ARCHITECTURE CIVIL ENGINEERING ENVIRONMENT
The Silesian University of Technology No. 1/2008

USING OF SIMULATION PROGRAMS FOR HEAT OUTFLOW DETECTION IN BUILDING PARTITIONS

Tomasz Steidl [a], Dominik Wojewódka [b]

[a] Faculty of Civil Engineering, The Silesian University of Technology, Akademicka 5, 44-100 Gliwice, Poland
E-mail address: tomasz.steidl@polsl.pl

[b] Faculty of Civil Engineering, The Silesian University of Technology, Akademicka 5, 44-100 Gliwice, Poland
E-mail address: dominik.wojewodka@polsl.pl

Received: 26.11.2007; Revised: 27.12.2007; Accepted: 14.01.2008

Abstract

Thermovision- is a basic non-invasive tool used to test buildings in relation to thermal protection. Wider and wider use of this tool in diagnostic practice extorts a need for reliable evaluation of test results – thermograms. Substantial problem related to analysis of obtained results is lack of reference thermograms enabling accurate interpretation of thermograms. Innovation of tested method of trial tests results interpretation is in the attempt to use possibilities of program, used for simulation of thermal phenomena in building partitions, to obtain reference temperature distribution on analysed partition surface. Program ESP-r is a good tool to carry out thermal-dampness analyses in a building, a room, and a single partition. Program possibilities include also virtual measurement of temperature on partition surface and in its layers. Carried out analyses of temperature measurements performed in situ and virtual measurements have shown lack of correspondence between obtained results.

Streszczenie

Znaczne straty ciepła zauważalne w budynkach mieszkalnych wywołują potrzebę trafnej diagnostyki stanu technicznego obiektu. Termowizja – dobre narzędzie do bezinwazyjnych badań budynków, wykazuje potrzebę rzetelnej oceny wyników badań – termogramów. Problem stanowi brak termogramów odniesienia umożliwiających trafną interpretację wyników przeprowadzonych badań termowizyjnych. Innowacyjność artykułu polega na próbie wykorzystania powszechnie stosowanego programu do symulacji cieplnej budynków (ESP-r) do uzyskania referencyjnego rozkładu temperatury na przegrodzie. Program ESP-r okazał się znakomitym narzędziem do wyznaczania globalnych strat ciepła i badania komfortu cieplnego pomieszczeń, natomiast do szczegółowej analizy zjawisk zachodzących na powierzchniach przegród budynków zaleca się wykorzystanie innych dostępnych programów komputerowych.

Keywords: **Building simulation; Heat outflow; Thermovision; Thermal bridges; Temperature field; ESP-r.**

1. INTRODUCTION

Building regulations valid in Poland till mid 90's were not very demanding in respect to energy consumption, which was related to common opinion about its availability and low cost of production. Big raise of power prices and pursuit to limit use of non-renewable energy materials, resulted in taking various actions aiming at decreasing amount of used energy in heated buildings. Structure of energy consumption in residential buildings shows that over 1/3 of used energy is used to heat rooms.

2. THERMAL DIAGNOSIS OF PARTITIONS IN RESIDENTIAL BUILDINGS

The greatest potential in actions aiming at improvement of thermal quality of residential multi-family buildings constructed after 1945 is related to reduction

of heat loss through external partitions. The basic issue of partitions thermal diagnosis is accurate quality and quantity assessment of these losses. Advanced thermal diagnosis of building partitions is not only activity related to typical identification of thermal bridges in building partitions but should also become a tool helping to make decisions regarding modernization activities in utilized buildings. In the same way thermal diagnosis of external partitions at the design stage should result in decrease of buildings energy-consumption and thus lowering cost of their utilization.

2.1. Supporting diagnostic activities

Expert carrying out thermal diagnosis of building to improve its utilisation parameters has got very limited number of tools supporting its accurate performance. In practice the most frequent method of carrying out thermal diagnosis of building partitions in outdoor conditions is the use of thermovision. Thermal pictures of partition surface created with the use of thermovision camera, subjected to appropriate computer processing, are one of the best assessment methods of partition thermal quality. However, similarly to other in situ testing, also thermovision tests are burdened with particular error. In case of thermovision pictures the biggest problem is in great sensitiveness of obtained results related to temporary change of external conditions the tests are carried out in. The key issue is proper interpretation of carried out thermograms by people dealing with computer processing of picture. The sum of errors made in the process of testing and assessment may result in entirely incorrect conclusions regarding actual thermal quality of partition.

