The buildings innovative method fencing thermal regime study

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Abstract. The building envelope thermal regime field studies without disturbing its structure and integrity during the transition period (autumn) are given. Experimental data on the building inner and outer walls temperature and the heat flux density were obtained using the “Teplograph” heat flux density meter. The temperature changes graph on the residential building outer and inner walls during the day is constructed.

Introduction
Nowadays the great importance in Russia is given to energy conservation. A less complicated method of reducing heat losses for heating is often used, associated with increase in the enclosing structures heat transfer resistance. But this energy saving method is rarely cost-effective, because raising the resistance to heat transfer by the existing insulation materials use can greatly increase the walling cost. These costs can increase the savings from the wall raising the heat-shielding properties.

Energy saving in buildings and structures is based on:
1. heat preservation in heating, ventilation and air conditioning systems;
2. ventilated exterior walls devices;
3. external fences additional weatherization;
4. the walls behind the heating device thermal insulation (from the inside);
5. device ventilated windows;
6. three-layer or heat reflecting (in infrared radiation) glazing;
7. devices of glazed loggias;
8. application of air heating using heat pump installations and low-potential energy (condensate, water, air).

Also now is the issue of finding and implementing energy saving measures and solutions in the engineering systems field for the heat engineering implementation and technological processes with a minimum of heat losses. Great significance here is: the building materials thermophysical properties knowledge, heat-insulating, only facing materials and products used and developed. Thermophysical properties (TPP) of fences greatly affect such modes as: heat and air for buildings and structures of various applications, as well as the work of such systems as: heating, ventilation and air conditioning, which currently consume a significant amount of thermal energy.

For finding the buildings and structures TPP enclosing structures the non-destructive testing method is used. To determine the TPP, there is no need to destroy the substance-material, create
additional heating or cooling of the enclosing structure, create special conditions on the enclosing structure surface (blackness degree, heat transfer coefficient), which allows not to use electrical and thermal energy and does not require the experimental installations requiring energy costs creation. The proposed method is quite natural conditions, which is enclosing design.

At various times of the year, the building’s fencing is heated and cooled. Similarly, within 24 hours due to solar activity, the temperature of the building envelope varies. As a result, heat flows pass through the building enclosing structure, which change within 24 hours (and also within 365 days): during the winter period, the heat flow is from the inner wall to the outer one, and in the summer - the opposite is true. As a result, temperature waves appear in the enclosing structure.

Then, in order to find a complex of thermal characteristics (heat-conduction coefficients, volumetric heat capacity and thermal diffusivity), there are enough natural conditions: cooling the outer wall structure in the cold season or heating the outer wall in the warm season.

In the existing methods for determining the thermophysical properties (TPP) of building materials and products used in construction, devices with a significant consumption of thermal energy are used. To avoid this, namely the energy saving application and heat loss reduction to the environment from the external fencing of buildings, it is necessary to know the thermal conductivity $\lambda$, thermal diffusivity $a$, heat flux density $q$.

The figure shows the field data obtained every hour during 24 hours the temperature on the surface of the inner and outer wall, the temperature of the internal and external air, heat flux on the external surface of the wall, W / m$^2$.

Max heat flux density at night was: $q_{\text{max}} = 19.2$ W / m$^2$, Exterior wall temperature was: $t_{\text{ext}} = 0.9$ °C, internal wall temperature: $t_{\text{int}} = 26.1$ °C, temperature difference between the outer and inner walls: $\Delta t = 26.1 - 0.9 = 25.2$ °C, uniform wall thickness: $\delta = 0.2$ m.

Min the heat flux density was a day and equals $q_{\text{min}} = 2.5$ W / m$^2$.

![Figure 1. Experimental temperature and heat flux distributions fencing building in transition](image-url)
Using the developed technique [1, 2, 3] and the obtained field data calculated the coefficient of heat conductivity \( \lambda \), W / (m \cdot K), volumetric heat capacity \((c_p)\), J / (m\(^3\) \cdot K), thermal diffusivity \( a \).

To determine the coefficient of thermal conductivity, the temperatures used on the surface of the internal \( T_{\text{int}} \) and external wall \( T_{\text{ext}} \), max heat flux on the outer wall surface \( q_{\text{ext}} \), W / m\(^2\). Coefficient of thermal conductivity \( \lambda \) is:

\[
\lambda = \frac{(d_{\text{max}} \cdot \delta)}{(t_{\text{int}} - t_{\text{ext}})} \\
\lambda = \frac{(19,2 \cdot 0,2)}{25,2} = 0,15
\]

Max. Temperature wave amplitude \( \vartheta_{\text{max}} \) on the building fencing outer surface between 16 and 7:30 h. equals [4, 5]:

\[
\vartheta_{\text{max}} = 0,5(t_1 - t_2), \\
\vartheta_{\text{max}} = 0,5(1,9 + 1,2) = 1,55,
\]

where \( t_1 = 1,9 \) ºC – is the external wall temperature at 4 p.m.; \( t_2 = -1,2 \) ºC – is the external wall temperature at 7:30 p.m.

