Anna Lis, Danica Košičanová

EVALUATION OF HEAT GAINS COMPONENTS IN HEAT BALANCE OF BUILDINGS

Introduction

The heat balance of buildings correctly influences on heat consumption for heating. Heat losses in a building result from heat penetration through external and internal partitions as well as from heating up the air exchanged in the ventilation process. As far as heat gains are concerned, the factor that positively influences heat balance of the building is solar radiation. Both radiation duration and radiation rate are although limited. Approximately 80% of the total amount of sunlight falls on the spring and summer months. The average daily total radiation on a horizontal plane in Czestochowa is shown in Figure 1 (data on a basic IMGW Katowice).

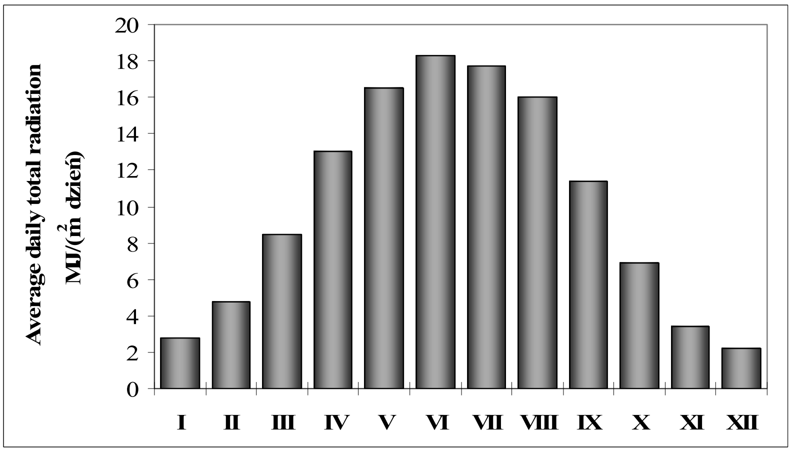

Fig. 1. The average daily total radiation on a horizontal plane in Czestochowa

During the heating season an average sum of total solar radiation amounts to 1.44 kWh/m^2/24 hrs. By rational use of solar energy savings are possible, mainly related to passive and active part of its use for the purposes of heating and hot water preparation. Savings associated with the preparation of hot water are particularly prominent in the summer. It's possible to meet the annual needs in this area within 30÷60% [1]. Some heat gains result from the existence of additional heat sources connected with the utilisation of building. One of the heat sources in buildings are the people staying in the rooms. Heat which is emitted by humans consisted of sensible heat and latent heat. The gains come also from hardware and electrical equipment, from gas equipment as well as lighting. For computers, servers, monitors, printers and other computer and telecommunications equipment heat gains are 90% of the electrical power collected by these devices [2].

1. The characteristic of research buildings

Research was conducted in a dozen or so single-family one- or two-storey buildings. All of these buildings were built in traditional technology that means with structural tiles, whole bricks and nested bricks. Two of the analysed buildings had a complete basement and one had a partial basement. In only one of considered buildings the basement was heated. All the roofs in analyzed buildings were wooden construction and were covered with tiles or sheet roofing-tile. The buildings were situated on north with elevation in which the glazed surface was minimal, while the elevation with maximal glazed surface was situated on south. One of the analysed buildings is shown in Figure 2.

Fig. 2. One of the analysed buildings

In order to analyze the changes in the value of heat gains in the heat balance of buildings was determined some significant architectural and constructional features of research building like:

– usable surface A_u,
– heated surface A_f,
– heated cubic capacity V_e,
– external wall's surface A_{we},
– cooling partition's surface A,
– shape's coefficient A/V_e,
– window's surface A_g,
– glazed surface A_g/A_{we},
– window's surface/heated surface A_g/A_f,
– window's surface/heated cubic capacity A_g/V_e.

The values of statistical indexes of research parameters for analysed buildings are shown in Tables 1 and 2.

