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Influence of Sustainability on Comprehensive Assessment of Buildings

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Influence of Sustainability on Comprehensive Assessment of Buildings

J Jurča[1,*], P Horák[1]

[1]Brno University of Technology, Faculty of Civil Engineering, Institute of Building Services, Brno, Czech Republic

E-mail: jaromir.jurca@vutbr.cz

Abstract. Present design of buildings and the way of building assessment focus primary on decreasing of energy consumption, efficient energy management and reduction of greenhouse gas emissions having significant impact on climate change. This emphasis stems from European Union 2020 targets. However, in the issue of comprehensive building assessment are missing headline targets or limits to achieve type-stable level of indoor environment quality. Under the scope of sustainable building assessment can be considered aspect of acoustics, natural and artificial lighting, air quality or thermal behaviour. By means of sustainable development are applied wider targets directly and indirectly influencing overall building performance. This contribution describes connection between application of specific aims of sustainability applied by BREEAM with final influence on energy efficiency and indoor environment in terms of evaluation of thermal comfort using predicted mean vote and predicted percentage dissatisfied indices. The subject of analysis is office building in Brno.

1. Introduction

The current trend in building design is largely mirrored by the need to reduce impact on the environment. Green buildings are getting to the foreground, the demand for using systems of renewable energy is constantly increasing and more and more are used globally recognized or local certification systems to improve overall performance of the building. But is this race for energy reductions and reaching of sustainability through certification on the right place?

Firstly, the purpose of applying certification system is often seen as a marketing move to improve market position but not as a way how to improve quality of the building, to make the building more energy efficient or to reduce the environmental impact of the building. Secondly, previous studies[1]demonstrated, that having a certified facility may not necessarily mean bringing of benefits to the building users. Nevertheless, certification of buildings offers comprehensive approach in assessment of buildings. One of the most known certification system is British BREEAM assessing and certifying the sustainability of buildings[2]. Methodology of BREEAM was applied on the office building Office Box II in Brno, Czech Republic.

Effective adaptation of sustainable solutions and measures through BREEAM is undertaken through range of issues that assess energy efficiency, water use, health and wellbeing, materials, waste, ecology, pollution, etc. [3]. In the certification is the possibly highest potential for reaching the most credits signifying higher certification level in energy efficiency and reduction of energy consumption. In Czech republic using of global certification scheme for energy assessment is supported by accepting of local national standards [4],[5] and calculation tools. These calculation tools except energy assessment also often provide way how to comprehensively assess buildings in means of day lighting, Life Cycle Cost (LCC), Life Cycle Assessment (LCA), passive design or thermal comfort. Using of simulation programmes is very beneficial in terms of analysing effect of thermal mass [6] and therefore allows observation of accumulation of buildings construction. One of the results of previous study[7]shown, that high-mass envelope technique in contrast to light-mass techniques helps to maintain better comfort conditions. However, indoor thermal environment is influenced in many ways. The quality of the building envelope is one of the other factor. Different approach in analysis of various low-energy cooling technologies [8] demonstrated the satisfactory measures for keeping optimal thermal comfort without taking into account energy efficiency. Another study [9] presented use of thermal comfort analysis to identify causes of discomfort. Comprehensive assessment of buildings is multidisciplinary approach evaluating different aspects in mutual connection, but significantly in terms of energy efficiency. Assessment of relationship between energy efficiency and thermal comfort can be undertaken in different extent on various case studies with many rare boundary conditions.

This article is dedicated to analysis of thermal behaviour of indoor environment in the office building certified by BREEAM. Within the analysis are compared three variants of building high-mass envelope with the same value of heat transfer coefficient, but different composition. Results of simulations are subsequently evaluated according to standard ISO 7730[10]using predicted mean vote (PMV) and predicted percentage dissatisfied (PPD) indices.

2. Methodology

2.1. General approach

The analysis is based on an experimental method using dynamic simulation, the same as has been used formerly in previous study [8]. Thermal comfort of the actual building proposed as Baseline variant is evaluated. Baseline variant is compared to two alternative variants. The analysed alternative variants are high-mass construction compositions based on findings of study [7]. Table 1 summarizes the general aspects observed within the study.

Table 1. Methods and aims observed within study.

