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DUŠAN KATUNSKÝ*

THE INTERACTION BETWEEN THERMAL FLOWS AND BUILDING CONSTRUCTION INCLUDING ITS UNDERGROUND AND ENVELOPE STRUCTURE

ZALEŻNOŚĆ PRZEPŁYWU CIEPŁA OD KONSTRUKCJI PODZIEMNEJ CZĘŚCI BUDYNKU I JEGO OBUDOWY

A b s t r a c t

This contribution presents some indoor quality evaluation results and is also a supplement to the research project VEGA 1/0695/08 "Thermal flows in interaction of building construction and underground as well as external outdoor conditions for large space hall buildings", supported by Slovak Fund for Scientific Research. The article deals with the indoor climate physical parameter analysis in numerous types of large-volume industrial production halls, considering the effects and influence on the interior conditions in the winter and summer periods. Industrial building concepts differ from non-residential buildings or blocks of flats, which necessitate a different approach to the building structure concept proposal, the internal environment and the prognosis of heating energy consumption.

Keywords: *industrial buildings, hall objects, thermal flows, heat density, humidity flows, underground space, energy consumption for heating*

S t r e s z c z e n i e

W artykule omówiono wybrane rezultaty z przeprowadzonej oceny warunków wewnętrznych. Artykuł stanowi uzupełnienie projektu badawczego VEGA 1/0695/08 „Thermal flows in interaction of building construction and underground as well as external outdoor conditions for large space hall buildings", wspieranego przez Słowacki Fundusz Badań Naukowych. W artykule przedstawiono analizę wpływu fizycznych parametrów na klimat wewnętrzny w wielu rodzajach obszernych budynków halowych, w warunkach letnich i zimowych. Różnice pomiędzy budynkami przemysłowymi a mieszkalnymi i innymi budynkami niemieszkalnymi sprawiają, że konieczne jest tu specyficzne podejście przy określaniu warunków wewnętrznych i prognozowaniu zużycia energii na ogrzewanie.

Słowa kluczowe: *budynki przemysłowe, obiekty halowe, strumienie cieplne, gęstość strumienia cieplnego, przepływ wilgoci, przestrzeń podziemna, zużycie energii na ogrzewanie*

* Prof. Ing. Dušan Katunský, CSc., Institute of Building and Environmental Engineering, Civil Engineering Faculty, Technical University of Košice, Slovakia.

1. Introduction

The focus of attention in this paper are the physical components of the internal environment and their mutual interaction in industrial buildings, especially these of hall type. The research was conducted in co-operation with the grant projects VEGA 1/9023/02 “The Interaction of Physical Factors in the Creation of an Appropriate Working Environment” and 1/2562/05 “Evaluation of thermal, humidity and lighting conditions of the production industrial buildings“ related to the research project 1/0695/08 entitled „Thermal flows in interaction of building construction and underground as well as external outdoor conditions for large space hall buildings“, supported by Slovak Fund for Scientific Research.

2. The experimental research scope

The internal climate of industrial production buildings, especially these of hall type is characterised by non-homogeneity of individual types of this climate. Subsequently, the non-homogeneity is characterised by non-stationary energy flows in the building in space and time. Their qualitative and quantitative expression at an anticipation level is rather complicated. One of the methods that can be employed is the integrated simulation method in marginal conditions of the exterior climate model in the form of a reference test year for the condition of the Slovak Republic. Within the framework of the three research projects mentioned above, the attention is focused on the selected physical components of the internal environment of hall industrial buildings, especially thermal, humidity and day lighting conditions in relation to the energy demand analysis. The objective of the research is to work out methods for optimising these conditions with regard to the building envelope design as well as the environmental technique and energy intensity reduction during their operation. To do so, one should change their approach to the industrial building envelope design, which should result in environmentally relevant, economically efficient and sustainable architecture. The research project solvers/developers devoted special attention to industrial buildings designed for textile, electrical, electronic, pharmaceutical and machinery production.