The thermal absorption fencing coefficient is [3]:

\[
B = q_{\text{max}}^\text{ext} / \vartheta_{\text{max}}^\text{ext}, \\
B = 19,2 / 3,2 = 6 \text{ W/(m}^2\text{K)}.
\]

To determine the volumetric heat capacity, the thermal conductivity coefficient was used \( \lambda \), W / (m \cdot K) found by the formula (1) and the maximum amplitude of temperature wave oscillations \( \vartheta_{\text{max}} \), found by the formula (2). The volumetric heat capacity of the fence equals [6, 7]:

\[
(c_p) = \frac{(B^2 \cdot z)}{(\lambda \cdot 2\pi)}, \\
(c_p) = \frac{(36 \cdot 86400)}{(0,15 \cdot 2 \cdot 3,14)} = 3301,
\]

where \( z = 86400 \) – is a full period of temperature fluctuations on the external fence surface.

Figure 2 shows the obtained field data every 1 hour for 24 hours the surface temperature of the internal \( T_{\text{int}} \) and external wall \( T_{\text{ext}} \), ºC, temperature of the internal \( T_{\text{int.a}} \) and external air \( T_{\text{ext.a}} \), ºC, heat flux on the external \( q_{\text{ext}} \) wall surface, W / m\(^2\).

At max heat flux at night \( q_{\text{max}}^\text{ext} = 19,1 \) W / m2, the temperature of the external wall was: \( t_{\text{ext}} = 1,8 \) ºC, internal wall temperature: \( t_{\text{int}} = 26,2 \) ºC, temperature difference between the external and internal wall: \( \Delta t = 26,2 - 1,8 = 24,4 \) ºC, building wall thickness: \( \delta = 0,2 \) m.

Min the heat flux density was in the afternoon and amounted to \( q_{\text{min}}^\text{ext} = 5,6 \) W/m\(^2\).

Applying the method developed by [8] and the field data obtained during the experiment, they calculated the thermal conductivity coefficient \( \lambda \), W / (m \cdot K), volumetric heat capacity \((c_p)\), kJ / (m\(^3\) \cdot K), thermal diffusivity \( a \), m\(^2\)/s.

To find the coefficient of thermal conductivity the surface temperatures of the internal \( T_{\text{int}} \) and external wall \( T_{\text{ext}} \), ºC, max heat flux on the outer wall surface \( q_{\text{ext}} \), W/m\(^2\). Coefficient of thermal conductivity \( \lambda \) is:

\[
\lambda = \frac{(d_{\text{max}} \cdot \delta)}{(t_{\text{ext}} - t_{\text{int}})},
\]
\[ \lambda = (19.1 \cdot 0.2) / 24.4 = 0.16 \text{ W} / (\text{m} \cdot \text{K}) \]

Max temperature wave amplitude \( \vartheta_{\text{max}} \) on the outer surface of the building fencing between 15 and 6 hours is equal to [9]:

\[ \vartheta_{\text{max}} = 0.5(t_1 - t_2) = 0.5(5.2 + 4) = 4.6 \degree \text{C}, \]

\[ \max \] on the outer surface

\[ \text{max} \]

\[ \text{max} \]

\[ \max \]

\[ t_1 = 5.2 \degree \text{C} \] is a wall temperature at 3 p.m.; \( t_2 = -4 \degree \text{C} \) is a wall temperature at 6 p.m.

The fence thermal absorption coefficient is determined by the formula [10]:

\[ B = q_{\text{max}}^{\max} / \vartheta_{\text{max}} = 19.1 / 4.6 = 4.15 \text{ Vt} / (\text{m}^2 \cdot \text{K}). \]

\[ \max \]

To find the volumetric heat capacity, the thermal conductivity coefficient \( \lambda \), \( \text{W} / (\text{m} \cdot \text{K}) \) calculated by the formula (1) and max amplitude of temperature wave oscillations was used \( \vartheta_{\text{max}} \), \( \degree \text{C} \), calculated by the formula (2). Volumetric heat capacity of the fence is determined by the formula [11, 12]:

\[ (cp) = (B^2 z) / (\lambda \cdot 2\pi), \]

\[ (cp) = (17.2 \cdot 864000) / (0.16 \cdot 2 \cdot 3.14) = 1479 \text{ kJ} / (\text{m}^3 \cdot \text{K}), \]

where \( z = 86400 \text{ s} \) – is the full period of temperature fluctuations on the external fence surface.

Calculated thermal conductivity data \( \lambda \), bulk heat capacity \( (cp) \), thermal diffusivity coefficient \( a \), presented in the table for two days of measurements.

\[ \text{Table 1. Thermophysical properties of the building} \]

| Coefficient of thermal conductivity \( \lambda \), [W/(m·K)] | Volumetric heat capacity \( (cp) \) [kJ / (m³ K)] |
|------------------------------------------------------------|-----------------------------------------------|
| 0.15                                                       | 3301                                         |
| 0.16                                                       | 1479                                         |
Summary
Found by calculating [13] data thermal conductivity coefficient $\lambda$, volumetric heat capacity $(cp)$, thermal diffusivity $a$ on different days for the studied wall of the building are different. This suggests that during the day due to solar radiation, the temperature of the building envelope varies. As a result, heat flows that vary during the day pass through the building envelope.

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