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THERMAL PROPERTIES OF BUILDINGS IN SUMMER

TEPELNĚ TECHNICKÉ PARAMETRY STAVEB V LETNÍM OBDOBÍ

Abstract

The topic of this contribution consists of a quality assessment of the interior environments of the selected rooms in the non-production building so as to secure the requirements for thermal stability in summer. Based on theoretical calculations and experimental measurements, the initial state of the interior environment in the rooms was assessed and then suitable measures leading to improvement in interior environment quality were proposed. Simultaneously, a daylight exposure assessment was taken into account and the thermal load of the room was assessed.

Keywords

Thermal stability of the room in summer, maximum increase in the indoor temperature in the summer, maximum indoor temperature in summer, daylight factor, heat load in the room, measures against the sun.

Abstrakt

Obsahem příspěvku je posouzení kvality vnitřního prostředí vybraných místností nevýrobní budovy z hlediska zajištění požadavků na tepelnou stabilitu v letním období. Na základě teoretických výpočtů a experimentálního měření byl vyhodnocen původní stav vnitřního prostředí místností a následně byla navržena vhodná opatření vedoucí ke zlepšení kvality vnitřního prostředí. Současně bylo zohledněno posouzení denního osvětlení místnosti a zhodnocena tepelná zátěž místnosti.

Klíčová slova

tepelná stabilita místnosti v letním období, nejvyšší denní vzestup teploty vzduchu v místnosti, nejvyšší denní teplota vzduchu v místnosti, posouzení denního osvětlení místností, činitel denní osvětlenosti, tepelná zátěž místností v letním období, protisluneční opatření.

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1 INTRODUCTION

The overheating of building interiors in summer is a problem which a lot of buildings (above all the ones with a high proportion of glazing on their facades) have to cope with. It is possible to avoid the excess thermal load of the room in summer in various ways. In addition to air-conditioning, the amount of heat gains can be influenced above all by passive or active elements of sun protection.

The passive elements are those firmly connected with the structure of the building and they do not allow the controlling of sunshine penetration into the interior (e.g. marquises, balconies, glazing). The active elements bring the possibility of controlling the sunshine, thus also controlling the daylight of the interior as required (blinds, window blinds, etc.).

In this contribution, an assessment was carried out on the effectiveness of the selected passive and active elements of sun protection in the specific rooms of the chosen building.

DESCRIPTION OF THE ASSESSED BUILDING AND ROOMS

In order to assess the quality of the interior environment in summer, office rooms in the building of the Civil Engineering Faculty of the VŠB-TU Ostrava were chosen. The assessed buildings were evaluated from several points of view – their thermal stability and the thermal load of the buildings and as to the amount of daylight in the rooms as well.

The selected assessed rooms included office spaces with windows in the east facade of the “H” building of the Civil Engineering Faculty at VŠB-TU Ostrava, Ludvíka Podéště street. Two office rooms were monitored.

A) Room LP H506/2 – floor space 14.2 m^2, window 552 m^2.

B) Room LP H507/2 – floor space 14.2 m^2, window 5.52 m^2.

The constructions bounding the two rooms are medium-heavy to heavy structures, and this significantly influences their accumulation properties. The surface of the window 5.52 m^2 occupies up to 65.7% of the total perimeter wall surface of 8.4 m^3. The window frame occupies 23% of the total surface of the window. The window is shaded by an above-window marquise from the outdoors (overhang of 1.3 m) and partly, in the morning time, by an opposite high-rise residential building (in a distance of approx. 193 m).