3. Thermal and humidity flows through envelope structures

The survey results have shown that the temperature level of the internal air and relative humidity in industrial buildings pose a serious problem. In majority of cases, in industrial buildings there are more demanding conditions of the heat-humidity state of the internal environment than in residential or non-residential buildings (office buildings). On the cellular concrete envelope of a hall-type industrial building the diffusion of water vapour was observed simultaneously with the effect of liquid transport of humidity. For a non--linear mathematical model of the heat and humidity transfer in porous materials a numerical algorithm of solution was created. It concerns the determination of non--stationary heat and humidity transfer not only in X-direction, e.g. through the mass of the external envelope (the thickness of the wall), but also depending on time t [s].

The calculation results have proved that the proposed method provides satisfactory numerical problem solutions in corresponding marginal conditions of the solutions. In a specific hall-type building the *in situ* measurements of heat and humidity on the external envelope were conducted. At the same time a verification of proposed calculation models was carried out. The results obtained from the measurements are comparable with the numerical solution of the proposed models of heat and humidity transfer.

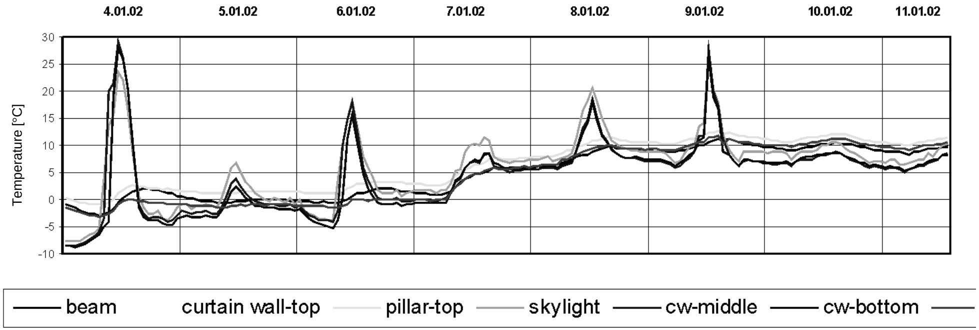

Fig. 1. Changes of internal surface temperatures in measured structures
in production hall in January 2002
Rys. 1. Zmiany temperatury powierzchni wewnętrznych w halach produkcyjnych
mierzone w styczniu 2002

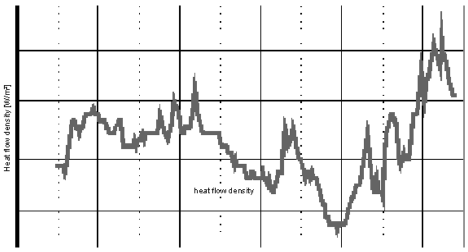

Fig. 2. Heat flow – density q [W/m^2] – roof
Rys. 2. Gęstość strumienia cieplnego q [W/m^2]
– dach

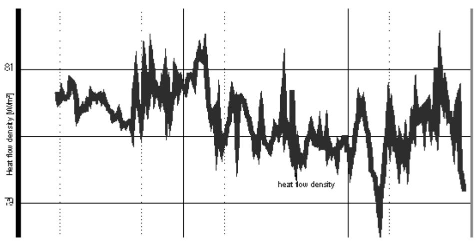

Fig. 3. Heat flow – density q [W/m^2] – glassing
Rys. 3. Gęstość strumienia cieplnego q [W/m^2]
– oszklenie

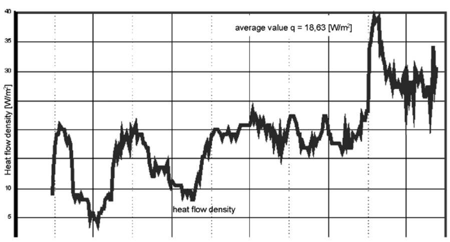

Fig. 4. Heat flow – density q [W/m^2] – ext. wall
Rys. 4. Gęstość strumienia cieplnego q [W/m^2]
– ściana zewnętrzna

