Calculated heat-and-technical indicators of brick external walls of the historical residential buildings

Viktor Pukhkal$^1$ and Vera Murgul$^{2,3}$

$^1$Saint Petersburg State University of Architecture and Civil Engineering, Vtoraya Krasnoarmeiskaya str. 4, St. Petersburg, 190005, Russia
$^2$Moscow State University of Civil Engineering, Yaroslavskoe shosse, 26, Moscow, 129337, Russia
$^3$Peter the Great St.Petersburg Polytechnic University, Polytechnicheskaya, 29, St. Petersburg, 195251, Russia

E-mail: vera.murgul@mail.ru

Abstract. The analysis of the external brick walls structures of the historical residential buildings (constructions of XIX century and the beginnings of the 20th century) in St. Petersburg is carried out. The heat-and-technical indicators (coefficient of heat conductivity of brick and coefficient of the heat transfer of external brick walls) are defined. That is established that the use of modern norms of design is possible. The obtained data allow to carry out some heat-and-technical and moist calculations during designing of heating systems as well during the development of measures for energy saving.

1. Introduction
During the inspection of historical residential buildings the main attention is paid to the strength characteristics of the protecting structures and their heat-insulating properties are not considered. Meanwhile during the reconstruction of these buildings many designs cannot be replaced and then it is necessary to study the heat-insulating properties of protections for the assessment of heat losses and for the check of the possibility of condensation of moisture.

In this article heat-and-technical characteristics of the bricklaying of historical residential buildings (constructions of XIX century and the beginnings of the 20th century) in St. Petersburg are considered.

External walls from of brick buildings of the first half of the 19th century were erected with thickness not less, than 71 cm. The laying was made on limy solution.

In the second half of XIX – the beginning of the 20th centuries the type of the apartment profitable house (constructed for leasing) was created. A lot of 5-storey houses appeared.

The rules of laying of brick walls in St. Petersburg remained the same as in the previous period. With the advent of cement the lower 8 rows of a socle part of walls which have appeared in soil now usually did on cement mortar, and other laying - on limy. In the laying of crossing points, arches and eaves applied cement mortar. Since the beginning of the 20th century for a laying complex solution (sand, lime, cement) was used. Thickness of walls can be various.

A lot of multy-storied houses were exposed to reconstruction and capital repairs. Houses were built on, several small buildings were united in one, chambers of the first floors were reconstructed into the trade rooms, but in most cases, bearing designs did not change.
2. Methods and Materials

The main thermotechnical index of the outer walls is the heat transfer coefficient

\[ k = \frac{1}{R}, \text{W/(m}^2\text{K)} \]  

(1)

where \( R \) is the resistance to the heat transfer of a multilayer outer guard with homogeneous layers without heat conducting inclusions.

\[ R = R_{\text{int}} + R_w + R_{\text{ext}}, \text{m}^2\text{K/W} \]  

(2)

Where \( R_{\text{int}} \) is the thermal resistance of the inner surface of the outer fence, \( m^2\text{K/W} \); \( R_w \) is the thermal resistance of the enclosing structure, \( m^2\text{K/W} \); \( R_{\text{ext}} \) is the thermal resistance of the outer surface of the outer fence, \( m^2\cdot\text{°C/W} \);

Thermal Resistance:
- the inner surface of the outer fence

\[ R_{\text{int}} = \frac{1}{\alpha_{\text{int}}}, \text{m}^2\text{K/W} \]  

(3)

- enclosing structure with consistently arranged homogeneous layers

\[ R_w = R_1 + R_2 + \ldots + R_n + R_{\text{es}}, \text{m}^2\text{K/W} \]  

(4)

Where \( R_1, R_2, \ldots, R_n \) are thermal resistances of individual layers of the enclosing structure, \( m^2\text{K/W} \);

- outer surface of outer fence

\[ R_{\text{ext}} = \frac{1}{\alpha_{\text{ext}}}, \text{m}^2\text{K/W} \]  

(5)

Where \( \alpha_{\text{int}} \) is the heat transfer coefficient of the outer surface of the enclosing structure, \( \text{W/(m}^2\cdot\text{K)} \);

\( \alpha_{\text{ext}} \) is the heat transfer coefficient of the outer surface of the enclosing structure, \( \text{W/(m}^2\cdot\text{K)} \).

Thermal resistances of individual layers of a multi-layered enclosing structure

\[ R = \frac{\delta}{\lambda}, \text{m}^2\text{K/W} \]  

(6)

Where \( \delta \) is the layer thickness, m;

\( \lambda \) is the calculated coefficient of thermal conductivity of the layer material, \( \text{W/(m} \cdot \text{K)} \).

The analysis of the available data on the bricks, which were selected from laying of historical buildings [1, 2] proves that the bricks, applied in the bricklaying are non-uniform on their density and heat-and-technical indicators.

The brick plants, located near St. Petersburg, released bricks of three types.