A PROPOSAL FOR ANTI-SUN MEASURES

In order to assess the effectiveness of the anti-sun provisions, two types of anti-sun foils as passive elements and outdoor blinds as an active element were chosen. In the table 1, parameters of the former glazing are compared to the anti-sun elements (taken from the manufacturer):

Tab.1 Parameters of the window glazing and the assessed foil

	Total sunshine permeability	Direct sunshine transmittance	Direct sunshine reflectance	Direct sunshine absorbance	Shading coefficient	Light transmittance
	g [-]	τ [-]	ρ [-]	α [-]	s [-]	τ_s [-]
Double glazing unit	0,76		0,08			0,85
Window with an interior heat insulating foil NSN60	0,42	0,35	0,31	0,34	0,52	0,56
Window with an exterior anti-sun foil Silver 50XT	0,55	0,42	0,61	0,25	0,50	0,47
Outdoor blinds	0,12					

The total transmitted heat energy through the glazing *g* is increased by a component of the transferred absorbed thermal energy α into the interior. The shading coefficient *s* expresses the filtration effect of the glazed surface fitted with a foil. The selected types of anti-sun foils were chosen in respect to a further assessed property –daylight of the room.

THERMAL STABILITY OF THE ROOM IN SUMMER

The thermal stability of the room in summer is a criterion determined by ČSN 730540 [1] and it is among the comparing coefficients set by the Public Notice nr. 148/2007 Coll., on energy demands of buildings. Meeting the requirement for the thermal stability ensures the thermal comfort of users in the interior environment of the room in summer.

The thermal stability of the rooms in summer is assessed by means of two criteria according to ČSN 73 0540, to be specific, by means of the highest daily increase in the air temperature in the room $\Delta\theta_{ai,max}$ [°C], and by means of the highest daily temperature in the room $\theta_{ai,max}$ [°C]. The calculation methods are described in detail in the standards [2] and [3].

1.1 The Results and Assessment of the Theoretical Calculation

The calculations of the thermal stability were carried out for four options – the initial state, the state with the anti-sun foil (indoor or outdoor), the state with the anti-sun foil and outdoor blinds and the state with outdoor blinds. For calculations, the software Teplo 2009 [7] (thermal transmittance through the construction), Stabilita 2009 [8] (the highest daily increase in the air temperature in the room), and Simulation 2009 [9] (the highest temperature in the room) were used. The highest temperature and the highest increase in temperature are set for non-stationary (linear) outdoor edge conditions.

Tab. 2 The assessment of the highest daily increase in the room air temperature in summer

Room	Options	Highest daily increase in temperature	Required standard value	Assessment (passed/failed)
		$\Delta\theta_{ai,max}$ [˚C]	$\Delta\theta_{ai,max,N}$ [˚C]	
H506/2	Initial glazing state	12,7	5,5	failed
	Indoor window foil NSN60	8,1	5,5	failed
	Outdoor blinds + indoor foil NSN60	2,0	5,5	passed
	Outdoor blinds	3,0	5,5	passed
H507/2	Initial state	12,2	5,5	failed
	Outdoor window foil Silver 50 XT	9,6	5,5	failed
	Outdoor blinds + outdoor foil Silver 50 XT	2,3	5,5	passed
	Outdoor blinds	3,0	5,5	passed

The assessment of the criterion requirement showed that the use of anti-sun foils for window panes had decreased the highest increase in the air temperature in the room by 2.6 to 4.6 °C. However, it is not enough for meeting the requirement. If the outdoor blinds and foils are combined, the highest increase in the air temperature in the room decreases by 9.9 to 10.7 °C. The requirement is thus met.

Tab. 3 Assessment of the highest daily temperature of the air in the room in summer

Room	Options	Highest daily temperature	Required standard temperature	Assessment (passed/failed)
		$\theta_{ai,max}$ [˚C]	$\theta_{ai,max\ ,N}$ [˚C]	
H506/2	Initial glazing state	37,3	27	failed
	Indoor window foil NSN60	26,2	27	passed
	Outdoor blinds + indoor foil NSN60	24,3	27	passed
	Outdoor blinds	25,8	27	
H507/2	Initial state	37,3	27	failed
	Outdoor window foils Silver 50 XT	27,7	27	failed
	Outdoor blinds + outdoor foils Silver 50 XT	24,4	27	passed
	Outdoor blinds	25,8	27	passed

The assessment of the criterion requirement showed that the use of the anti-sun foils on glass had decreased the air temperature in the room by 9.6 – 11.6 °C, but it was not enough for meeting the requirement (only in the room H506/2). If the outdoor blinds and foils are combined, the increase in temperature is 12.9 to 13°C lower. The requirement is met.