TABLE 1

The parameters of analysed buildings (own research)

Statistical indexes	A_f	V_e	A_{we}	A/V_e
	m^2	m^3	m^2	m^{-1}
$\bar{x}$	231.1	581.9	199.3	–
H	–	–	–	0.9
s	36.2	110.1	57.8	0.1

$\bar{x}$ - arithmetic mean, H - harmonic mean, s - standard deviation

TABLE 2

The parameters of analysed buildings (own research)

Statistical indexes	A_g	A_g/A_{we}	A_g/A_f	A_g/V_e
	m^2	%		m^{-1}
$\bar{x}$	39.6	20.2	17.3	6.9
H	–	–	–	–
s	11.3	3.7	5.0	1.8

$\bar{x}$ - arithmetic mean, H - harmonic mean, s - standard deviation

Also were determined:
– air change's quantity to ventilation,
– number of people inhabiting the buildings,
- location of the building in relation to the directions of the world.

2. The analysis of heat gains

The heat gains in analysed group of buildings were estimated. With the transparent partitions are associated the solar gains. The value of heat gains come from people and electrical equipment or lighting are dependent on the functional use of the buildings and on the manner of the utilisation of building by people living in them. The value of designated heat gains are shown in Table 3.

TABLE 3

Heat gains (own research)

Statistical indexes	Heat gains	
	kWh/year	GJ/year
min value	16 868.0	63.5
max value	38 893.0	128.78
H	26 140.0	92.9
s	6 192.4	17.9

H - harmonic mean, *s* - standard deviation

Analysing fluctuations of the values of heat gains in the general heat balance of given buildings the influence of the surface of transparent partitions, the heated surface of the rooms and cubic capacity was examined. The given relations are illustrated by Figures 3 and 5-11. Figure 3 shows the evolution of heat gain's value depending on the total area of windows for the entire building.

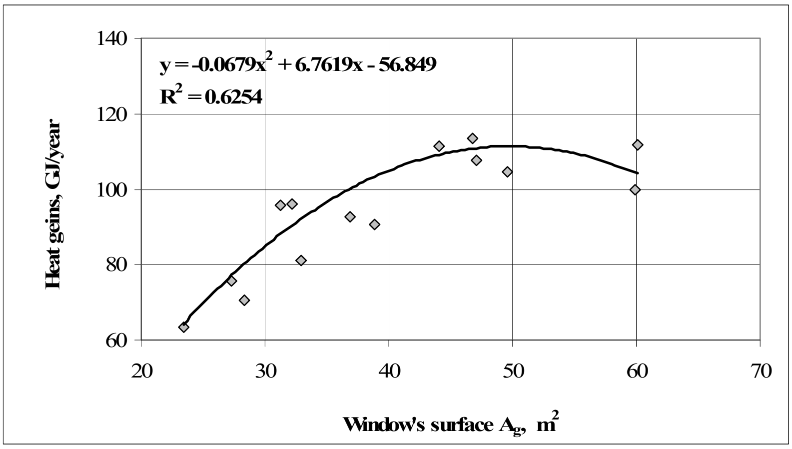

Fig. 3. The influence of window's surface A_g on heat gains (own research)

With the transparent partitions involves the use of solar gains. These gains are larger in the initial and final months of the heating season. During this period, we also are dealing with more cloud cover. The average cloud cover for Czestochowa is shown in Figure 4 (data on a basic IMGW Katowice).

The heat gains are also higher for the rooms of the glazing in the south elevation. The ratio of heat gains to heat loss improves by an average of 20% in single-family houses and 10% in multi family houses [3]. The difference between the sunny and sunless day in January is shown in a large momentary share of solar energy in general momentary heat balance. It represents approximately 30% of the total energy needs of the room. In daily profile, however falls to 6.5%. Efficiency of heating system can be less then about 3.1%. Full use of the gains from the solar radiation is possible with equipment heating installation at weather automatic. Savings in the months of high sun exposure can amount to 40%. In designing energy-efficient buildings, simply increasing the window's surface can increase the heat consumption for heating in the global heat balance, because of increased heat losses during sunless days. Big window's surface increase gains from the solar radiation, but more often are the cause of excessive heat losses. Substantial glazing has a negative impact on the microclimate conditions in the rooms during the summer. Become a cause of overheating of the rooms and loss of the people thermal comfort.

