GRANT journal
ISSN 1805-062X, 1805-0638 (online), ETTN 072-11-00002-09-4
EUROPEAN GRANT PROJECTS | RESULTS | RESEARCH & DEVELOPMENT | SCIENCE

Microclimate depending on solar radiation

Jiří Labudek[1]
Lenka Michnová [2]
Lubomír Martiník[3]
Marcela Černíková [4]

[1] Katedra prostředí staveb a TZB, Fakulta stavební, VŠB-TU Ostrava; jiri.labudek@vsb.cz
[2] Katedra prostředí staveb a TZB, Fakulta stavební, VŠB-TU Ostrava; lenka.michnova@vsb.cz
[3] Katedra prostředí staveb a TZB, Fakulta stavební, VŠB-TU Ostrava; lubomír.martinik@vsb.cz
[4]Katedra prostředí staveb a TZB, Fakulta stavební, VŠB-TU Ostrava; Ludvíka Podéště 1875/17, 708 33 Ostrava-Poruba
marcela.cernikova@vsb.cz

Grant: SP2011/182
Název grantu: Gradient teploty a změna proudění vzduchu u transparentního pláště způsobené solárním zářením
Oborové zaměření: Stavebnictví

Abstrakt In the project “SP2011/182-Gradient temperature and airflow changes in the transparent shell caused by solar radiation” a long-time measurements in space of emergency staircase near transparent facade shell were taken. The effect of global solar radiation on the microclimate and the thermal stability of the internal environment were monitored. The paper is based on the values obtained from the current measurements in the period May - August 2011.

Keywords Temperature, transparent shell, measurement, indol environment

1. INTRODUCTION

It is indisputable that energy consumption is becoming one of the major contemporary issues of modern times. Energy consumption of course also occurs in the summer when it is necessary to reduce significant solar gains through transparent shells. The subject of this paper is the specific field of the energy sector for buildings in relation to the energy processes of transparent shells. This paper is focused on observing the changes in the internal environment from within the fully transparent shell caused by global solar radiation. Measurements should determine the change in the interior temperature and possible changes in airflow from the interior of the fully glazed shell. After understanding these modes, we can generally determine the technical adjustments and changes in the compositions of these types of structures.

It also means providing more effective control of the parameters of the internal environment, thereby ensuring more economical indoor thermal comfort. To achieve these results, long-term measurements of temperature were carried out throughout the height of the transparent shell, consisting of the building of the Faculty of Civil Engineering VŠB-TU Ostrava.

2. MEASURING CONDITIONS

The average number of hours of solar light (no clouds) in the CR ranges from 1,400 to 1,700 hours/year. The duration of solar radiation in the Czech Republic can vary on average by up to 500 hours per year. The smallest number of hours is in the northwest region. Locations usually differ from each other by an average of ± 10%. The number of hours increases towards the southeast, therefore more problems with overheating of the building interiors occur there.

Measurements are conducted in the spaces of the fire escape stairwell of the building of the Faculty of Civil Engineering VŠB TU Ostrava. The measurements recorded all the required data including the air temperature θ_{ai} of the interior. Interval for storing and averaging the data was fixed for 15-minute periods. During August, the interval for recording of the measured data was changed to 60 minutes due to the distinctive thermal stability of the internal environment. All measured values were processed in Microsoft Excel [11] and the results cataloged using contingency tables. If global solar radiation acts on an outside transparent façade, then the shortwave solar radiation energy [6] that impacts the absorption area will penetrate the space depending on the overall permeability coefficient of the transparent glass wall system. The absorption area in the end will eventually give off heat through radiation and convection into the air interspace. Such changes cannot be routinely modeled, so it is necessary to gain experience with this changes in the internal environment through long-term measurements.
With some degree of certainty, it can be said that the effect is the same as when we assume that solar radiation directly heats up the air flowing through the recesses of the solar wall, and therefore with certain simplicity, the solar wall can be viewed as a “giant ventilating solar heater”.
With greater temperature, the volume of air grows and its density decreases. Or it becomes lighter than less warm air (in relation to volume). The lightly heated air then rises. The movement of warm air creates airflow. It concerns the theory of the solar chimney according to [5].

