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Method elaboration for determining heat losses within heat leakage bridges occurring in isothermal and cooling bodies

Abstract

This paper presents the author's method for the heat flux evaluation on the basis of a thermal photograph. This method is based on the comparison of surface temperatures of two areas where one of them is a thermally loaded with a known heat flux and the other control area which is not thermally loaded. With the method presented in the article analysing heat fluxes in places of high heat flux gradients occurring within heat leakage bridges, especially the service ones connected with the material humidity where heat flux density sensors can give substantial errors when the flux on the sensor surface is averaged.

Keywords: heat leakage bridge, heat flux density, thermovision, isothermal body.

1. Introduction

Heat flux density meters commonly called heat meters are generally used for the evaluation of building insulating properties. A typical heat flux density sensor covers the area diameter from tens to two hundred millimetres and its principle of operation is averaging the heat flux density within the measurement. When determining the building heat losses (for areas repeatedly larger than the size of the heat flux density sensor) averaging does not influence negatively the measurement accuracy. The situation concerning the heat loss measurements within the heat leakage bridges is different. The heat flux within the heat leakage bridges undergoes big changes. Depending on the type of the heat leakage bridge (design, technology or service) the heat flux or the heat leakage bridge shape change. Mounting the sensor for the heat flux density measurement within the heat flux gradient causes big measuring errors what finally disqualifies the heat flux density meters in the sphere of heat loss measurement within the heat leakage bridges.

From the moment of the thermovision technique wide-spreading, the thermovision cameras are used for location of places of insulating properties worse than the basic part of the partition, i.e. heat leakage bridges. The advantage of the thermovision cameras is recording the surface temperature distribution on the selected area in tens or hundreds of thousands points at a time. The processing such a large amount of information by a camera microprocessor the user usually obtains a colourful map of the surface temperature distribution. However, recording the surface temperature and searching the temperature anomalies (the temperature increases and decreases in relation to the other part of the partition) does not allow to obtain information on the amount of heat, with reference to the surface unit, penetrating through the heat leakage bridge.

The paper presents the method for the heat flux density determination basing on the recorded thermovision photograph.

2. Literature review

Opportunities to use the results of the thermovision measurements for the determination of the local heat coefficient U are described in literature [1]. Insulating parameters of typical building partitions were analysed in the laboratory conditions on real objects. The author was used the heat flux density meter and the thermovision camera.

Some authors [2] believe that measuring the heat flux density, a measure of heat flux density meter to be the only method to determine the overall heat transfer coefficient U.

Basing on the analysis of the results the author [1] showed that "… the value U can be determined on the basis of measurements made both with the use of the thermographic method and the heat meter; it does not depend on the applied measuring method…", "… but on the fact that the measurements were carried out in the steady-state of heat flow through the partition". The author [1] showed in her work the heat meter measurement limitations "when measuring with the heat meter it is difficult (and even practically impossible) to determine the surface heat insulation distribution of the partition (heat leakage bridges, insulation defects) and choosing the representative place of the measurement."

3. Method description

In order to determine the heat flux the comparative method was used. During the first stage, there was used the set of partitions of different insulating properties (10, 20 and 40 mm of Styrofoam) heat loaded with known heat flux. Replaceable partitions mounted on the model stand (Fig. 1) in connection with the different temperature controller settings of heating and refrigerating devices mounted outside and inside the model of the refrigerating body allowed to obtain the different heat flux density ($Q_{heatbox}$) values within 20-60 W/m^2. The heat flux was determined with the use of the heat box set to the examined partition inside the body model (Fig. 2). During the tests the thermovision camera objective was directed to the tested plate loaded with the known heat flux and the control plate, made of the same materials (surface emissivity factor ε) as the tested plate which was not heat loaded (Fig. 3), situated near the tested plate. The Figure 4 presents the thermovision photo of the tested plates.

After making series of tests (heat fluxes density $Q_{heatbox}$ = 20-60 W/m^2), the recorded series of thermovision photos were analysed with the use of the software delivered with the thermovision camera ThermaCAM Reporter 2000. The analysis was reading mean surface temperatures of the heat loaded plate and the not loaded one and calculating the areas temperature difference for the flux which caused the temperature increase of the heat loaded plate surface. The analysis results of the series of tests enabled to obtain the dependence of the difference of temperatures and heat flux within the range of most often occurring temperature differences on the heat leakage bridges in the refrigerating bodies.