1.2 The Results and Evaluation of Experimental Temperature Measurement of the Indoor Air in the Room in Summer

The experimental measurement of the thermal properties included temperature measurement of the outdoor and indoor air and of the inner surface temperature of window panes in the assessed rooms. The thermal measurements were carried out in the period between April and July for the original condition of the room, and in the period between August and October for the proposed measures. The measurement was carried out by means of a device made by Ahlborn, including the respective thermal sensors. Temperatures were monitored in hour intervals on the assessed days.

The measurement was carried out in two office rooms, LP H506/2 and LP H507/2 for three options – the initial state, the state with indoor or outdoor anti-sun window foils, the state with the outdoor blinds and the outdoor anti-sun window foil.

Table 4 shows the results of temperature measurement in each of the rooms. Owing to the limited space reserved for this article, only the results from the selected days were chosen for this table.

The measurement results prove (as the theoretical calculation did before) that the initial state shows significant exceeding of the maximum allowable value of the air temperature in the assessed rooms in summer. Using of anti-sun window foils can lower the maximum average indoor temperature by 4.1 to 6.2°C compared to the initial state. This decrease can be significantly felt as to the thermal comfort of the users. The measured values of maximum temperatures are close to the standard requirement. However, they do not meet it. Only the combination of the measures with the outdoor blinds can lower the air temperature in the room under the maximum allowable standard value. Therefore it can be assessed as the best one.

Tab. 4 Measuring of the highest daily temperature of the air in the room in summer

Room	Options	Date of the measurement	The max. indoor air temperature	The max. outdoor air temperature	The average indoor air temperature	The average outdoor air temperature
			θ_{ai} [°C]	θ_e [°C]	$\phi\theta_{ai}$ [°C]	$\phi\theta_{ae}$ [°C]
H506/2	Initial state	14.8.	33,6	20,7	30,1	19,9
	Indoor window foil NSN60	26.9.	28,9	22,1	26,2	18,9
H507/2	Initial state	14.8.	35,7	25,9	33,2	23,4
	Outdoor window foil Silver 50 XT	26.8.	27,6	21,6	27	21,0
	Outdoor blinds and outdoor foil Silver 50 XT	20.9.	23,1	21,1	24,1	16,2

1.3 The Results and Evaluation of the Experimental Temperature Measurement of the Indoor Air in the Rooms in Winter

The measuring of the indoor temperature was carried out in winter. The reason for that was that it was necessary to check the effect of the applied indoor anti-sun and heat-insulating window foil in the room LP H 506/2 on the air temperature. Both the assessed rooms were compared only for the option with the application of the window foil and under the same indoor heating conditions and outdoor conditions. The benefits of the heat-insulating indoor window foil which increased the average room temperature by 1.5°C are evident from the results. The measuring results are mentioned in table 5.

Tab. 5 Measuring of the indoor air temperature in winter

Room	Options	Date of measuring	The average indoor temperature	The average outdoor temperature
			θ_{ai} [°C]	θ_e [°C]
H506/2	Indoor heat-insulating window foil NSN60	8.1.	23,7	5,6
H507/2	Outdoor window foil Silver 50 XT	8.1.	22,2	5,6

ASSESSMENT OF THE DAYLIGHTING IN THE ROOM

The basic requirements for daylight are specified in ČSN 73 0580 [4]. Indoor rooms intended for the stay of people during the day must have an appropriate level of daylight.

The daylight level in the newly designed rooms is found by means of the values of the daylight coefficient *D [%]* in checkpoints distributed in the regular network on the horizontal datum plane. The height of the datum plane shall be 0.85 m above the floor level (if not required otherwise).