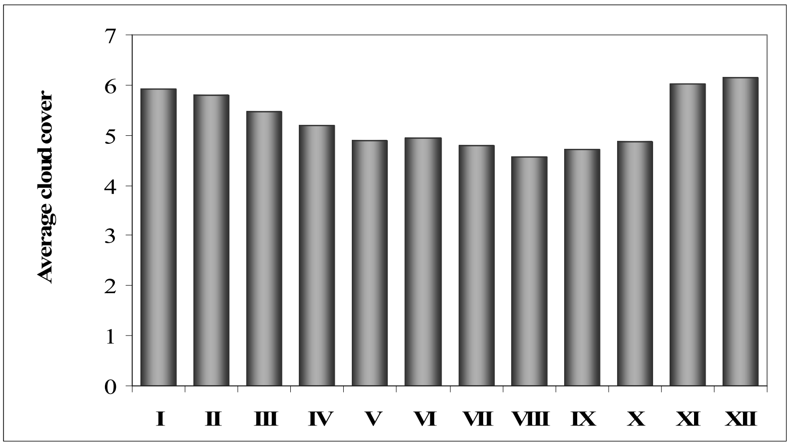

Fig. 4. Average cloud cover for Czestochowa

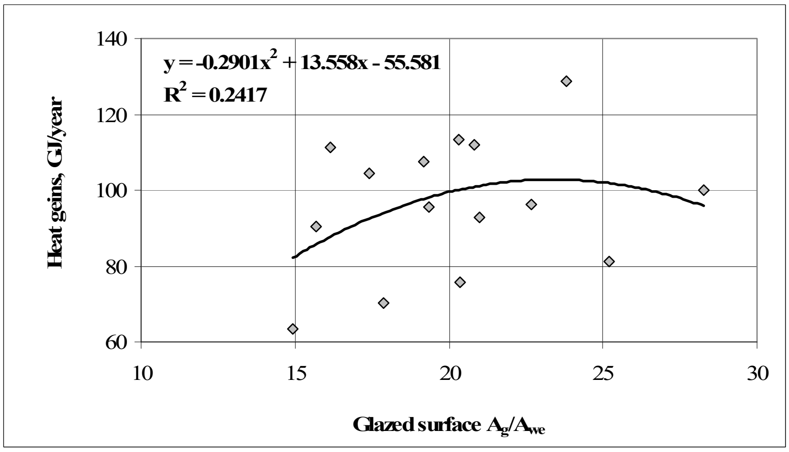

Fig. 5. The influence of glazed surface A_g/A_{we} on heat gains (own research)

Figure 5 shows the evolution of heat gain's value depending on the glazed surface (ratio of window's surface A_g to the external wall's surface A_{we}). Changes in

the value of heat gains only in 24% are dependent on changes in elevation glazing. The correlation coefficient in this case amounted to less than 0.5, which shows the average strength of the relationship between the analyzed characteristics.
Figure 6 shows the distribution of heat gain in relation to the heated surface on the rooms in analyzed group of buildings.