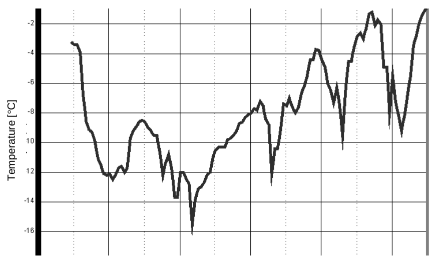

Fig. 5. Behaviour of external temperature during measured period
Rys. 5. Temperatura powietrza zewnętrznego
w okresie pomiarowym

Figures 2–4 measured heat flows – heat density in machinery production hall through envelope structures – *in situ* q [W/m^2] in December 2002.

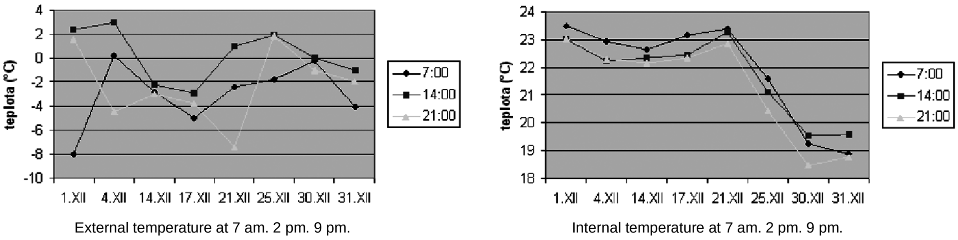

Fig. 6. Measured external and internal temperatures in production building (electro-technical production) – *in situ* in December 2004

Rys. 6. Pomierzona *in situ* temperatura zewnętrzna i wewnętrzna w budynku produkcyjnym (produkcja elektrotechniczna) w grudniu 2004

4. Energy consumption for heating in winter period

The experimental *in situ* measurements were carried out in hall-type industrial buildings that have identical design but the orientation of whose is opposite in relation to the points of the compass. In the winter period the measurements of surface temperatures of envelope structures, heat-humidity conditions of the internal environment and heat flows were

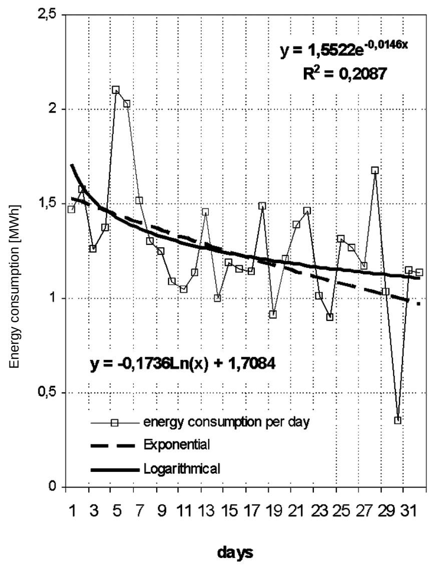

Fig. 7. Exponential and logarithmic regression dependences of daily energy consumption according to external temperature

Rys. 7. Regresja wykładnicza i logarytmiczna dziennego zużycia energii i temperatury zewnętrznej

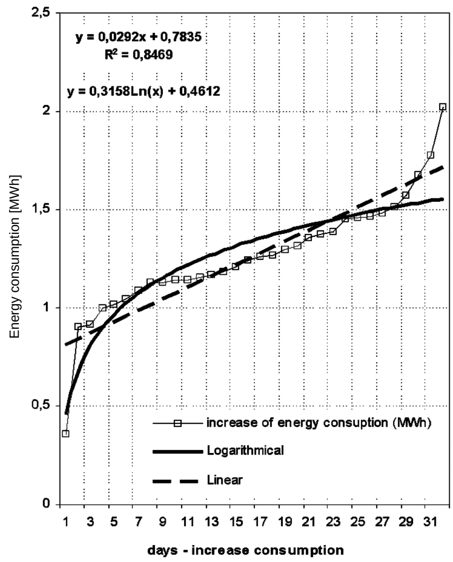

Fig. 8. Resulted regression dependence – equation from the lowest to the highest day – consumption

Rys. 8. Wynikowe równanie regresji od dnia najmniejszego do największego zużycia energii conducted. Simultaneously, the recordings of energy consumption for heating were carried out. The measurement results have shown that the evaluation methods of heat-moisture conditions of the internal environment in residential and non-production buildings cannot be directly applied to assess industrial hall type buildings.

