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Interactions of the artificial light sources and the window glazing of buildings

***Abstract**. The article focuses on the issue of determining the real value of the heat transfer coefficient on the window glazing U_g in interaction of the window glazing and the artificial lighting. Measurements by the method of measuring the heat flow in situ conditions showed certain effects of the artificial lighting on the value U_g of the transparent constructions of a building. This knowledge can be used for energy performance evaluation of buildings.*

***Streszczenie.** W artykule podjęto probe określenia współczynnika transferu ciepła wynikającego z interakcji oszklenia i sztucznego oświetlenia. Współczynnik transferu ciepła zależy między innymi od konstrukcji budynku. (**Interakcja sztucznego oświetlenia i przeszklenia budynku**)*

Keywords: artificial lighting sources, window glazing, heat flow
Słowa kluczowe: sztuczne oświetlenie, przeszklenie budynku, transfer ciepła

Introduction

Nowadays, there is much attention paid to the energy performance of buildings in accordance with the requirements of Directive 2002/91/EC in the recast of Directive 2010/31/EC on the Energy performance of Buildings Directive (EPBD recast) [1]. Evaluation of energy consumption of buildings is focused on four points: heating, preparation of warm water, ventilation/air conditioning and lighting. The calculation methodology is focused on these mentioned areas performed by the responsible specialists. The object of this article is to show the interaction between individual locations of consumption with emphasis on the interactions between the lighting and the heating of a building – by its exterior building constructions. The specific aim is to bring the interaction between the windows glazing and the artificial lighting exposure, which is transformed into the heat flows on the glazing. Preference of transparent constructions to opaque peripheral constructions is done by the fact that the dynamic changes of the heat flows are more evident on the glazing than on the full peripheral walls [2].

Life cycle and interactions of the windows glazing and the light sources in a building

Lighting system – the light sources and the glazing affect mutually and they can affect each other during the entire life cycle of constructions. The interactions can be seen in the design phase, but the evaluation of energy consumption of buildings according to STN EN 15 603 [3] does not count with the interaction of the artificial lighting and windows, which would result in a change of the value of the coefficient U_g. In operational (measured) evaluation of energy consumption, there is included this interaction.

The given value of the coefficient U_g is influenced by

- construction – material solution of glazing :

- type of glazing – single, double or triple, dimensions, low emission or selective glazing, i.e. physical properties of glass,
- type of filling with inert gases between glazing and the width of the gap,
- type of distant profiles of glazing (warm frame),

- operating conditions: maintenance, cleanness of glazing, mechanical damage, shielding elements.
- environmental conditions – the influence of different energy sources that influence the heat flows density of glazing, for example, radiant heat and light sources in the interior, etc.

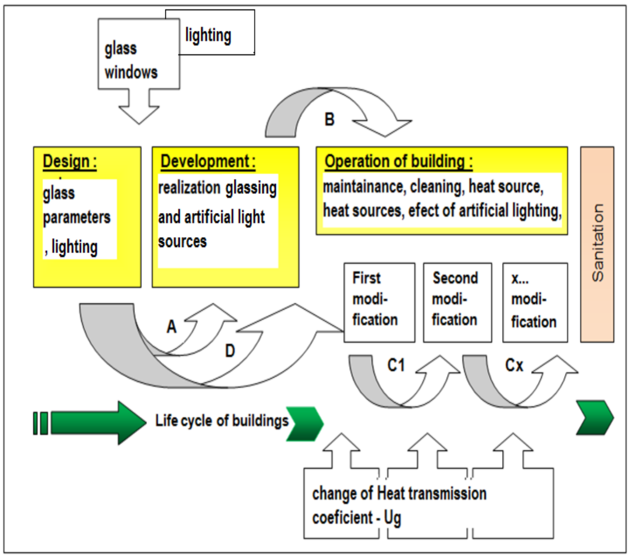


Fig.1. Life cycle of interactions of the glazing constructions and the system of the artificial light – changes A,B,Cx.

Dependence of the heat flow density is proportional to:
- time effect of energy sources, where heat flows are produced in glazing by their transformation,
- distance of sources from glazing,
- directivity of sources in relation to glazing,
- type of energy sources (e.g. diversity of sources of artificial lighting),
- transfer of energy flows, for example, of an artificial light through the barriers towards glazing (curtains, blinds, drapes),

- measurement conditions:

- location of measurement of heat flows – in the middle of glazing , or on the edge – by the frame,
- from homogeneity of the material composition of construction in the direction of measured heat flow,
- the quality of instrumentation,
- proper application of the chosen method of measurement, etc. [4].