Method	Dynamic simulation, Fanger’s model, steady-state conditions
Subject	Office building Office Box II, 3rd floor
Target	Thermal comfort analysis. Comparison of massive external wall variants with equal U-value and observation of influence on thermal comfort
Simulation boundaries	Stable – Construction data, local climatic data, solar gains, shading effects, HVAC data, lighting and equipment data, occupancy and activity data Variable – Building construction layers within variants, see Table 2
Tools	DesignBuilder version 5.0.3.007, EnergyPlus 8.5, Microsoft Excel 2016
Outcomes	PMV, PPD, Surface temperatures,
References	[7][9]
Standards	ISO 7730, ČSN 73 0540-3

The building model used within the analysis accounts with actual building form and orientation, external and internal layout, construction techniques, building services and other input date as is listed in Table 1. Illustration of the building model is shown on Figure 1.

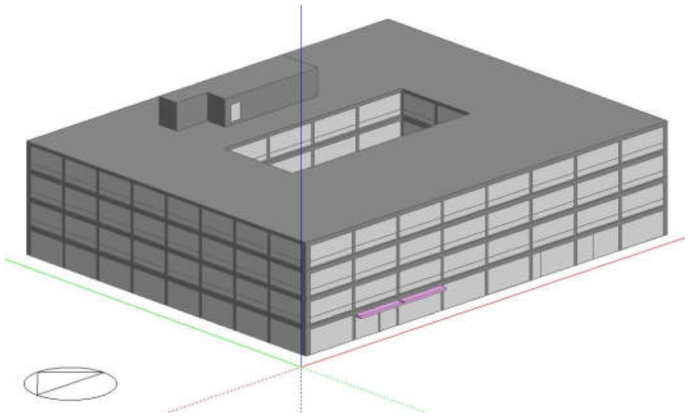

Figure 1. Model of the Office Box II building

The baseline variant outlined in Table 2 represents the actual state of the building evaluated in thermal comfort analysis. Variants 1 and 2 have been composed to provide comparison against baseline. Proposed alternative variants were analyzed within the same model with the same boundary conditions. In the baseline variant and in the both other variants, the envelope of the building is made of heavy construction. The building's skeleton system does not allow the use of lightweight envelope.

Table 2. Variants and constructional characteristics.

Ref.	Construction layers	t (mm)[a]	λ (W/m K) [a]	c (J/kg K)[a]	ρ (kg/m^3)[a]	U (W(m^2 K)[ab]
Baseline	Plaster (innermost)	15	0.870	1600	840	
	Reinforced concrete	200	1.430	1020	2300	
	Insulation	140	0.035	880	100	0.23
	Ventilated air gap	40				
	Facing brick (outermost)	100				
Variant 1	Plaster (innermost layer)	15	0.870	1600	840	
	Reinforced concrete	200	1.430	1020	2300	0.23
	Insulation	140	0.035	880	100	
	Facade plaster (outermost)	2	0.700	1000	1800	
Variant 2	Plaster (innermost layer)	15	0.870	1600	840	
	Reinforced concrete	200	1.430	1020	2300	
	Insulation	130	0.035	880	100	0.23
	Air gap	40	0.19			
	Facing brick (outermost)	100	0.84	800	1700	

[a] t = thickness; λ = thermal conductivity; c = specific heat; ρ = density; U = heat transfer coefficient
[b]Overall heat transfer coefficient for a variant of construction composition as a whole

Using the Design Builder software were calculated operative temperatures, PMV values and indoor surface temperatures with a time step detail of one hour during the whole year. For evaluation of thermal comfort are guiding PMV values at the periods of occupancy. Outside these periods it is not necessary to maintain optimal level of indoor environment, which would in the other case cause discomfort. Simulation outputs were subsequently post-processed in Excel for comparison of variants.

2.2. Building construction and building systems

The building consists of four-storeys of which upper three storeys provide open space office area. The construction system of the building consists of reinforced concrete skeleton with axial ground dimension 48 x 60 m. The basic module is 6 x 7,5 m and atrium in upper three storeys divides object into four wings. The envelope of the building is ventilated facade with corrugated metal panels in combination with facing bricks and double-glazed windows. Layer of thermal insulation provide 140 mm thick hydrophobized mineral wool. Layout of 3rd floor is illustrated on Figure 2.