2.1 Measuring equipment used

The following systems devices were used for the measurements:

- Data logger ALMEMO 5690-2 with large-screen display, high speed measurements and small dimensions.
- Global solar radiation sensor. This sensor is good for outdoor measurements in meteorology, medicine and biology. The sensor has anodized aluminum housing, a cover made from plastic that transmits UV radiation, which provides resistance to rain and water with no condensation forming on the inside cover. The sensor is powered from the ALMEMO instrument.
- AHLBORN temperature sensors. These temperature sensors were installed on each floor of the monitored fire escape stairwell. Errors occurred during the measurement, resulting in the sensors being moved to the reference floor to check for deviations. After this measurement, the sensors were put back in place. When evaluating the data, it was determined that 4 sensors were not working properly and their data were excluded from the measurements.

Tab. 1: The equipment used for measuring radiation

Global solar radiation sensor.	Placement of the sensor on the transparent facade
	

3. HEAT LOSS IN THE SPACE VERSUS SOLAR GAINS

3.1 Heat loss

The heat loss from the fire escape was developed in the program Losses 2010 according to [2]. The affected composition of the structure necessary for the calculation was evaluated in the program Heat 2010 [7] for the required values of heat transfer coefficient U [$Wm^{-2}K^{-1}$].

The fire escape stairwell is oriented to the southwest. The entire wall of the monitored space is glazed up to the height of building. The parameters of this wall were calculated according to [1].

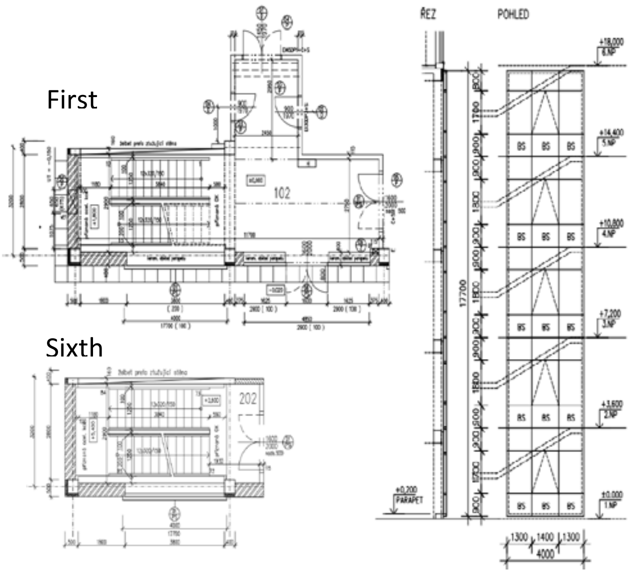


Fig. 2: The floor plans for the first and sixth floors, a section of the stairwell and look at the glass façade of the fire escape [4].

An important finding is that we must use external dimensions of the heated area bordering the structure in computer program.

Tab. 2: Input parameters of the fire escape space

INPUT DATA:		
Volume of the heated zones of the building	V	672.0 m^3
Area bordering the structure	A	346.2 m^2
Prevailing proposed indoor temperature	Θai	20.0 °C
Proposed outdoor temperature	Θe	-15.0 °C

The resulting value of heat loss of the stairwell space is favourable. The space under consideration does not comply with the maximum average heat transfer coefficient. It is also influenced by the fact that it is only part of the building. The value of heat loss of the stairwell is adequate to the size of the space and the surface of the glass walls.

Tab. 3: The resulting values calculated in the program Losses 2010 [8].

Evaluated quantities	**Indoor calculated temperature**	**Calculate d values**	**Normative requirements**	
-	°C	-	Normative value	Note
Total heat losses	20°	10.188 kW	-	Not assessed with the normative value
Average heat transfer coefficient Uem		0.60 W/m^2K	<0.59 W/m^2K	Maximum average heat transfer coefficient Uem,N

3.2 Solar gain

The mathematical model does not consider the accumulation of heat and some variable values according to [3]. The solar gain is generally calculated according to the relationship:

$$Q_S = \sum_j I_{sj} \cdot \sum_n A_{snj} \quad [W]$$

Isj … total solar radiation [J/m^2] impacting the surface unit n with orientation j during the simulation period;
Asnj … effective solar collector area [m^2] of surface n with orientation j;
The effective collector area of the ventilated solar wall A_s [m^2] is determined by the relationship:

$$A_S = A.F_S.F_C.F_F.g \quad [m^2]$$

Where:
FS … shading correction factor, which is considered only for continuous shading [-];
FC… shielding correction factor [-];
FF… frame correction factor, determined by dividing the translucent area and the total area of the component;
g … total permeated solar radiation [-], expressing the proportion of energy impacting the non-shielded glazing and the amount of energy that passes through the glazing;