U_g value is more or less declared as a constant value and is used in design practice. In situ conditions, however, there is its value variable depending on the combination of action of effects mentioned above.

The value U_g can be functionally expressed as follows:

$$U_g = f(C, O, E, T, I_x) \quad (1)$$

where: *C* - construction of glass, *O* - operation, *E* - environment impact, *T* - time, I_x - interaction where "x" subscript indicates number of possible interaction.

Non-uniformity of U_g coefficient value is affected by the interactions between the glazing and the lighting system, which is one of the possible interactions expressed by I_x value. It is necessary to answer the question of what kinds of the lighting sources are involved in the change of the U_g coefficient value and to what extent, which is described in the following experiments.

Experimental assessment of heat flow density in constructions in stationary (fixed) laboratory conditions

Experimental measurement of heat flow density was carried out on the window glazing in a block of flats in terms of quasi-stationary conditions by method of heat flow measurement with the help of the measuring system called Almeno.

Measurements of dependencies between heat flow density and illumination intensity.have been made on glass-covered part of double-insulated glass plastic window. Heat flow density measurements were made in dependence to illuminance, distance and type of artificial light source. Measuring sensor for heat flow density was placed on outer (external) side of the window. Each kind of artificial light source was measured from 3 different distances: 30 cm, 60 cm and 90 cm from window. In each distance, illuminance, heat flow density and temperature of glass surface were measured. Final measured values of the different artificial light sources are shown in Figures 3,4,5.

Fig.2. Measurement site view of heat flow density and illuminance on insulation double-glass during stationary conditions

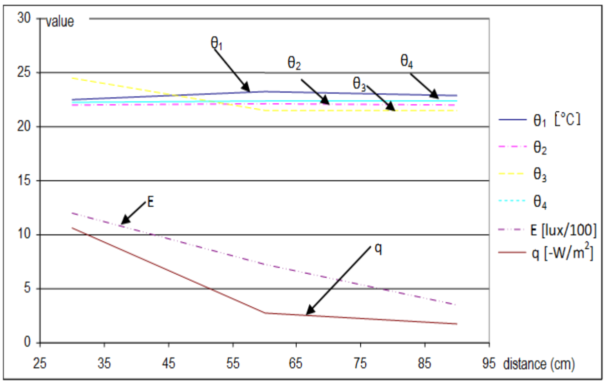


Fig.3. Final measured values of heat flow density and illuminance in stationary conditions – marking E (table 1)

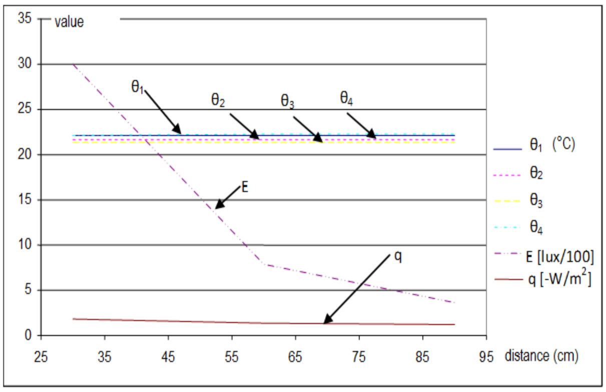


Fig.4. Final measured values of heat flow density and illuminance during stationary conditions – Blue LED type JDR 24LED

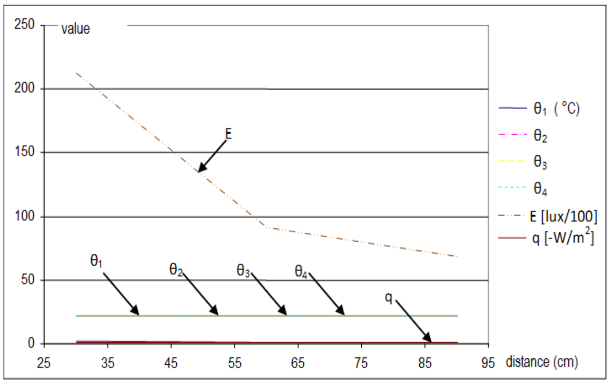


Fig.5. Final measured values of heat flow density and illuminance during stationary conditions – fluorescent lamp type 11W EDI LIGHT