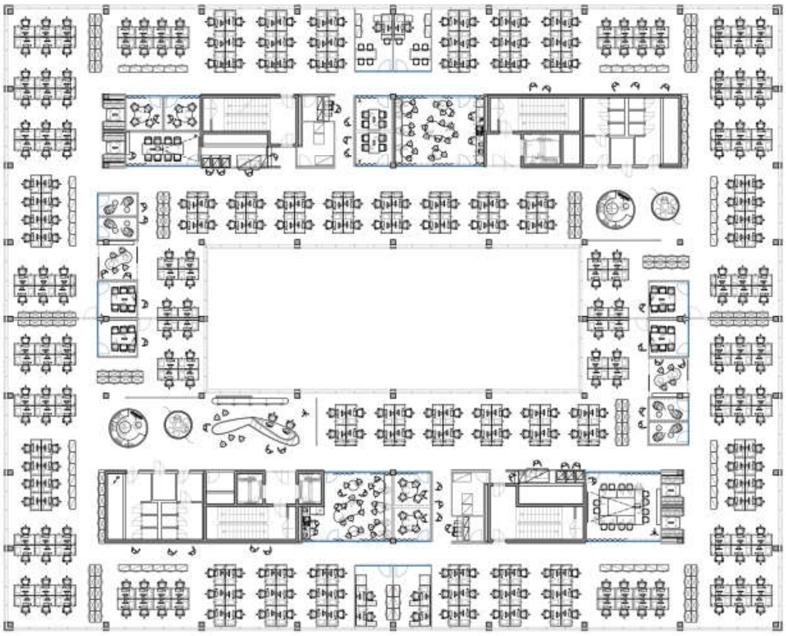

Figure 2. Layout of 3rd floor of the Office Box II building.

2.3. Interior and exterior environment

The building is located in warm temperate climate of Cfb type according to Coppen Geiger classification. In the winter season average exterior temperatures are varying around 0 °C to -5 °C, during the summer around 18 °C to 23 °C. Heating and cooling in is predominantly provided by induction units. Ventilation and air treatment of office spaces provide air-handling units located on the roof of the object. These units' pre-heat or pre-cool air which is ducted into the office area and then is locally treated within smaller working areas according to current temperature and occupant needs. The standard set internal temperature for summer is 24 °C and 20 °C for winter during occupation periods and users have possibility to change temperature within the range of 2 °C. The operation of building services is shown in Table 3. Maintenance of local and overall temperature using induction units provide sufficient stratification of fresh incoming fresh air reducing drafts and allowing to reduce potential local overheating from solar gains. As been previously demonstrated [6],[8] to achieve required temperatures at the beginning of occupancy period, pre-cooling/pre-heating is carried out during off peak hours. As well as in publication[6], thermal behaviour and its impact on indoor environment has been observed.

Table 3. Time schedule of buildings operation.

	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Holiday
Time 1.	0:00:01	4:00:00	4:00:00	4:00:00	4:00:00	8:00:00	8:00:00	0:00:01
Value	1	1	1	1	1	1	1	2
Time 2.	21:00:00	21:00:00	21:00:00	21:00:00	21:00:00	12:00:00	12:00:00	0:00:00
Value	2	2	2	2	2	2	2	0

0 = Turned off

1 = Comfort

2 = Circulation

2.4. *Thermal comfort*

For the evaluation of thermal comfort are nowadays used two distinct approaches. The first approach was developed by Fanger in the 1970s [10], the second approach [12] uses adaptive model, which considers reaction of people, when change causing discomfort occurs. Using Design Builder calculation of PMV was done according to standards [10],[13] used in practice. The classic Fanger's approach aims to predict the mean thermal sensation of group of people using PMV index categorized on seven-point sensation scale and their percentage of dissatisfaction through PPD index. Human thermal balance expressed by PMV is affected by environmental parameters as indoor air temperature, indoor mean radiant temperature, indoor air velocity and indoor air humidity and by personal parameters metabolism and clothing. Considering these parameters within the calculation of PMV according to standard ISO 7730 is the boundary of comfort environment recommended for PMV values varying between -0,5 and 0,5. PPD as a function of PMV does not exceed 10%.

In the view of the thermal comfort analyzed according to ISO 7730 [10], percentage dissatisfied (PD) caused by radiant asymmetry of surrounding surfaces. By monitoring of this parameter is possible to describe behavior of the structure in the events of sudden temperature changes or high surface temperature differences affecting the thermal comfort [10]. Therefore, PD can provide greater detail than just evaluating PMV.