The total permeation of solar radiation perpendicular to the plane of glazing $g_\perp$ [-], which is slightly larger than the value and must be corrected by the relationship:

$$g_w = F_w.g_\perp \quad [-]$$

Fw … correction factor [-], which depends on the type of glass, latitude, climate and orientation, is approximately equal to:

$$F_w = \frac{g}{g_w} = 0{,}9$$

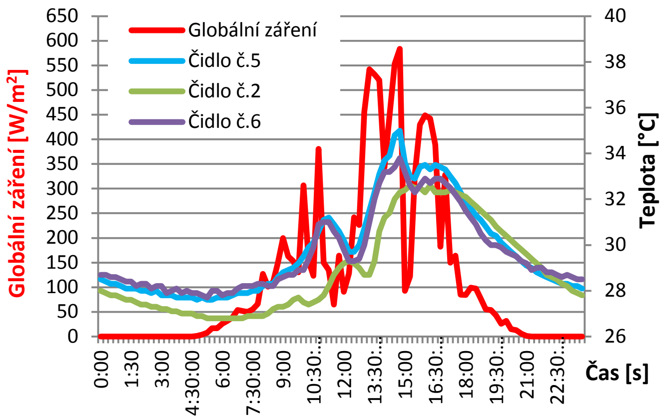
Tab. 4: A comparison of losses and solar gains calculated from different external temperatures

Indoor calculated temperature	Outdoor proposed calculated temperature	Calculated losses	Solar intensity	Calculated solar gains	Excess solar gains
°C	°C	kW	W/m^2	kW	kW
20°	-15	10.19	230	13.34	3.15
	-5	7.34	300	17.40	10.06
	0	5.91	170	9.86	3.95
	+5	4.49	230	13.34	8.86
	+10	3.06	330	19.14	16.08
	+30	-2.65	370	21.46	24.11

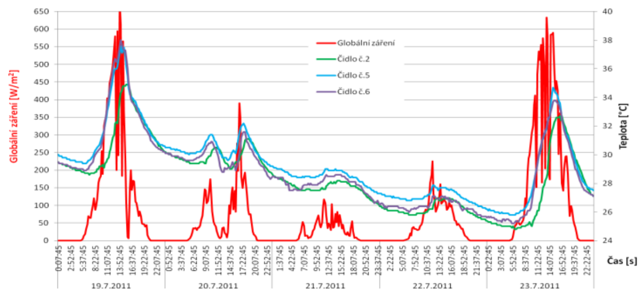
The following table represents the heat loss for different temperatures of the air outside. The value of -15°C is the minimal outdoor calculated temperature, which represents the region of Ostrava, where the space being evaluated is located according to the normative table of ČSN 730540 [2]. The proposed external air temperatures in summer yield a negative result, which means there is a tendency to overheat the space.

4. TEMPERATURE STABILITY OF THE INTERIOR

Buildings with low thermal inertia rapidly heat up in sunlight, but also quickly cool down at night. On the contrary a high thermal inertia in buildings provides more stable temperatures, because the building walls serve as a sort of thermal energy storage bank during the day and this heat is emitted at night when the sun goes down and the air cools down. Practically no drop in the temperature of the internal environment occurred in the measured space, which indicates enormous solar gains, minimal heat loss and a high value of accumulated thermal energy.



Graph 1: Graph showing the dependency of indoor air temperature on global solar radiation



Graph 2: Graph showing the dependency of the temperatures measured by each sensor on global solar radiation for 5 days

The evaluated fire escape space was assessed using the calculation program Stability 2010 [9] and program Simulation 2010 [10]. The space is evaluated for thermal stability in summer. Thermal stability is calculated here by computing the two programs due to a more accurate determination of the calculated result. The program Stability 2010 itself [9] is more suitable for determining (of the) thermal stability. Using Simulation 2010 [10], measures can be proposed here that would need to be implemented in the event of overheating in summer.

An important finding here is entering the area of the structure and volume of the space that surround the evaluated area from internal dimensions, since the thermal stability inside the room is being evaluated. The entire composition of the structure must also be entered with the outer coating to properly determine the coefficient of reflectivity.

Tab. 5: The resulting values calculated in the program Stability 2010 [9] and Simulation 2010 [10].