Experimental assessment of heat flow density in constructions in unstationary winter conditions in situ

Experimental measurement of the heat flow density was carried out on the window glazing in an apartment building by the method of measuring the heat flow with the measuring system Almeno 2290-8 (plate for measuring the heat flow, radiation sensor, luxmeter, temperature sensors). From several measurements on the insulating double glazing, there is selected the measurement from the date 11.2.2012. Measurements and evaluation are based on:

a/ the change of the type of sources and their illumination, the light is the same, individual types of sources are shown in Table 1,

b/ the change of the distance of the source, (0,5 m and 1,0 m – perpendicular to the centre of the glazing),

c/ the direction of the heat flows (during the heating period from the interior towards the exterior).

Table 1. Characteristic of sources

Marking	Sort source of lighting	Glass cover
A	Bulb 60 W Tesco	clear
B	Saving bulb 11W Edi Light, China (I = 305 lm) – energy class B	opaque
C	Ilumka E14 60 W Narva CZ, energy class E, (I = 640 lm)	clear
D	Bulb 60 W Sylnania Brilliant Sativ	milk
E	Searchlight bulb R50 E14 60 W, Satin Narva Bel Bohemia- energy class E	opaque
F	Saving fluorescent lamp EDI light Austria 11 W	milk
G	LED Spotlight 24 LEDs E14 China	clear
H	Bulb 40 W Sylvania decor 40 W - coloured	H1 blue H2 red H3 green

The procedure of the continuous measurement was based on changes of the individual artificial lighting sources during the intervals: 5 minutes dark, 5 minutes in the mode – source is switched on *A*, 5 minutes of dark – source is switched off *A*, 5 minutes source *B*, 5 minutes dark, 5 minutes source *C* ... etc. View of the measurement is in Fig. 6, 7.

Fig.6. View of the measuring system

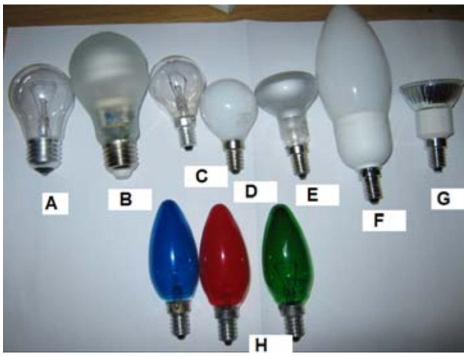


Fig.7. Evaluated artificial light sources

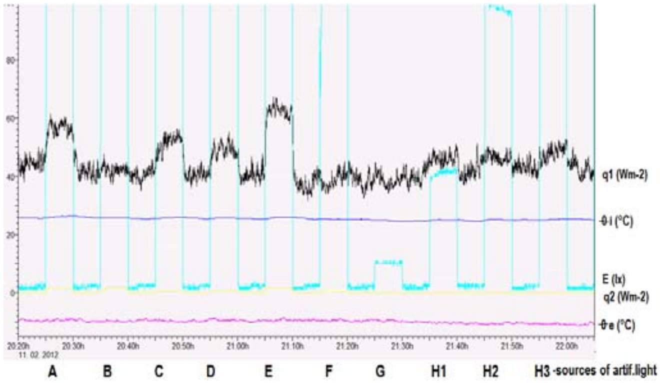
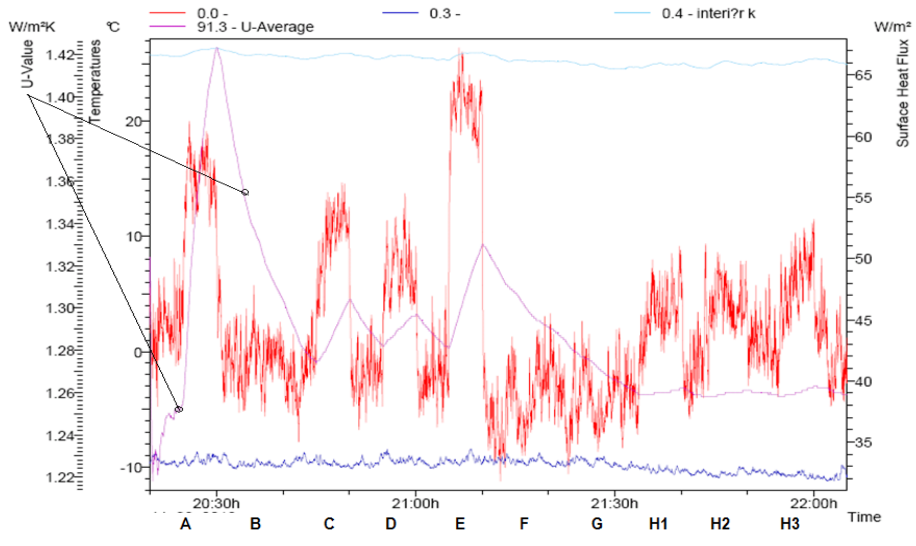


