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COLLATION OF QUALITATIVE RESEARCH WITH QUANTITIVE FEM RESEARCH IN TERMS OF TWO DIMENSIONAL HEAT FLOW

PRÓBA KORELACJI BADANIA JAKOŚCIOWEGO IN SITU Z ANALIZĄ ILOŚCIOWĄ MES W ASPEKCIE DWUWYMIAROWEGO PRZEPŁYWU CIEPŁA

Abstract

The paper concerns an attempt to collate qualitative research with quantitative FEM research in terms of two dimensional heat flow. It shows the accuracy of both methods, according to in situ researches with a thermal camera and models – done with software Therm 5, Therm.

Keywords: simulations, heat transfer, thermal bridge, in situ, modeling

Streszczenie

Artykuł dotyczy próby zestawienia badań jakościowych z badaniami ilościowymi w zakresie MES dwuwymiarowego przepływu ciepła. Próba korelacji obu metod, według badań *in situ* przy użyciu kamery termowizyjnej i modeli – wykonane z oprogramowaniem Therm 5, Therm.

Słowa kluczowe: symulacje, przepływ ciepła, mostek termiczny, badania in situ, modelowanie

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1. Introduction

Due to the existing legal and formal rules, regulations resulting from the NFOŚ programs relating to subsidies to the newly-erected buildings nearly zero energy, the problem of verification and modeling of thermal bridges has become an important issue from the point of view of both the investor the verifier of projects. From the scientific point of view, the matter could seem simple. On the other hand, the task sounded like an easy way to correlate the design assumptions with their verification on a real object. Typically, verification of the numerical model is associated with laboratory testing or an in situ examination. In general, the measurement (whether in the laboratory or in the experimental object or an existing object) is treated like a check on the theoretical results. In addition, verification and accuracy of measurement of heat flow through the building's envelope is important, both for determining the energy balance of the building, as well as diagnosing the causes of the destruction of construction joints.

The subject of the paper focuses on the combination of the two methods of testing and analysis of two-dimensional heat flow – a qualitative in situ research executed using an infrared camera and a quantitative research performed with FEM software. Its aim is to attempt to correlate the results, assess the accuracy and to show the advantages and disadvantages of *p*/*m* methods.

2. Subject of analysis

The subject of analysis were buildings located in south part of Poland, Małopolska, in the fourth climatic zone. Buildings, taken into account, are located in Wieliczka, Brzesko, Tarnów, Radłów (as it is showed in Fig. 1). A qualitative study was performed in February and March of 2013. The construction of outer walls is described in Table 1.

Fig. 1. Brzesko, Radłów i Wieliczka houses subjected to research

3. Methods of analysis

A comparative analysis of *in situ* measurements of real objects is described above (computer modeling using MES). Measurement of *in-situ* (in-) was used as a verification of both models and the temperature distribution and the boundary conditions such as the temperature at the surface of the partition.

Table 1

External partitions, thermal characteristics of the examined objects

Thermal characteristics of the examined objects			
No.	Type of material	thickness [cm]	l [W/mK]
Object 1	hollow block Porotherm	25	0.88
	thermal insulation EPS	5	0.042
Object 2	solid brick	30	0.77
	thermal insulation EPS	8	0.042
Object 3	hollow block MAX	28.8	0.43
Object 4	reinforced concrete	25	1.7
	thermal insulation EPS	10	0.042

The analysis of *p*/*m* buildings in terms of two-dimensional heat flow were done using: situ measurement and a computer modeling method of MES. For the measurement, the following measuring equipment was used:

– for qualitative research, an infrared camera VIGOcam v50 bolometer detector with resolution of 384 × 288, the measured wavelength ranging from 8 to 14 mm, and the detector sensitivity of two 2 degrees Celsius;
– for the quantitative study – software integrated with VIGOcam: Therm, and to model the selected calls Therm 5 – a program that uses finite element method algorithm;
– Hygrometer VOLTCRAFT PL-100TRH probe Type *K*, Temperature range: 0 to + 60°C; Type *K*: from – 200 to 1372°C. Temperature measurement accuracy: ±1°C, Humidity measuring range: 0–100% RH, Humidity accuracy: ± 2.5%,
– VIDEO THERMOMETER IR-pyrometer model: 7550, Range: –50 ... + 1600°C, Optics: 50: 1, 1% accuracy +/–, Adjustable emissivity: 0.10–1.00. For the modeling models – done with software Therm 5, Therm.