The values of the daylight coefficient indoors or in the functionally limited part of the indoor space must not be lower than it is determined for the respective visual activities according to ČSN 73

0580 [4]. As to the permanent stay of people indoors or in the functionally limited part of the indoor spaces, the minimum value of the daylight coefficient D_{min} must be equal to at least 1.5%.

The aim was to check whether the application of the foils would cause a worsening of visual conditions under the minimum allowable standard limit in the office room. The parameters of the total light transmission of the glazing are mentioned in table 1.

1.4 The Results and Evaluation of the Theoretical Calculation

The calculated values were compared to the requirements of ČSN 73 0580-1 [4]. The software WDLS 4.1 [9] was used for the calculation. The results of the calculation and the evaluation are mentioned in the table 6.

Tab. 6 Assessment of the daylight in the rooms

Room	Option	Minimal value of the daylight factor	Required minimum standard value	The value of the daylight factor in the place of the desk	Evaluation
		D_{min} [%]	$D_{min,N}$ [%]	D [%]	
H505/1	Initial state	2,4	1,5	4,7	Passed
H506/2	Initial state	2,4	1,5	4,7	Passed
	Indoor window foil	1,5	1,5	3,0	Passed
H507/2	Initial state	2,4	1,5	4,7	Passed
	Outdoor window foil	1,3	1,5	2,6	Passed only in the functionally limited part

The assessment showed that daylight of all the assessed rooms in the original condition met the standard requirement $D_{min,\ n}$. After the application of the anti-sun window foil in the room H506/2, the requirement was also met. However, the minimum value D_{min} fell. After the application of the anti-sun window foil in the room H507/2, the requirement was met in the functionally limited part of the room, the one bounded by an isophote 1.5%. In the place of the desk (the working site), enough natural daylight for the respective visual activity is provided.

1.5 The Results and Evaluation of the Experimental Measurement of the Daylight Factor in the Rooms

The daylight measurement was carried out under the standard conditions according to ČSN 73 0580 [4] – permanently overcast winter sky and dark terrain – in three rooms in January. The device produced by Ahlborn, incl. the respective sensors for illuminance (luxmeter), was used. The illuminance of the outdoor horizontal non-shaded plane was measured on the roof of the new building of the Civil Engineering Faculty. The illuminance of the checkpoints in the indoor environment of all the office rooms was measured. These points are; at the desks, at a height of 0.85 m above the floors, 1 m from the interior walls and 2 m from the windows. The daylight factor was determined on the basis of the calculation from the measured values. The results of the measurement are mentioned in table 7 and they can be compared to the theoretical calculation.

Tab. 7 Illuminance measurement and determination of the daylight factor

Room	Option	Date of measureme nt	Illuminance at the checkpoint	Outdoor illuminance	Daylight factor
			E [lx]	E_H[lx]	*D* [%]
LP H505/2	Initial state	10.1.	105	2225	4,7
LP H 506/2	Indoor window foil	10.1.	57	2225	2,6
LP H507/2	Outdoor window foil	10.1.	42	2225	1,9

ASSESSMENT OF THE HEAT LOAD IN THE ROOMS

The aim of this part is to map and catch the situation in the monitored rooms of the building during very hot summers using simulation and calculations.

The windows of the office rooms are directed to the east (azimuth 98°, gradient 90°). This results in a very intensive incidence of sun radiation in the morning, at sunrise, lasting almost up to noon, all year around.

It follows from this situation that it is necessary to protect these rooms not only from the increased sun radiation, which is the cause of the increased heat load in all these office rooms in the “H” building, but also from adversely bright sun exposure, which is not suitable for educational work on computers. As a result of this situation, a human being may become more tired, thus his/her work productivity may decrease.

The calculations were carried out according to the applicable standards ČSN 73 0540 [1] and ČSN 73 0548 [5]. The standard was used despite the fact that the room was not air-conditioned, but it was used as the conditions which often occurr in the room under consideration are not dealt with in the other standards. This is because all of the standards expect that in the rooms of the respective category, the maximum allowable interior temperature would not exceed 26°C (alternatively 28°C). In addition to the aforementioned, this room would require air-conditioning at the stage of its design due to the measured temperature values.