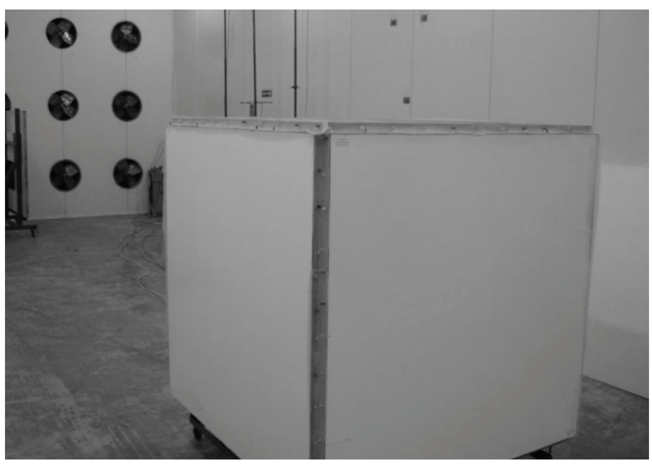

Fig. 1. Photo of body model with replaceable plates (author's photo)

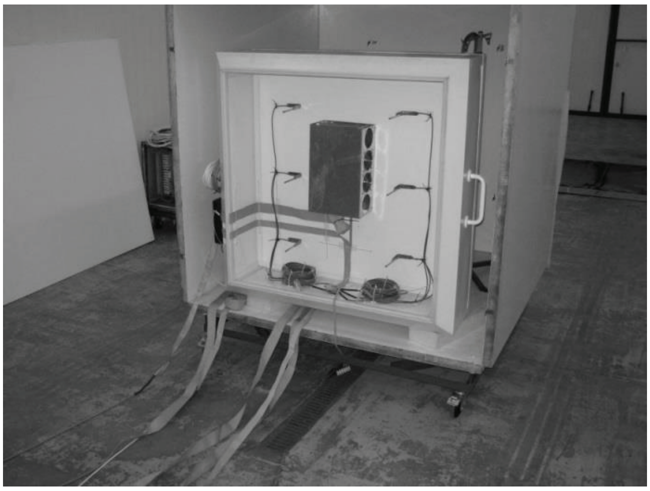

Fig. 2. Photo of heat box inside body model (author's photo)

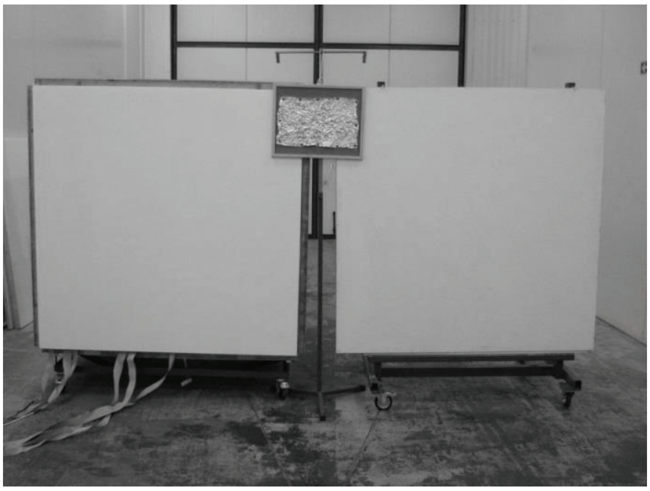

Fig. 3. Photo of test stand (author's photo)

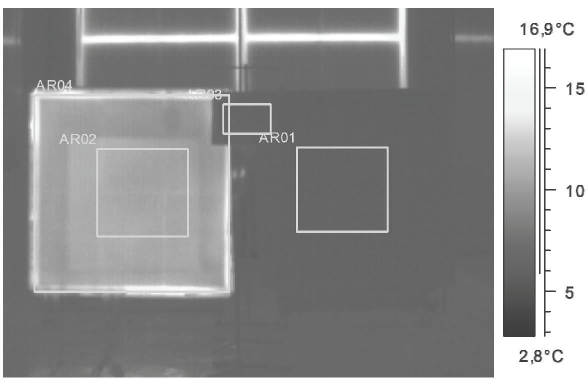

Fig. 4. Photo of plate being heat loaded with heat flux (on the left) and the control plate (on the right) (author's photo)

4. Tests results

The Fig. 5 presents the connection concerning the temperature and the heat flux differences obtained during the series of tests.

The high value of the correlation coefficient R^2 confirms good matching of the linear regression:

$$Q_{\text{heatbox}} = (14.49\,\Delta T + 0.27)\ \text{W/m}^2 \qquad (1)$$

to the ones measured during the series of experimental data testing.

Order to assess if the obtained thermovision photograph analysis device enables to determine the value of the heat flux density penetrating the heat leakage bridge with the satisfying accuracy (compared with the accuracy achieved with the use of the heat flux density meter), the validation of the method was performed.