Numerous computer applications supporting design works can be successfully used to verify thermograms quality. For this purpose ESP-r software, being advanced tool enabling analyses on the room level with possibility to obtain virtual point measurement of temperature, was used. In practice virtual measurement generated with the use of appropriate data base for local climate should correspond in quantity respect with point measurement of surface temperature, obtained with the use of thermovision camera.

3. DESCRIPTION OF STRUCTURE AND EMPLOYED RESEARCH METHOD

The subject of thermovision testing was a multi-family five-storey residential building located in Zabrze. During site inspection, numerous damages were identified at the internal surface of building partitions – moistured places and mildew blooms in most of the rooms. Increased level of air relative humidity as well as substantially locally chilled wall surfaces were noted in flats.

Thermovision tests were carried out in November 2005 in early morning hours, between 5.00 and 6.00 a.m. Tests were carried out in accordance with standard requirements [1]. Obtained results confirmed assumptions about low thermal quality of partitions.

Balcony wall presented in figure1. was selected for quality analysis of temperature distribution on the external surface.

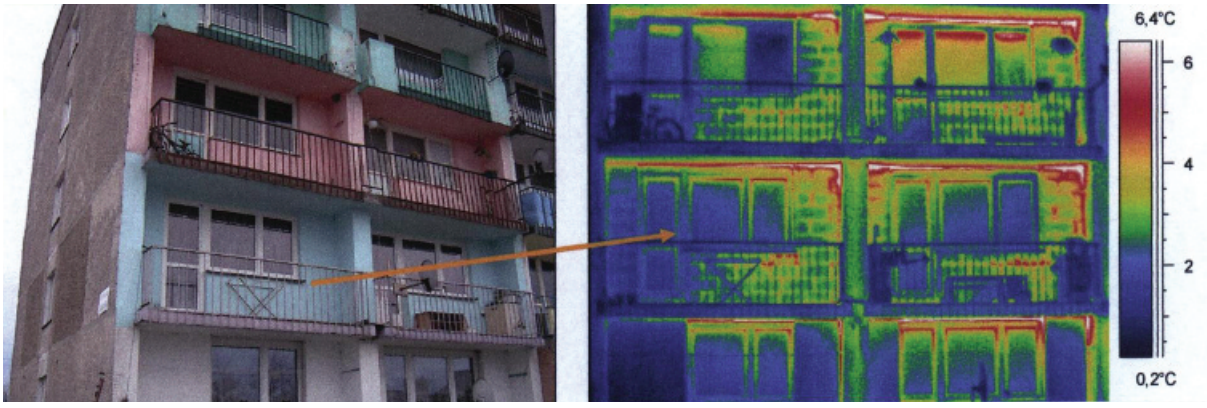
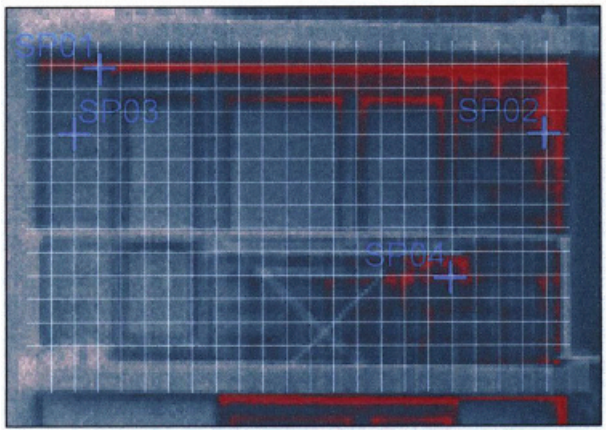


Figure 1.
Photo and thermovision picture of the selected partition



IR information	Value
Date of creation	2005-11-17
Object parameter	**Value**
Ambient temperature	2,0°C
Atmospheric	1,0°C
Label	**Value**
SP01	4,4°C
SP02	4,5°C
SP03	2,4°C
SP04	4,3°C

Figure 2.
Analysis of temperature in the mesh points

Substantial local disturbances to thermal field related to material heterogeneity of partition as well as leak of slabs joints were noted in the thermogram (Fig. 2).

In order to carry out quantity testing of diagnosed defects, partition surface was divided into range of small fields for which average temperature will be read out based on thermogram and results will be compared with analogical model constructed with the use of ESP-r program.

To obtain values of average temperature for small area surfaces analysed partition was divided into smaller units according to the employed scheme presented in the figure 3. Rectangular mesh of dimensions: vertical – 0.3 m, horizontal – 0.35 m was employed.

ThermaCAM Reporter Basic[2] program used for quantity analysis of thermograms was used to read out average temperature.