Normative regulations valid for the assessment of heating energy needs of residential building *in situ* cannot be applied to industrial buildings. From the solution of this sub-task many regressive dependences of energy intensity were stated. Figures 7, 8 show two of them. The results of the whole experimental research were evaluated in [2] and further published in [7].

In case of industrial hall-type buildings evaluation, it is inevitable to consider and differentiate the specifics of a production operation. Similar conclusions also apply to the assessment of energy needs for heating.

5. Experimental measurements of overheating in industrial buildings

Presently, heat protection of industrial buildings in the summer period significantly falls behind the level achieved in residential but also non-residential buildings. As the survey results have shown, the most significant problem of industrial buildings is their heat instability in the summer period, which manifests itself most distinctively in hall type buildings. At present, the calculation and evaluation of heat stability is oriented more towards residential and non-residential (office buildings).

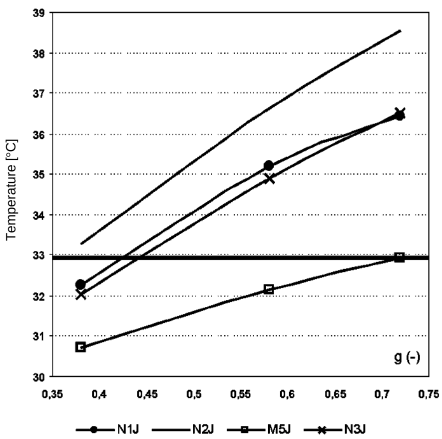

Fig. 9. The dependence $\theta_{ai,\max}$ [°C] on *g*-valueof glazing of selected calculation combination for the intensity of air exchange *n* = 1 [1/h] of the south orientation of a building model; the horizontal line represents the maximum temperature of the reference combination

Rys. 9. Zależność $\theta_{ai,\max}$ [°C] od wartości *g* oszklenia w poszczególnych wybranych przypadkach obliczeniowych, krotność wymian powietrza *n* = 1 [1/h], południowa orientacja modelu budynku; linia pozioma reprezentuje maksymalną temperaturę kombinacji referencyjnej

The real state of the hall type building heat stability was the subject of the solution [4] and was published in [3, 6]. The objectives of the sub-task can be summarised in the following points:

– obtaining factual, real heat values of the internal air by taking measurement *in situ* in selected hall type buildings in the summer period,
– verification of usability and accuracy of the chosen calculation methods (the method in accordance with Slovak National Standard – STN, EN ISO and the calculation

simulation by applying ESP-r) for the evaluation of heat stability of hall type buildings in the summer period,
– determination of the effect of the basic and supplementary entry factors and their parameters in the course of the internal air heat by calculation testing,
– requirements proposal for the evaluation of hall type building heat stability in the summer period and the creation of a simplified methodology for the evaluation reflecting the proposed requirements.

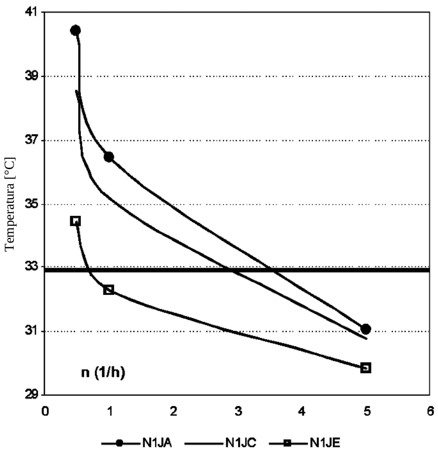

Fig. 10. The dependence $\theta_{ai,\max}$ (°C) on the air exchange intensity for the chosen calculation combination; the horizontal line represents the maximum temperature of the reference combination