The project documentation for this building was used as a basis for the processing. The main parameters included the coefficient of heat transmission of individual enclosing structures, incl. window panes, parameters of window structures as to sun radiation permeability, parameters of shading means (outdoor blinds, indoor aluminium blinds, indoor heat-insulating foil and outdoor anti-sun foil), indoor heat gains from working people, lighting, technical equipment and the further venting intensity of these rooms.

1.6 Options of the Heat Load in the Rooms under Consideration

Seventeen options of the heat loads in the selected rooms which differ by the set parameters were assessed. Due to the limited space reserved for this article, the detailed description of the individual options can be provided for inspection by the authors.

The Window without Shading Means (Options 1, 2, 3, 4, 5, 6, 7, 9, 11, and 17)

This state had been common up to the time when the outdoor shading blinds were installed. The indoor horizontal cloth blinds protected only from full sun radiation which penetrated into the assessed interior spaces. They managed to partially eliminate unpleasant direct sunshine. However, they could absorb the heat of the sun radiation well and increased the thermal load inside the rooms. As it was forbidden to air these rooms after working hours (night closing of the building), it happened that the interior shading means kept the thermal load inside the building.

The state of sun radiation transmission through the enclosing structures is mentioned in the options 1 and 2. The options 3, 4, 5, 6, 7, 9, and 11 are other possible options (e.g. increase in the outdoor air temperature, different temperatures of the interior air in the neighbouring rooms) which occur all year around.

The Window with the Outdoor Blinds (options 8, 14, 15, and 16)

After the installation of the interior shading blinds, the heat load condition was significantly decreased. It corresponds to the actual calculation, see option 8.

The Window with the Indoor Blinds (option 10)

The horizontal indoor cloth blinds which were originally installed were not able to protect against an increase in the thermal load from sun radiation (see the window without shading). Therefore, well-known common indoor aluminium blinds were considered. This condition is described in option 10.

The Window with the Outdoor Anti-Sun Foil (options 13, and 15)

The anti-sun foil Silver 50 was installed into the room LPH 507/2 as another option of possible protection against increased thermal load. This state is mentioned in option 13. Furthermore, in option 15, it is combined with the indoor blinds. Option 15 was also the maximum possible and the best condition which could be reached in this task.

The Window with the Indoor Heat-Insulating Foil (options 12, and 16)

The indoor heat-insulating foil, NSN60-line, was installed into the room LPH 506/2. This option is described in situations 12 and 16. Results were slightly worse when compared to options 13 and 15.

Ventilation Intensity

A supply of fresh air into the room always guarantees healthy conditions for every human activity. The standard requirements for the category of the rooms are determined for 1,5-fold change of the air. This requirement was the basis for all solution options 1-16. In summer, and when feeling an increased thermal load, people usually open windows in order to air the room more or at least to induce the feeling of cold due to flowing fresh air. This air flow is usally over 30°C in summer. Therefore, an “extreme option” was created. This option took hotter outdoor air (t_i = 33°C) into account, when the ventilation intensity through a fully open window commonly reached 15-fold volume of the respective room.

This condition is shown in the “extreme option”. The thermal load values are almost double! One can see here that the main carrier of the heat is not only the sun radiation, but mainly the heated fresh air.

Heat Accumulation in the Structures

Almost all civil engineering structures are great carriers of heat energy, especially concrete, reinforced concrete and masonry. Since the building was built as a skeletal construction with poured ceilings and prefabricated reinforced-concrete spandrel walls that are heat-insulated with mineral wool from the outside, the situation is the same. All interior partition walls and walls are made from Heluz blocks. Therefore, there is a situation in the building when the heat is accumulated in these structures and it cannot be dissipated from the respective room in summer (see ventilation intensity). Passive cooling at night is also prevented. This phenomenon reflects badly in the charts as the so □alled “second wave” which is, of course, partly affected by ventilation and interior heat gains.