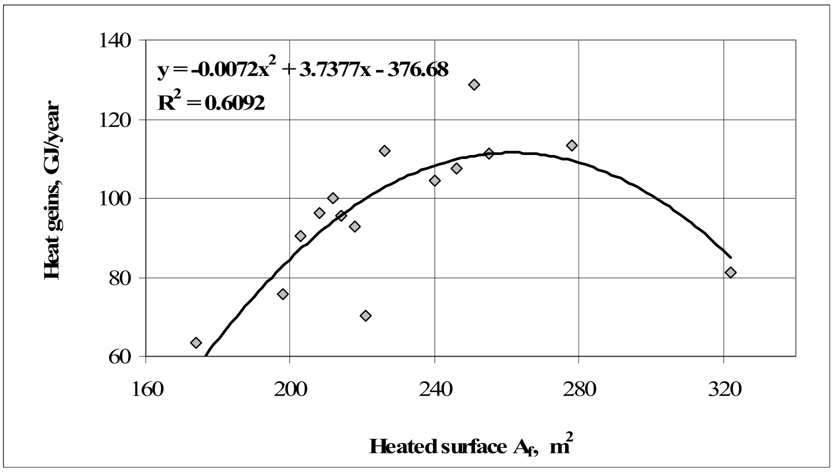

Fig. 6. The influence of heated surface A_f on heat gains (own research)

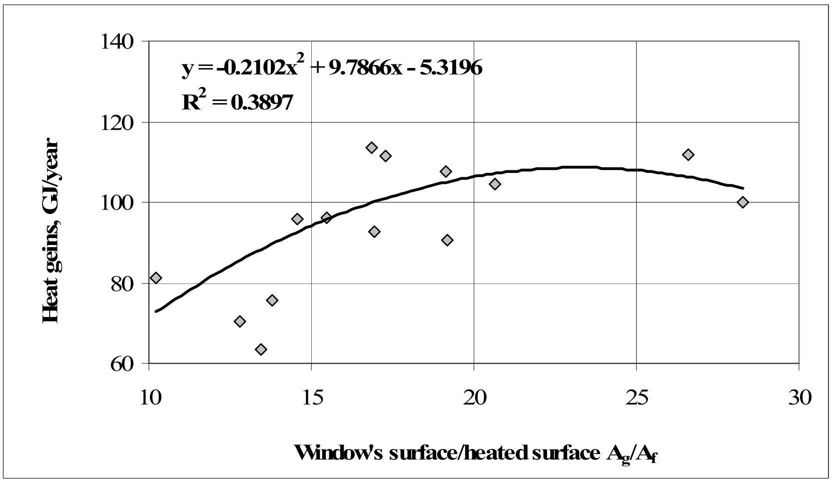

Fig. 7. The influence of window's surface/heated surface A_g/A_f on heat gains (own research)

Figure 7 presents that the changes in the value of heat gains only in 39% are dependent on changes in window's surface to heated surface factor. Correlation coefficient was equal to 0.62. Figure 8 shows the distribution of heat gain in relation to the heated surface on the rooms in analyzed group of buildings.

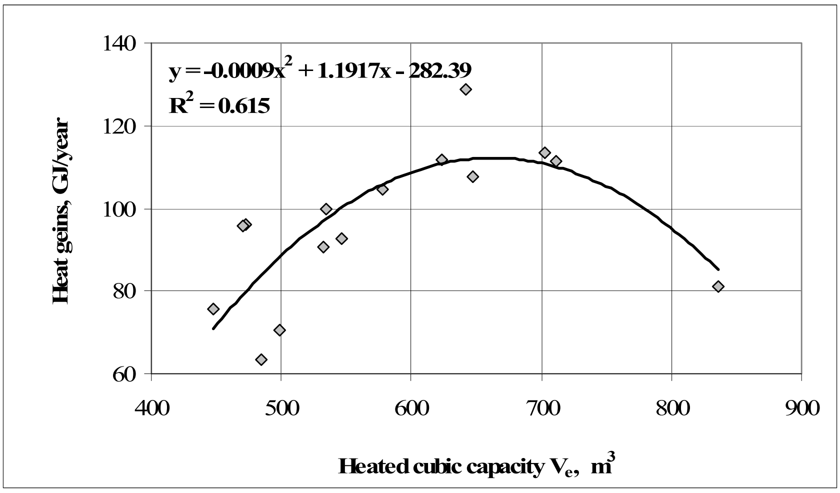

Fig. 8. The influence of heated cubic capacity V_e on heat gains (own research)