3. Results and discussion

The PMV and PPD indices shown on Figure 3. demonstrate annual profile of thermal comfort during the occupied periods in the 3rd floor of the building. Presented results show prevailing value of PMV between -0,5 and 0,3. This corresponds to PPD values below 10%. Thermal comfort analysis was in largely influenced by HVAC system, thermal accumulation of building and physical activity of people and their clothing characterized by CLO index [10]. The final profile of PMV, PPD indices is composed of multiple simulations, which considers clothing resistance in winter, summer and transitional period. Figure 4 shows annual outside dry-bulb temperature and CLO.

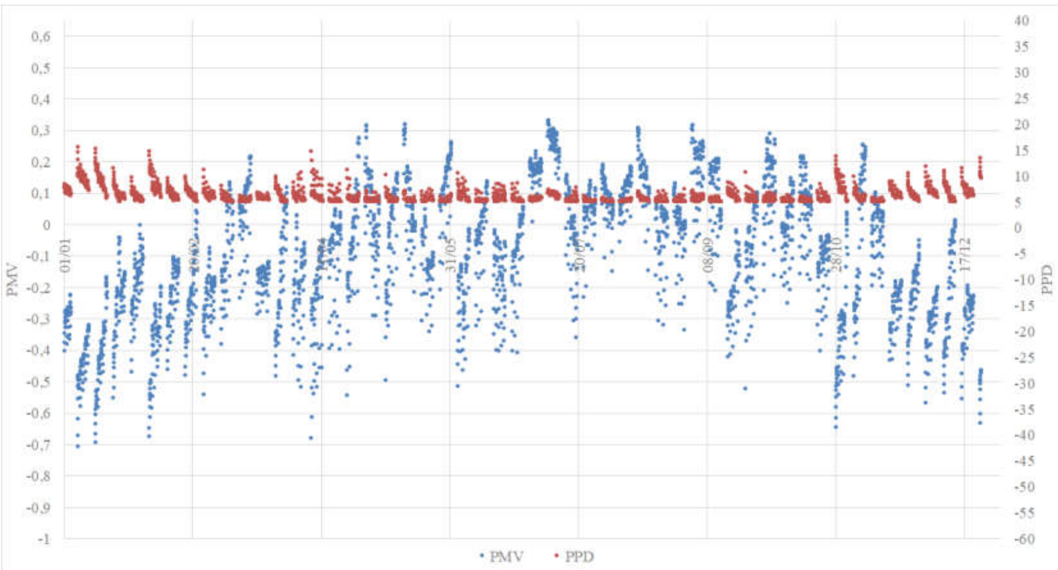

Figure 3. Annual profile of PMV, PPD indices – baseline variant.

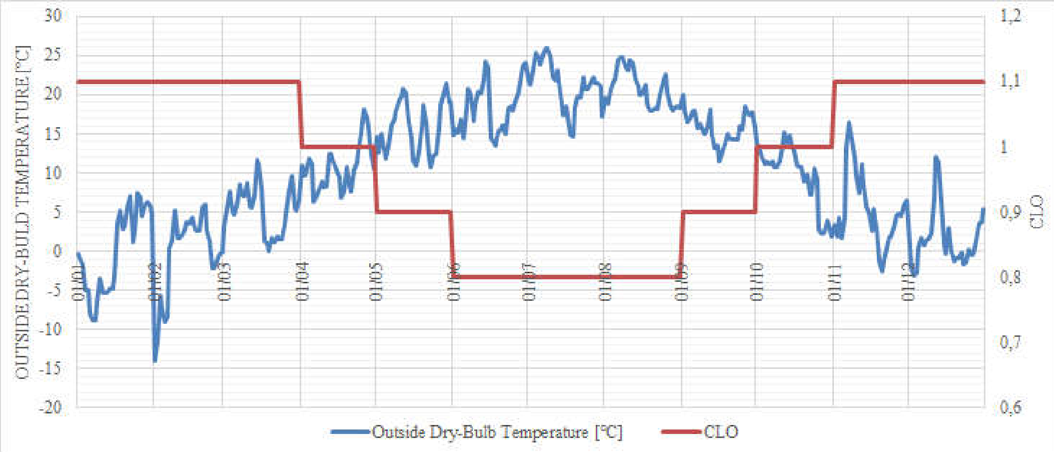

Figure 4. Annual profile of outside dry-bulb temperature and CLO.

