temperature distribution is added by various design features, such as cracks, loose fitting, technological holes [21].

As a result of a correctly made constructive decision, the temperature in the corner of the inner part of the wall can be increased by 4.3 times or by 7.25 °C (rose from 2.2 °C to 9.45 °C). The adopted technical solution was used in the construction practices [11, 22].

References

[1] Trabelsi A, Belarbi R, Abahri K and Qin M 2012 J. of Building Simulation 3 107
[2] Siligardi C, Miselli P, Francia E and Lassiananti M 2017 J. of Energy and Buildings 138 80
[3] Roberz F, Loonen R, Hoës P and Hensen J L M 2017 J. Energy and Buildings 138 432
[4] Alam M, Singh H, Suresh S and Redpath, D A G 2017 J. Applied Energy 188 1
[5] Chesnokova O G 2016 Bullet. of Volgograd State University of Architecture and Construction. Series: Construction and Architecture 45 94
[6] Chesnokova O G and Grigorov A G 2016 Science in the modern world: theory and practice (Ufa: Omega Sainz) 1 14
[7] Chesnokova O G, Chesnokova V D and Cherednichenko T F 2017 Bullet. of Volgograd State University of Architecture and Construction. Series: Construction and Architecture 50 16
[8] Perekhozhentsev A G and Chesnokova O G 2015 Internet-Vestnik of Volgograd State University of Architecture and Construction. Series: Polythematic 2
[9] Chesnokova O G and Grigorov A G 2016 Modern scientific research: theoretical and practical aspect (Ufa: Omega Sainz) 2 204
[10] Chesnokova O G, Tuhkareli V D and Tuhkareli A V 2017 E-journal: Engineering journal of Don 2
[11] Chesnokova O G 2016 Modern scientific research: current theories and concepts (Moscow: Scientific center "Olymp") p 306
[12] Method of Statement of Experience and Calculation of Coefficient of Thermal Conductivity for Ultrathin Thermal Insulating Materials: Methodical Recommendations about Thermal Engineering Calculations of MPO 001/2003 (Moscow: OGUP research Institute "Plumbers") p 25
[13] Menyhart K and Krarti M 2017 J. of Building and Environment 114 203
[14] Lakatos A 2017 J. of Materials and Structures 50 (2)
[15] Velicorodny Y A, Zharkov A F and Chesnokova O G 2014 Internet-Vestnik of Volgograd State University of Architecture and Construction. Series: Polythematic 1
[16] Krus M 1996 Moisture Transport and Storage Coefficient of Porous Mineral Building Materials: theoretical principles and new test methods (Stuttgart: IRB-Verlag) p 180
[17] Janssen H A 2013 J. of Building Simulation 6 103
[18] Williams P N, Sasic K A and van Schijndel A W M 2014 J. of Building Simulation 7 (3) 217
[19] Chesnokova O G 2017 Bullet. of Volgograd State University of Architecture and Construction. Series: Construction and Architecture 47 70
[20] Chesnokova, O G 2017 Bullet.of Volgograd State University of Architecture and Construction. Series: Construction and Architecture 47 51
[21] Koshi V, Madera J and Cherny R 2012 J. of Energy and Buildings 47 84
[22] Chesnokova O G 2017 New science: experience, tradition, innovation (Ufa: Omega Sainz) 2 130