Iron ore, or the burned-through brick, which was affected by flame had a dark vitreous surface and they are intended for the use for the crude places.

Red brick, which occupied the middle of the furnace during roasting, was exposed to moderate influence of flame, when unloading from the furnace had red color, the equal form, at blow made a clear sound. They were intended for construction of responsible stone designs.

The scarlet, or not-burned up brick during roasting was placed at the walls of the furnace and in the top layers, when unloading from the furnace had pale red color, at blow made a deaf sound. They were intended for internal ranks of laying and for lubricant. The scarlet brick, which was less strong and cheaper than red, was widely used in housing construction.

Samples of bricks in structures [1, 2] are presented in the figure 1.

Heat conductivity of porous materials, which include brick, is determined by their density (porosity). With the increase in density (reduction of porosity) the coefficient of heat conductivity increases and,
on the contrary, with the reduction of density (increase in porosity) the coefficient of heat conductivity decreases. The obtained dependence of coefficient of heat conductivity of the clay burned brick on its density according data is the following [3]:

\[ \lambda = 0.0005 \cdot \rho - 0.1257, \text{Wt/(m}^3\text{)}, \]  

(7)

where \( \rho \) is the density of brick, kg/m\(^3\).

Results of coefficient of heat conductivity calculation according to the dependence (1) for the brick samples which are selected from the structure [2] are presented in figure 2. Average value of coefficient of heat conductivity at the density of 1780 kg/m\(^3\) is 0.765 W / (m * K).

During heat-and-technical calculations it is also necessary to consider that considerable impact on heat conductivity of brick is exerted by its moist state. So, in the range of humidity of 0-3% for bricklaying from the burned clay brick, 1% of the increase in humidity of brick increases coefficient of heat conductivity of the laying for 34% [3].

According to data [4] for laying from red brick (density of 1700 kg/m3) on limy and composite or lean cement and sand solutions for the external walls the heat conductivity coefficient \( \lambda = 0.814 \text{ / m* J} \) is accepted as W (m* J) that coincides with modern norms for bricklaying with the density of 1800 kg/m3.

a)

b)

Figure 1. Cylindrical samples of bricks

a) Shuvalov Palace in St.Petersburg [1]; b) Public building in St. Petersburg [1]
3. Results

The calculation of coefficient of heat transfer for the external wall, according to modern standard requirements [5] and calculation procedures [6, 7, 8] (table 1), relevant for the beginning of the 20th century were executed. During calculation the following basic data were accepted:

- bricklaying from clay ordinary brick on cement and sand solution with the density of 1800 kg/m³; heat conductivity of bricklaying is $\lambda = 0.81 \text{ W/(m} \cdot \text{K)}$ [5];
- plaster cement and sand solution from the inside thickness is accepted the minimum thickness $\delta = 10$ by mm [5]; heat conductivity of plaster is $\lambda = 0.81 \text{ W/(m} \cdot \text{K)}$ [5].

The results of the calculation and the data given in [6-8] are summarized in Table 1.

| Structure of an external wall | Thickness, $\delta$, mm | Heat transfer coefficient, W/(m²·K) |
|------------------------------|-------------------------|------------------------------------|
| 4 1/2 standard bricks        | 1160                    | 0.625 |
| 3 standard bricks           | 1030                    | 0.694 |
| 3 1/2 standard bricks       | 900                     | 0.781 |
| 3 standard bricks           | 770                     | 0.893 |
| 2 1/2 standard bricks       | 640                     | 1.042 |
| 2 standard bricks           | 510                     | 1.252 |
| 1 1/2 standard bricks       | 380                     | 1.567 |
| 1 standard bricks           | 250                     | 2.093 |
| 1/2 standard bricks         | 120                     | 3.151 |

**Note:**
1. Values of coefficient of a heat transfer are presented for laying with the minimum enough masonry solution;
2. Thickness of bricklaying is presented without taking into account plaster.

**Figure 2.** Coefficient of heat conductivity of the brick samples [2]
For comparison, Figure 3 shows the dependences of the heat transfer coefficient on the thickness of the brickwork, determined in the calculation according to [5] (modern norms) and [6, 7] (methods of calculation for the beginning of the XX century). The calculation was made without considering the thermotechnical heterogeneity of the brickwork of the external walls. The deviation of the obtained values is insignificant and lies within the limits of the error in setting the initial data of the material properties of the layers of the outer wall structure.

![Graph of heat transfer coefficient vs. thickness of brickwork](image)

**Figure 3.** The values of the coefficient of heat transfer of the outer brick wall depending on the thickness of the brickwork, 1 - calculation according to [6, 7]; 2 - calculation according to [5]

4. Conclusions
1. The heat-and-technical indicators (coefficient of heat conductivity and coefficient of heat transfer) of external brick walls of historical residential buildings in relation to St. Petersburg were studied.
2. It were found out that during heat-and-technical calculations the use of modern norms of design is possible.

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