For comparison, critical, the most neglected, points, where there have been the most intense heat transmission were selected. These include (listed by type of node design) a combination of the cantilever with the outer wall, ring beams, window frames, door (lintels, sills, sides), a connection of foundation walls to the ground, corners of external walls, reinforced concrete columns placed in the exterior walls, such as building ceramics, identified and defined bridges "internal" resulting from the discontinuity of insulation and its misalignment.

For modeling the finite element method [1–3, 11, 12] was used. The verification of the thermal resistance partitions calculations was also carried out in accordance with [20]. Still, in some studies, eg.: [7, 8, 0, 13], one can find references to the simple ways of determining the estimated thermal bridges [4–6] and the applicable provisions of [15, 16, 18, 19] consistent with the Regulation of the Ministry of April 7, 2004 [21 as amended]. To simulate and analyze the flow of heat through building components – in orderto be credible – into the modeling data external and internal environment in accordance with [19, 20, 21] was not accepted, but according to the measurement data *in situ*.

4. Results

The first case being discussed is the combination of cantilever with the outer wall. A faulty arrangement of the insulating layer for the support results in excessive heat transfer to the outside. Measurement data in situ: temperature 0.7°C, humidity 90.3%, pressure 980 hPa, dew point –0.5°C. According to the infrared camera survey (Fig. 2), the temperature on the surface is – 7.3 degree Celsius. FEM model of the same place, with set earlier environmental values indicates the temperature of 7.25 degrees Celsius. The difference 0.05 Kelvin corresponds to the expected correlation between the results of both methods, it`s 0.68% less then 1% acceptance for statistical error.