Fig.8. Measurement graphical waveforms : q_1 – heat flow density on glazing $(W.m^{-2})$, θ_i – temperature in interior (°C), *E* – intensity of illumination on glazing (*lux*), q_2 – heat flow density before glazing $(W.m^{-2})$, θ_e – temperature in exterior (°C),

Subsequently, software WinControl recalculated the heat transfer coefficient U_g. Summary results of the experiment are shown in Table 2.

Table 2. The resulting measured values from the individual sources of artificial light

Marking of source	Measured value - max. intensity of ilumination E (lx)		Corrected of value U_g $(WK^{-1}m^{-2})$	
	distance 0,5 m from glazing	distance 1,0 m from glazing	distance 0,5 m from glazing	distance 1,0 m from glazing
A	1680	-	1,42	-
B	2000	-	1,3	-
C	600	175	1,33	1,26
D	810	220	1,295	1,235
E	1790	520	1,33	1,27
F	400	100	1,29	1,25
G	11	10	1,26	1,255
H1	44	-	1,261	-
H2	95	-	1,26	-
H3	160	-	1,263	-
tma	2		1,22	



	Label	From	To	Unit
1	Temperatures	-12.0024	27.1224	°C
2	Surface Heat Flux	31.092	67.908	W/m²
3	U-Value	1.2139	1.4271	W/m²K

Fig. 9. Graphical representation of U_g coefficient value change depending on the light source change measured at a distance of 0,5 m from the glazing

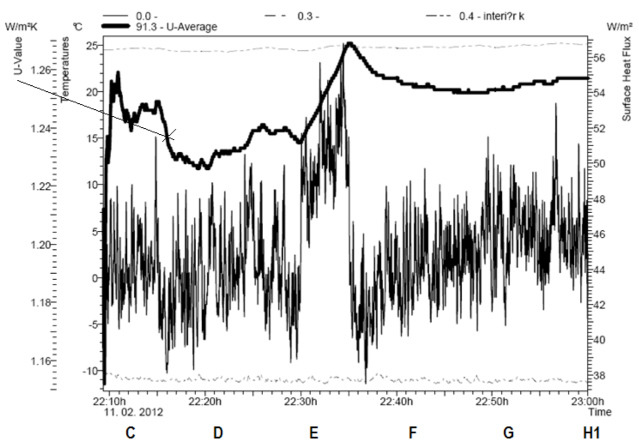


Fig. 10. Graphical representation of the U_g coefficient value change depending on the light source change measured at a distance of 1,0 m from the glazing

Conclusion

Some artificial light sources emit and transform the light energy into heat energy, which results in an increase of the heat flows on the window glazing. Those experiments showed:

- the interaction between the building constructions and the light system at selected lighting sources in terms of the increased heat flows,
- the selection of artificial light sources that cause an increase in the heat flow density on the insulating double glazing; the significant increase of the heat flows was recorded with bulbs, only minimal increases were seen with use of energy saving bulbs and LED lamp ,
- the size dependence of the heat flow value from distance,
- the non-uniformity of U_g coefficient value on the glazing area,
- the increase of the U_g coefficient value with added artificial lighting on the glazing against the dark about 3 % to 12 % depending on the type and illumination of artificial light source during the heating period in situ conditions.

It is possible to deal with these findings in the evaluation of interactions of the building constructions and the lighting systems for energy performance certification of buildings.

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