4. SIMULATION IN ESP-R PROGRAM

ESP-r (Eng. Environmental Systems Performance) [3], is one of simulation computer programs leading in the world and in Europe, used to model mass and heat flow in the building, making allowance for heating system and air-conditioning [4]. Thanks to possibility of modification of data base both material as well as climate one, the designer has got possibility to introduce his own material solutions for construction of partition and local climate data base. Program is a tool enabling analysis of impact of used materials and

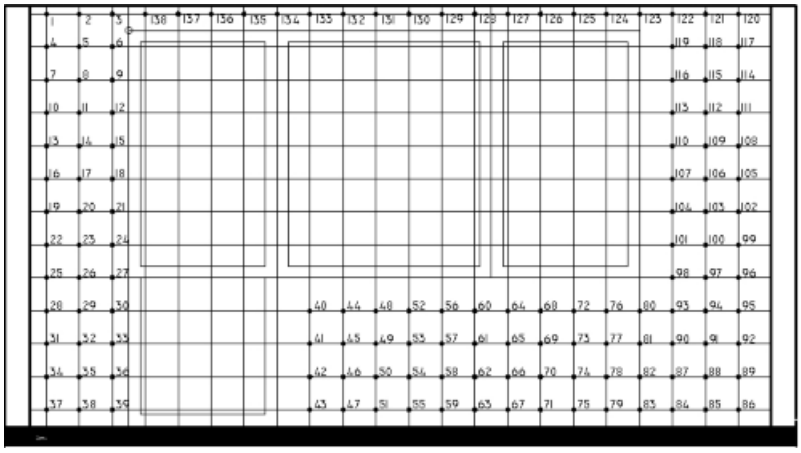


Figure 3.
Mesh used to read out average temperature for small area surfaces

local climate on heat losses as well as on conditions of thermal comfort in the rooms. Possibility of temperature measurement with the use of virtual sensor in the selected spots, including partition surface and cross-section, enables observation of alterations to thermal comfort in the room.

Using this possibility, attempt was made to use ESP-r program to find initial distribution of temperatures in the selected spots on the partition surface, using the method of placing virtual sensor for temperature measurement in area surfaces obtained as a result of dividing partition with earlier employed mesh.

4.1. Description of model constructed with the use of ESP-r program.

Realizing set target, model of residential room was made of dimensions and material-construction characteristics corresponding to actual state (Fig. 4). Temperature values will be read out on the selected surface of building model – balcony wall – for small area surfaces resulting from division of tested partition area according to previously employed mesh.

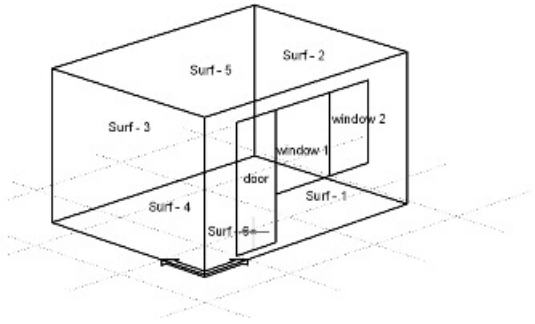


Figure 4.
Model of the room made with the use of ESP-r program

General characteristics of the model:

– dimensions : width of the room – 480 cm, height – 280 cm, depth – 360 cm (all dimensions in constructional axes);
– material data: emissivity coefficient, density, specific heat and other employed based on items [5], [6], [7] of references;
– model was oriented to the four cardinal points of the compass in accordance with reality;
– ventilation through infiltration was assumed – 0,3 exchanges/hour;
– basic model steering zone heating was employed maintaining air temperature in the room on the level of 20°C.

Very important task, to obtain results in the process of simulation, is possibly faithful reflection of outside climate conditions. In the program there is no climate data base for the area of Poland. It made the paper authors use data obtained in the course of many years of local climate measurements, carried out in the test station of Division of Ecological Building. Based on local climate measurements new climate data base was build for the reference year and then adjusted to ESP-r program requirements. Period with outside climate parameters corresponding to actual state at the moment of carrying out thermovision tests was selected for simulation. Climate parameters:

- Outside air temperature – 1°C;
- Air relative humidity – 93%;
- Wind speed – 4.1 m/s

5. TEMPERATURE ANALYSIS OF BALCONY WALL SELECTED AREAS

Surface area was divided into mesh of squares according to Fig. 3. Average temperature value can be obtained from each field. Due to limited complexity of model introduced in the program, partial reconstruction of measurement mesh scheme was required. Computational model is shown in Fig. 5.