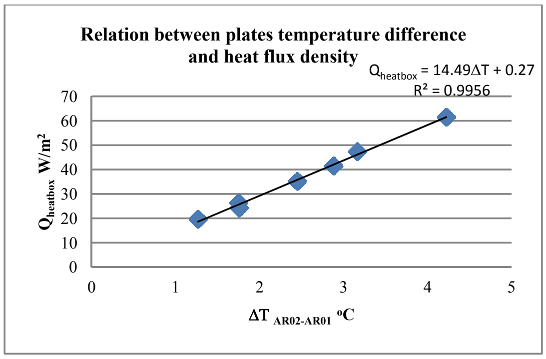

Fig. 5. Diagram presenting connection between temperature difference of heat loaded and control plates and heat flux density

5. Method validation

For the method validation the model stand was used where instead of plates with insulating material of different thickness, the plates with the heat leakage bridges models were mounted. The floor reinforcement model, the reinforcement model for fastening the aggregate and the model of screws fastening the body elements.

After the thermal stabilisation of the stand, the thermal image of the plate system (the plates with the bridges and the control plate) was registration with the thermovision camera.

In the effect of the carried out analysis, the obtained results were compared with the results of the heat loss measurements recorded with the heat box. The Table 1 contains the comparison of the test results of the heat leakage bridges models measurements of termovision camera (q_{IR}) with the heat flux measurements made with the use of the heat box (q_{ref}).

Tab. 1. Comparison of tests results of heat leakage bridge models measurements of termovision camera (q_{IR}) with heat flux measurements made with the use of heat box (q_{ref})

Heat leakage bridge model	q_{IR} W	q_{ref} W	Error %
Floor reinforcement	24.9	22.6	9.9
Aggregate suspension reinforcement	25.2	22.9	10.0
Model of screws	31.3	29.1	7.3

6. Uncertainty budget

Measurements made with the thermovision camera are not the most accurate ones. Many factors influence negatively the accuracy of the infrared radiation record (reflected apparent temperature, air temperature and humidity, optics temperature), and then the camera microcomputer calculates the temperature for the individual picture pixels on the basis of many parameters (surface emissivity ε, camera detector calibration tables.

Producers of the cameras guarantee the surface measurements accuracy with the use of the thermovision cameras of order ± 1-2°C or range ± 1-2%.

The camera used for the tests was checked concerning the measurements accuracy and uniformity in January 2012. For checking, the perfectly black body was used. Discrepancy recorded at the temperature 7.5^{o}C (ambient temperature during the tests of the refrigerating bodies when the heat leakage bridges in the bodies are observed) was about 0.1^{o}C and the standard area deviation of the perfectly black body was 0.1^{o}C. It seems that the residual check (a complete camera calibration at the producer's, on the special calibration stand was not made) confirmed the camera technical efficiency and allowed to expect that it is possible to achieve the temperature measurements accuracy of order 0.2^{o}C during the comparative tests. Determination of the surface emissivity ε of the laminate was made with the use of the method of heating up of 50^{o}C and using the reference material. The obtained result ε_{lam}=0.97 of the laminate shows that this material should be treated as the good one for the thermovision tests and the obtained results of the temperature measurements as reliable.

The heat flux density measurements were carried out through the measurement of voltage and direct current consumed by the set of heaters mounted in the heat box. The measurement accuracy was estimated for about 3%.

7. Conclusions

The performed analysis of the thermovision photographs of the heat leakage bridges models shows that using the comparative method it is possible to obtain information on the flux value within the heat flux gradient. The thermovision technique as the measuring technique is technically difficult to be carried out, however, it has many advantages causing that it is universal. No interference in the heat exchange system – no contact method, depicting the temperature distribution of small and big areas depending on the observation distance and the applied optics are undeniable advantages of the thermovision. The author, because of his professional work, (refrigerating transport) has elaborated and validated the comparative method for the sphere of the heat leakage bridges testing in the refrigerating bodies but the elaborated method can be also very useful in other spheres of heat/cool testing, for example, building engineering.

8. References

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Received: 14.03.2015 *Paper reviewed* *Accepted: 05.05.2015*

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The graduate of the Poznań University of Technology (1995), obtained the doctor's degree (2003). The author and co-author of studies concerning thermovision, especially tests of vehicles for the refrigerating food transport and refrigerating chambers for the food storage. He participated in design works as well as in the realization and starting up the station for testing the isothermal and refrigerating bodies according to the ATP standard of the Poznań University of Technology.

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