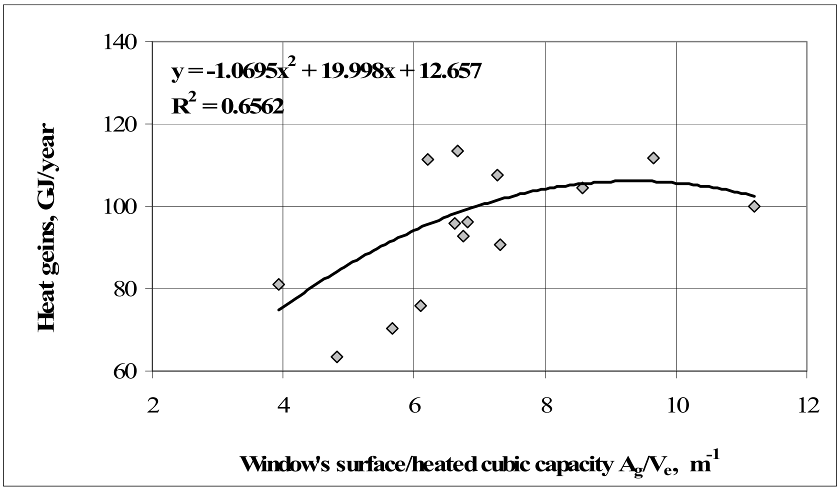

Fig. 9. The influence of window's surface/heated cubic capacity A_g/V_e on heat gains (own research)

Figure 9 shows that the changes in the value of heat gains in 66% are dependent on changes in window's surface to heated cubic capaticy factor and it is more beneficial to use. The influence of number of people inhabiting the buildings on heat gains presents Figure 10.

Number of people inhabiting the buildings has significant influence on heat gains. Correlation coefficient in this case is on the level 0.79.

Undoubtedly, a significant influence on the generated value of heat gains obtained from solar radiation is related to the appropriate location of the building in relation to the directions of the world, depending on a degree of elevation glazing.

This influence was analysed gradually turning the building every 45° in relation to the original location of elevation with the lowest glazing in the northern direction and to the elevation with the highest glazing in the southern direction. The results of the analysis are presented in Figure 11.

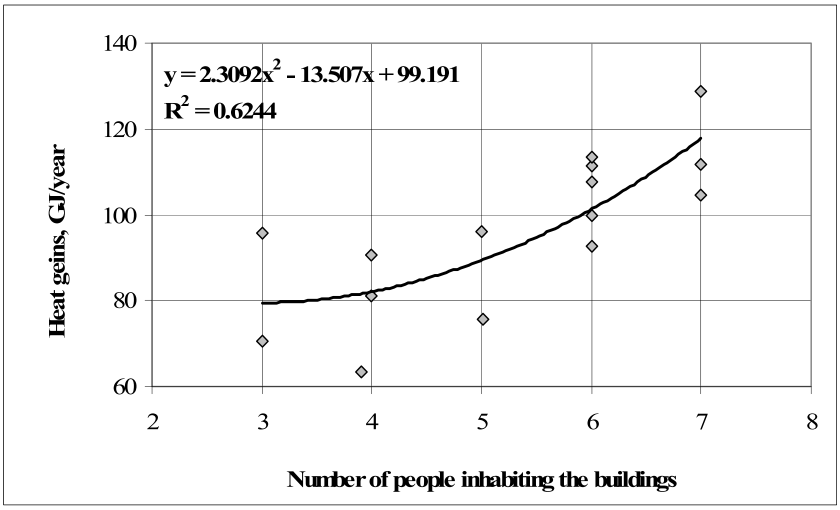

Fig. 10. The influence of number of people inhabiting the buildings on heat gains (own research)