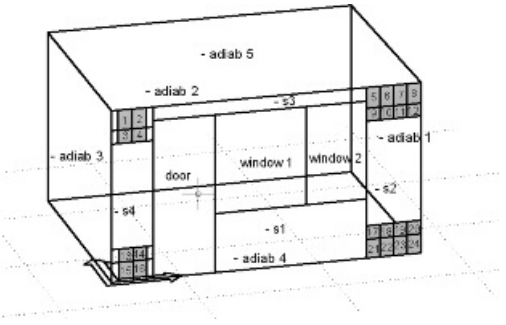


Figure 5.
Partial reconstruction of measurement mesh to get thermal map

Model presented in Fig. 5 was used for results preliminary evaluation.

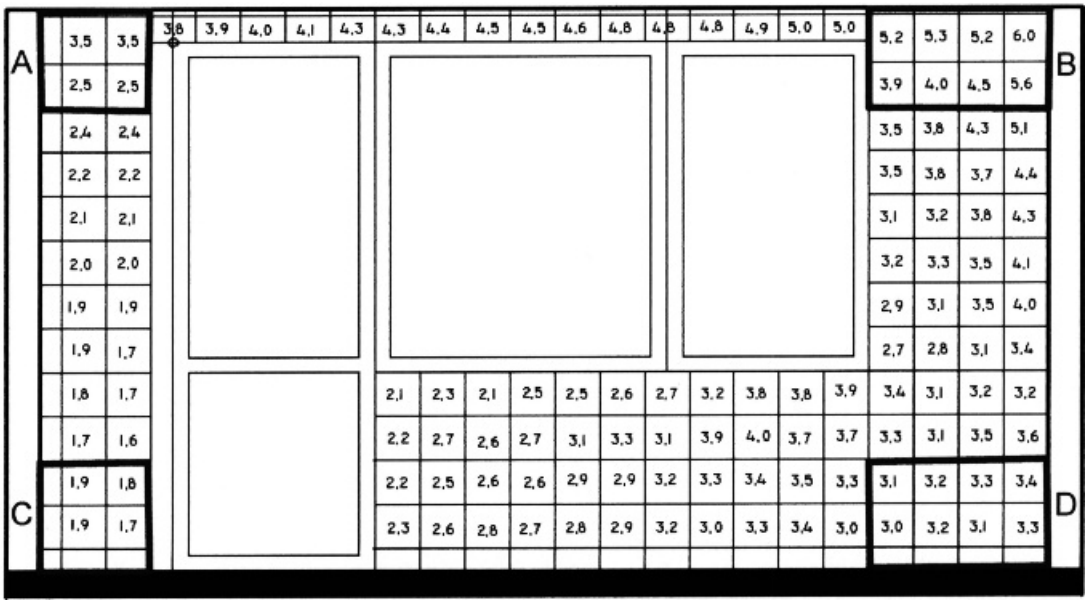


Figure 6.
Values of average temperature in fields read out from the thermogram, [°C]

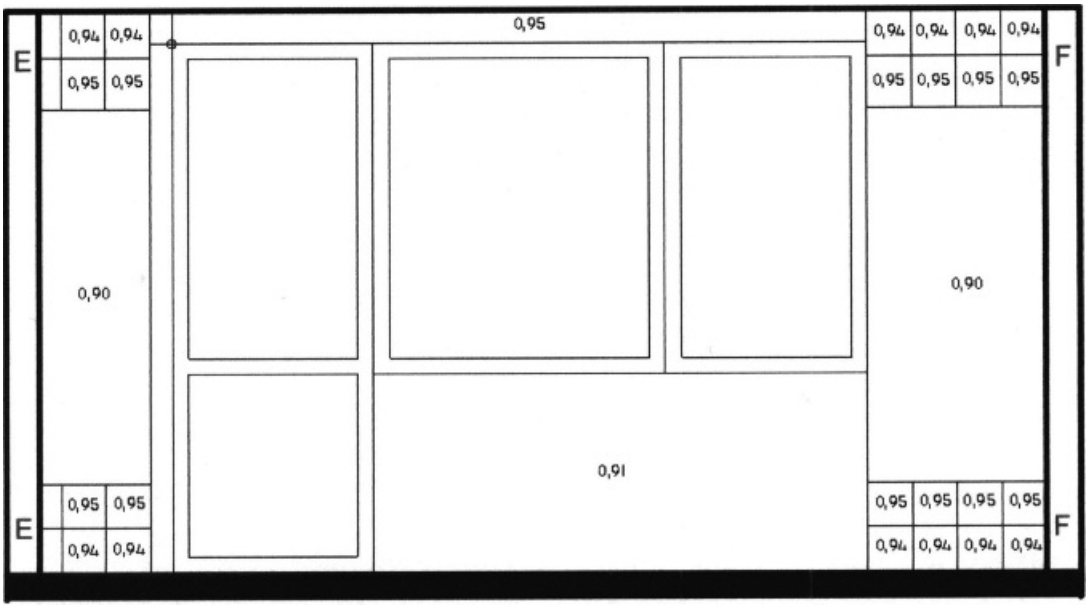


Figure 7.
Values of average temperature in fields obtained as a result of simulation, [°C]

5.1. Analysis of obtained results.

Values of temperature for areas creating thermal map and obtained as a result of thermograms analysis as well as computer simulation of the model constructed with the use of ESP-r program were presented and compared.