Evaluated quantities	**Indoor calculated tempera-ture**	**Calculated values**	**Normative requirements**	
-	°C	Unsatis-factory	Normative value	Note
Thermal stability in summer (Stability 2010)	20°	23.93 °C	<5 °C	Maximum thermal stability, $\Delta\ \theta_{a,max,N} = 5°C$
Thermal stability in summer (Simulation 2010)		70.43 °C	<27°C	Maximum thermal stability, $\theta_{ai,max,N} = 27°C$

The table shows that in both cases, the calculation of the results for thermal stability in summer is unsatisfactory. The building design bordering the structure has worked out so that the heat loss of the space is relatively low because of this. This fact is obviously favourable, as it partially contributes to lowering the energy consumption of the building. On the other hand, it contributes to overheating the building in summer, with the result of reducing the temperature comfort of staff and students.

An important factor that influences the temperature gradient is ventilation. We know from practical knowledge that there is no regular exchange of air and this heated air accumulates in the space and its relatively good structural design prevents the escape of heat energy from the space.

After comparing the high thermal stability of the fire escape stairwell and large solar gains, we concluded that the temperature gradient in this monitored part of the building works according to the original assumptions, but due to the lack of ventilation and high temperature stability, a balance of temperatures on individual floors occurs. The temperature gradient is therefore less evident.

5. DRAFT MEASURES AGAINST OVERHEATING THE INTERIOR

We can ensure the reduction in the heat load of the building from solar radiation in summer only by controlling the energy flow – restricting the accumulation of excess heat by the building. This can be solved with several options:

- Effective ventilation of excess heat
- A controlled system of blinds operating with solar global radiation sensors
- A controlled air-conditioning system

One of the possible variants for savings measures against overheating the interior is to employ the principle of the so-called solar chimney. As air enters at the bottom of the space in a preset density and temperature in the presence of solar radiation, a reduction occurs in the mass volume of air in the interior, causing it to flow out in the upper portion. The bottom part of the solar chimney sees air sucked out of the object, which secures the exchange of indoor air. This particular case provides for building an air intake through a ground heat exchanger, which would have a positive effect on both reducing indoor temperature in summer and increasing the temperature of the air intake during winter. This working “solar chimney” would moreover highlight the existing temperature gradient in the transparent shell. The advantage of a solar chimney is first and foremost the self-controlled operation, depending on the difference between exterior and interior temperatures. The smaller the temperature difference, the less need there is to exchange air with thermal loads and also the smaller the draft of the solar chimney [5].

Another variant that will have a positive impact on indoor air temperature during summer solar gains is the use of reflective foil on windows. This solution is being tested at this time on infill holes in the building of the Faculty of Civil Engineering and the preliminary results are promising. On a similar principle shielding with outdoor blinds also works but is prone to failure, especially in vertically continuous, transparent facades, where outdoor shielding technology reaches significant proportions. The disadvantage of outdoor blinds is also its impact on the overall architectural concept of the object.

The most powerful, but also operationally the most costly solution, is a centralized air conditioning system. If we were to physically modify the parameters of air in areas such as the fire escape stairwell, it would have a significant impact on the energy demands of buildings.

Due to the increasing pressure to reduce the energy demands of buildings, employing the principle of the solar chimney is clearly the most interesting option. This solution can be generally applied to most newly constructed buildings with transparent shells, and in this particular case, to most of the space in the new complex of buildings for the Faculty of Civil Engineering at VŠB -TUO. Separate fire areas must, of course, have a complete system of natural ventilation supplemented by fire dampers. The advantage is that heat sinks can be used for the upper vents to exhaust excess heat, which can perform both the function of ventilation during summer overheating and also fire protection.

6. CONCLUSION

If we compare the summer of 2011 to summer 2010, we find that this summer has more below-average temperatures and 60% more precipitation than last year. It can be concluded from these values that this year was not a typical situation of overheating the interior, and yet the long-term measurements showed that it occurred. The presumption therefore is that the statistically standard year has substantially greater problems with changing an internal climate based on global solar radiation, and that is why the professional community should continue to address this topic.

Zdroje

1. ČSN EN ISO 13947 – Thermal performance of lightweight shells (2007)
2. ČSN 73 0540-2 – Thermal protection of buildings – Part 2: Requirements (2007)
3. VAVERKA, J.; MEIXNER, M.; HIRŠ, J. Thermal technology and the energy demands of buildings. 1. 1. VUT Brno: Vutium, 2006. ISBN: 80-214-2910-0.
4. FAST project documentation – drawings of the building portion
5. http://3pol.cz/722-solarni-komin-vyuziti-solarniho-kominu-pro-prirozene-vetrani-budov
6. http://www.businessinfo.cz/files/2005/061106_oborova-prirucka-oze.pd