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Investigating heat engineering characteristics of building envelopes using infrared cameras

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Different economical reasons force the world to produce more and more energetic efficient buildings. The building envelope’s parameters are the mostly important parameters which define this efficiency. For several recent years some methods were created to monitor the envelope state using infrared methods. Such methods provide with the information about the current envelope consistency. Primarily this can be used to monitor defects on the surface of the envelope (figure 1, right). Such defects become obvious (figure 1, left) if the air is cold outside the building and the heating system operates inside the building. The defect looks like a zone with a temperature greater than one at the nearby zones.

Figure 1. Using an infrared image to detect thermal bridges.

When designing new buildings it is usually taken into account that the air of the building exploitation requires the building to preserve the heat efficiently. Dew to different reasons the heat engineering parameters of the construction’s materials change with time. After several years of exploitation not only the envelope’s structural defects determine the thermal resistance value. As the material is aging it the modified heat engineering parameters must be taken into account.

This way a more complicated problem must be solved. It can be solved using infrared camera together with several other measuring devices. The measurement procedure consists of two parts. At the first part a temperature recording devices are installed on the building coating in several points. As it has been shown previously when measuring several temperature time series for a rather large while one can calculate local heat engineering parameters of the envelope’s point. The calculation is done by solving the inverse heat transfer problem.

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This can be done using the plausibility functional method that can be reduced in this case to the square deviation of two functions: a measured one and a calculated one. This function is usually the temperature time series of the chosen zone of the envelope. To calculate the temperature time series it is needed to solve the direct problem of the heat conductivity. The mathematical approach usually provides the researcher with three values: the thermal conductivity of the insulator layer of the coating and the two values of the thermal emissivity coefficient at the both surfaces of the envelope.

$$R_0^r = \frac{F}{\bar{R}_0}, \quad \bar{R}_0 = \sum_{j=1}^{K} \frac{F^j}{R_0^j} \tag{1}$$

$$R(\vec{r}) = \frac{1}{\alpha_{out}} \frac{T_{in}^{air} - T_{out}^{air}}{T(\vec{r}) - T_{out}^{air}} \tag{2}$$

After the local heat engineering parameters of the filler structure are defined through the first part of the measurement the found values can be used to calculate the average heat transfer resistance. The equation 1 shows the typical way to calculation this resistance. In the equation F is the surface of the envelope, F_j is the surface of a fragment of the envelope and R_j is the corresponding resistance value, K is the number of the surfaces. A special model is used to distribute these values to the whole envelope of the building. The model compares the temperature of the each point of the image with the corresponding heat transfers resistance value (figure 2, right). The comparison rule is presented by formulae 2 where T_{in}^{air} is the temperature of the inner building air, T_{out}^{air} is thee environment temperature and $T(\vec{r})$ is the temperature of the current point $\vec{r}$ of the surface of the envelope. a_{out} is the external thermal emmisivity of the envelope surface. The calculation procedure requires the infrared image of all of the parts of the envelope (figure 2, left). The estimations show that the error of the averaged heat transfer resistance calculation does not exceed 15 %. After the resistance value is calculated the researcher also can use the infrared images to find structural defects.

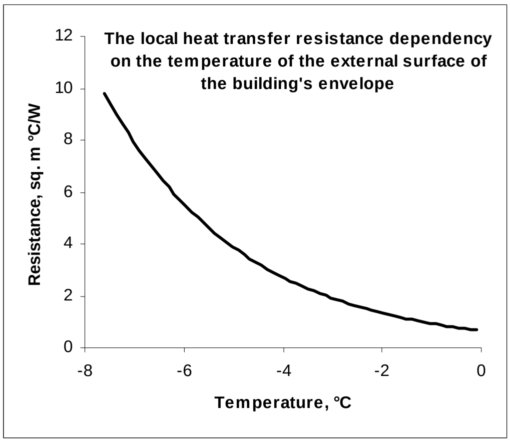

Figure 2. Calculating the averaged heat transfer resistance using special model.

This technology was used to estimate the quality of buildings by request of Moscow Government. More than 500 buildings including civil structures, many-storied buildings, palaces, industrial buildings were surveyed. Some of the corresponding methods have been certified by “State Standard” and agreed with Federal Agency of science and education of Russian Federation and “State City Technical Supervision”.