Figure 6, presents values of average temperature for each field, read out from the thermogram with the use of ThermaCAM Reporter Basic program, whereas figure 7 presents values obtained as a result of model simulation in ESP-r program.

Garncarek's method [8] was used to compare values of average temperature for fields presented in figures 6 and 7 to evaluate heterogeneity of thermal field.

Measurement of thermal field heterogeneity – h, for geometrical fields corresponding to each other on analysed partition, presents as follows:

- field A (thermogram) ⇨ field E (simulation in ESP-r)

  $h_A = 6{,}67$ $h_E = 0{,}07$

- field B (thermogram) ⇨ field F (simulation in ESP-r)

  $h_B = 5{,}35$ $h_F = 0{,}06$

- field C (thermogram) ⇨ field E (simulation in ESP-r)

  $h_C = 0{,}73$ $h_E = 0{,}07$

- field D (thermogram) ⇨ field F (simulation in ESP-r)

  $h_D = 0{,}86$ $h_F = 0{,}06$

Example of calculations is presented below:

where:

$$h = \frac{k}{n(k-1)} \sum_{i=1}^{k} \left(n_i - \frac{n}{k} \right)^2 \qquad (1)$$

k – amount of elements of the mesh,

n_i – following element of the mesh,

$n = n_1 + n_2 + ... n_k$ - sum of values of all elements

• field B (thermogram)

values of the temperature [accuracy 0.1˚C] and reduced values of the temperature:

52	53	52	60
39	40	45	56

13	14	13	21
0	1	6	17

k = 8

$n_i – n_1, n_2, n_3, n_4, n_5, n_6, n_7, n_8$

n = 1 + 6 + 17 + 21 + 13 + 14 + 13 = 85

$h_B = 5.35$

• field F (simulation in ESP-r)

values of the temperature [accuracy 0.1˚C] and reduced values of the temperature:

9.4	9.4	9.4	9.4
9.5	9.5	9.5	9.5

0	0	0	0
0.1	0.1	0.1	0.1

k = 8

$n_i – n_1, n_2, n_3, n_4, n_5, n_6, n_7, n_8$

n = 0,1 + 0,1 + 0,1 + 0,1 = 0,4

$h_F = 0.06$

Temperature values obtained in ESP-r program show homogeneity, despite of diversification of place on partition. Elimination of thermal bridges in these spots is very little probable even after properly carried out modernization of the building. Taking into account material and constructional parameters of the model, obtained almost ideal homogeneity of thermal field distribution is very puzzling.

ESP-r program, as very advanced balance tool, has got too simplified model of heat flow making allowance for unidirectional heat flow [9]. In effect if there is a need for detailed analysis, then software based on more complex mathematical model should be used, in which studied part of area surface is discretisated and calculations are made on nodal level. Number of nodes on the one side needs to be big

enough to obtain sufficiently accurate result, and on the other side possibly small to simplify computational complexity to the maximum.

Authors of the ESP-r program are working to include in the program mathematical models which represent new generation of nodal mesh giving more allowance for complexity of internodal conduction. A new approach to this issue is to enable simulation of buildings with consideration to three-dimensional heat flow, taking into account effect of thermal bridges presence [9].

6. SUMMARY

Expected simulation of thermal field did not resulted in the anticipated effects despite the use of local climate data base applied in the program, several changes of field testing subjects, repeated thermovision tests and model simulation. Therefore further modification of partition model was abandoned – finding the method of virtual sensor applied in ESP-r program not sufficiently adjusted to diagnosis requirements, despite the fact that prior analysis of literature regarding possibility of simulating program in this respect indicated possible use of method employed in this way.

ESP-r program turned out to be a great tool for simulations of building behaviour after various boundary conditions, both external and internal, faithfully rendering actual parameters, are applied. The program is very suitable to determine global heat losses for structures as well as to diagnose changes of rooms thermal comfort parameters. For detailed analysis of phenomena taking place on building partitions surface it is recommended to use of other available programs such as e.g. Therm 5.2 or Trisco.

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