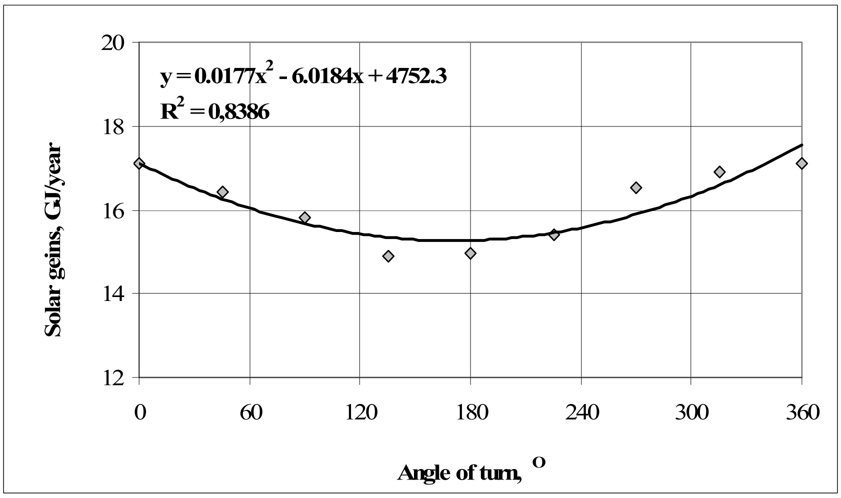

Fig. 11. The influence of location of the building in relation to the directions of the world on solar gains (own research)

Correlation coefficient in this case is on the level 0.92. Solar gains in the given buildings remained at the level 16.1 GJ/year with the standard deviation equalling 0.9 GJ/year.

Conclusion

Every building, due to its purpose and design of existing canons, has certain characteristics. They relate to accepted architectural and building solutions as well as material and construction. These solutions determine the characteristics of thermal-energy performance of the building and having a direct impact on the consumption of heat for the heating. The heat balance of buildings correctly influences on heat consumption for heating. In addition to the characteristics of the structures of the building and its installations large impact on heat consumption has the process of its operation, resulting from the use of the building. In the heat balance of building heat gains reduce the value of the heat consumption. A factor which has a significant part in creating heat gains is solar radiation. It is important here, both the size of window's surface and location of the building in relation to the directions of the world. Important are also gains generated by equipment and people.

Based on analysis was found:

- for the sake of analysis the influence of transparent partitions on heat gains it is more beneficial to use the window's surface to heated cubic capacity factor,
- the changes of window's surface to heated cubic capacity factor by 66% influenced the changes in heat gains,
- the changes of window's surface to heated surface factor by 39% influenced the changes in heat gains,
- the changes of number of people inhabiting the buildings by 62% influenced the changes in heat gains,
- directing the elevation with the maximal transparent partitions towards north causes about a 15% drop in gains from solar radiation,
- another factor that lowers the gains from radiation is shading the elevation.

References

[1] Košičanová D., Košičan M., Spotreba tepla v tehlovom bytovom dome v priebehu zatepľovania, Správca bytových domov 2008, 2, 50-52.

[2] Vranay F., Vranayová Z., Heating for intelligent building - case study, [in:] Visnik nacionaľnovo universitetu Ľvivska politechnika 2008, 627, 226-231.

[3] Lis P., Lis A., Okna a straty ciepła i wentylacja ogrzewanych budynków edukacyjnych, Czasopismo Techniczne 2006, 103, z. 5-B, Zeszyt specjalny, Międzynarodowe Seminarium ENERGODOM 2006, część II, Wydawnictwo Politechniki Krakowskiej, Kraków 2006, 423-432.

Abstract

In this paper the results of investigations on buildings heat gains components are introduced. The factors, which influence heat gains in analysed building were identified. The changes of value of these quantities on the influence of individual factors were estimated.

Streszczenie

W artykule przedstawiono wyniki badań dotyczących zysków ciepła w budynkach. Zidentyfikowano czynniki wpływające na zyski ciepła. Oszacowano wpływ czynników na zmiany wartości zysków ciepła.