Rys. 10. Zależność $\theta_{ai,\max}$ [°C] od intensywności wymian powietrza dla wybranych przypadków obliczeniowych; linia pozioma reprezentuje maksymalną temperaturę kombinacji referencyjnej

6. Thermal flows in the underground part of large-volume production halls

Physical and technical requirements, maintenance quality details as well as the basic structural framework are significant elements with respect to the interaction of an industrial production building and its underground part. The building thermal protection criteria ought

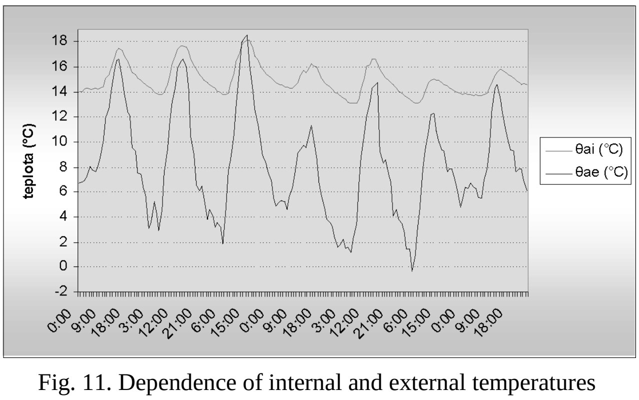

Fig. 11. Dependence of internal and external temperatures on selected days in March 2007

Rys. 11. Wykres temperatury zewnętrznej i wewnętrznej w wybranych dniach marca 2007 to deal with the floor structure as well as with the bearing and ground structures, which subsequently should have a significant influence on the energy requirements of this type of buildings. The experimental temperature measurement in the underground part has been carried out in a production building (72 × 36 m, height 10 m) in a series of five search units at 1, 2 and 3 meters respectively below the floor level and in the distances of 0.5 m; 1.0 m; 1,5 m; 2 m respectively from the external wall. One search unit has been located in the subsoil in the middle of the hall underground part. The measurements have been taken continually throughout the year. The results have been evaluated and published in [7-11].

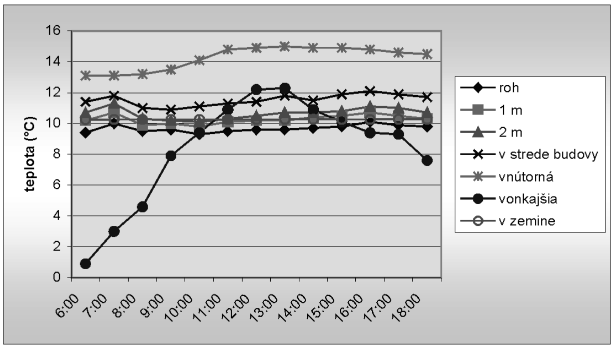

Fig. 12. The dependence of temperature changes in soil at 1, 2, 3 m underground
Rys. 12. Zmiany temperatury w gruncie na głębokości 1, 2, 3 m
w wybranym dniu marca 2007

7. Conclusions

Ensuing from the stated objectives, the experimental research solutions focus on the indoor work environment condition analysis in selected hall buildings. In view of a steadily increasing number of industrial buildings being erected in the Slovak Republic, the research concentrates on the area of current scientific and technological development.

At the same time, there appears a possibility for practical application of the knowledge gained due to the research in real conditions of new industrial buildings construction. It is necessary to assess and analyse the building as a whole considering the interactions between the internal environment components and the outer climate and energy consumption. Therefore a special attention will be directed to the interaction, e.g. between the internal air temperature – relative humidity – energy consumption; the level of daylight – overheating in the summer period – demand for HVAC. Simultaneously, the solutions are sought to individual sub-tasks concerning the transfer of heat to the sub-soil and the inclusion of former and unused industrial buildings in the active building stock. In order to do so, there will be employed a mutual combination of two types of experimental research, i.e. the experimental measurements *in situ* and the experimental calculation by means of simulation programmes.

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