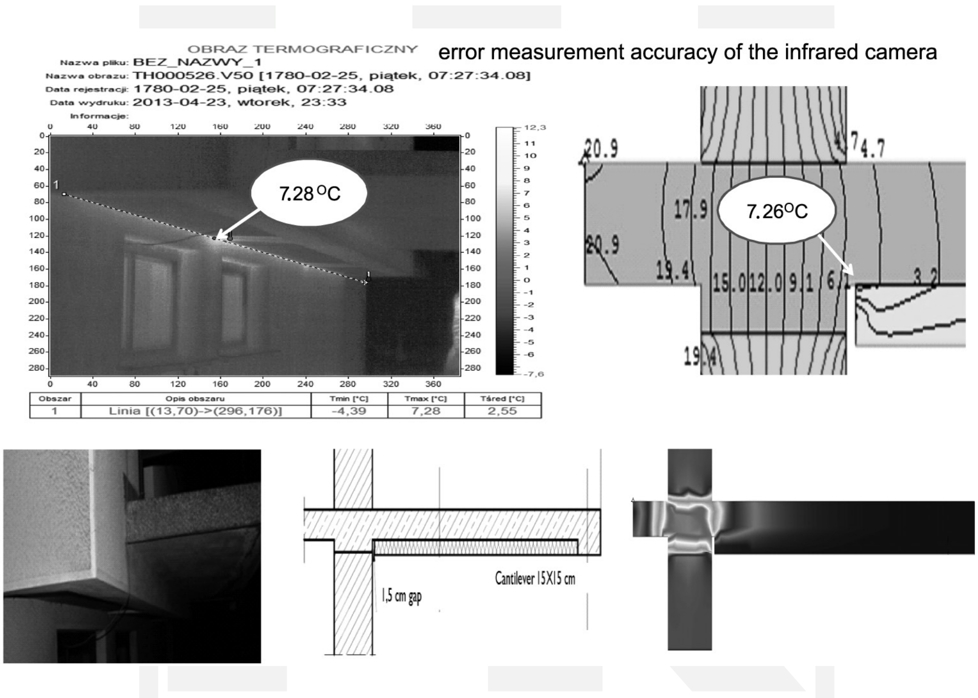

Fig. 2. Temperature distribution on the surface of constructional cantilever

In the latter case, the verification of the results of numerical simulation by comparison to the results of measurements on a real object, showed a difference of 14 Kelvin, which constitutes a significant mistake and is, of course, unacceptable. In this case, for the analysis, the gap between floor and construction wall was chosen (Fig. 3). The gap results from the lack of continuity of thermal insulation. Measurement data in situ: temperature 7.6°C, humidity 43.3%, pressure 980 hPa, dew point –3.4°C. According to the infrared camera survey, the temperature fluctuates in the slot limit – 8.16°C. After that, the FEM model observed the score of 6.8°C (Fig. 3). The difference of 14 Kelvins, does not coincide with the expected correlation between the results of both methods. The reason for this large difference is an error in specific environmental conditions during the thermal imaging inspection. The ambient temperature (accepted) was 22.5°C, the ambient temperature (measured by a VOLTCRAFT PL-100TRH) was 7.6°C, which translates into a more accurate quantitative method in the test case.

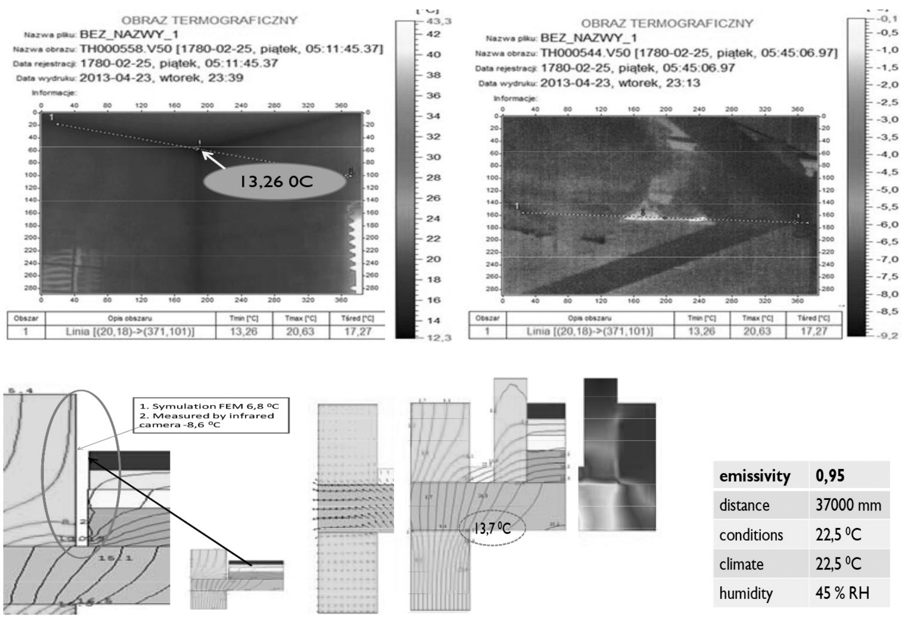

Fig. 3. Distribution of temperature, the gap between floor and construction wall

5. Conclusions

After an analysis of the extreme and most defective cases, conclusions have been drawn below. Thermal bridges were analyzed from a point of view of a cause-and-effect relationship. The two main reasons for the occurrence of weak spots, when it comes to thermal comfort is: design errors, mistakes in regulations resulting in air gaps, poor ventilation, increased heat loss, condensation-distance, fungus and mold, old-fashioned methods of the trade -increased heat loss, gaps in the insulation coating.

The correct analysis of thermal images is possible only with a report of environmental conditions such as temperature, humidity and the characteristics of the material such as a emissivity surface, the surface temperature. Sensitivity analysis should be carried out due to the performance of elements – aspects particularly crucial in view of the thermal conductivity coefficient.

It seems legitimate to accept an assumption that the analysis should be carried out in two ways, at the same time – the verification of the results – return ie., In exceptional cases, modeling can be a tool for the verification of measuring methods.

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