Interior Heat Gains

The main interior producers of heat include computers, laser printers and displays, both LCD displays and, above all, CRT displays. The interior lighting also contributes significantly (e.g. typical light bulbs in lamps and neon lights). Human beings are also carriers of heat energy. Since the thermal load in summer was dealt with, the presumption of office room lighting was not taken into consideration. This significant difference in the thermal load is shown in the options 1 and 2.

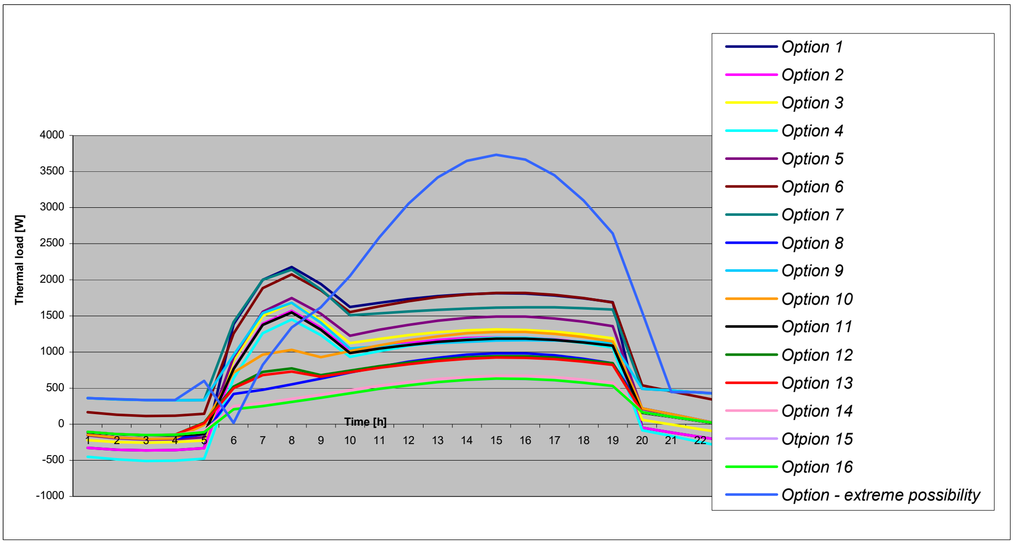

Fig. 1 The graph of heat load development during the day (rooms LPH 506/2 and LPH 507/2)

The best option seems to be the combination of the interior shading blinds and the anti-sun (or heat-insulating) foils, followed by the actual outdoor shading blinds. Only the use of anti-sun window foil may be a solution when the standard maximum air temperature is exceeded by several degrees Centigrade. For the assessed rooms, the solution was not sufficient.

However, it is necessary to pay attention to the qualitative parameters of the shading devices as to their shading coefficients and thermal absorption coefficients.

The building is directed to the east. Therefore, the "first wave" of the thermal load occurs in the morning because the sun is situated directly opposite the window panes. With the sun rising to the horizon, the first wave of the heat load gradually falls. It is also influenced by the supply of relatively cold fresh air and by the interior structures, in which the heat has not accumulated yet. This first wave is partly eliminated by the use of the respective foils.

The second wave occurs shortly after noon and it is caused by the gradual flowing of warmer and warmer heated air from the outside. This results in accumulation into all civil engineering structures, which then work as a well-heated stove. This property is very good in winter, but not in summer. Further, the interior heat gains from office technology contribute to this phenomenon. The highlight of the second wave is, therefore, usually at about 3 P.M., when this highlight occurs with a slight phase shift against the higher outdoor air temperatures. The air then gradually cools down.

ASSESSMENT CONCLUSION

For the future, it is recommended that impacts of the possible heat load should be taken into consideration during the actual designing of similar constructions which are going to have high demands with daylight and sun exposure or if they are going to have a largely glazed structure. Further, it is recommended that such measures which deal with the respective issues successfully and effectively should be accepted and imposed during the designing process if a change of the direction with respect to the points of compass is not possible.

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