From the annual profile of PMV and PPD indices is evident rising tendency during the week. This effect is caused by accumulation of perimeter constructions of the building. Figure 5 and 6 show this effect in greater detail in PMV/PPD typical week profiles.

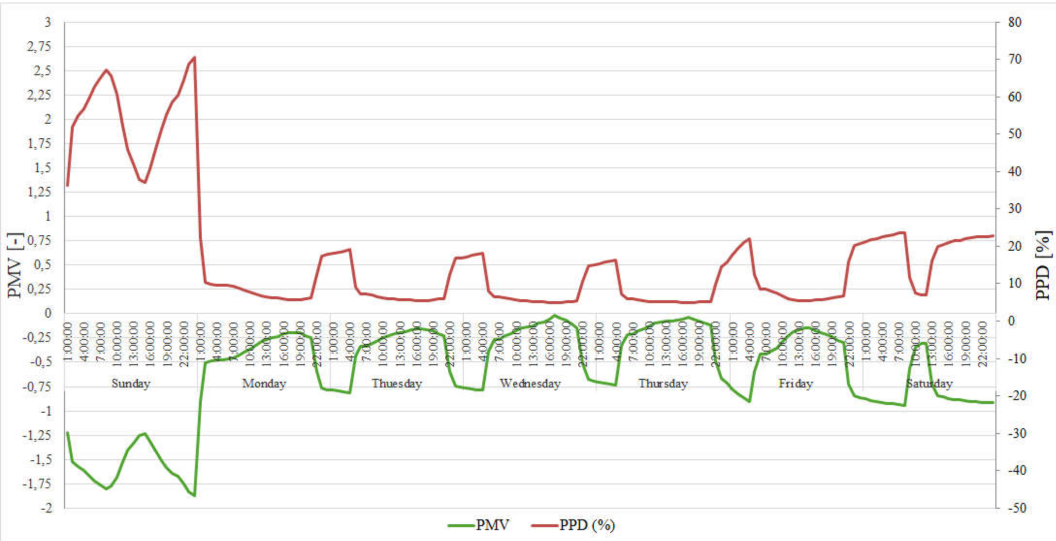

Figure 5. Simulated Fanger PMV and PPD indices for typical winter week.

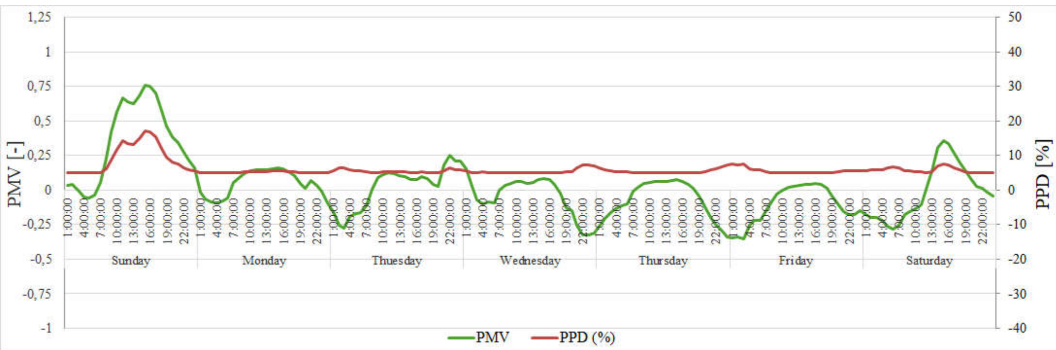

Figure 6. Simulated Fanger PMV and PPD indices for typical summer week.

The comparison of variants is done based on surface temperature differences. This difference between the baseline and variants simply indicates thermal behaviour during the year. On the vertical axis plus values represent warmer temperature of baseline against compared variant. Figure 7 shows comparison of the baseline and the Variant 1. In this comparison the baseline variant composing of ventilated air gap appears to be more beneficial in means of keeping higher and more stable internal surface temperature during the winter. Figure 8 comparing variant composing of closed air gap does not result more significant performance. The possible benefit can be in this case potentially explored in means of LCC.

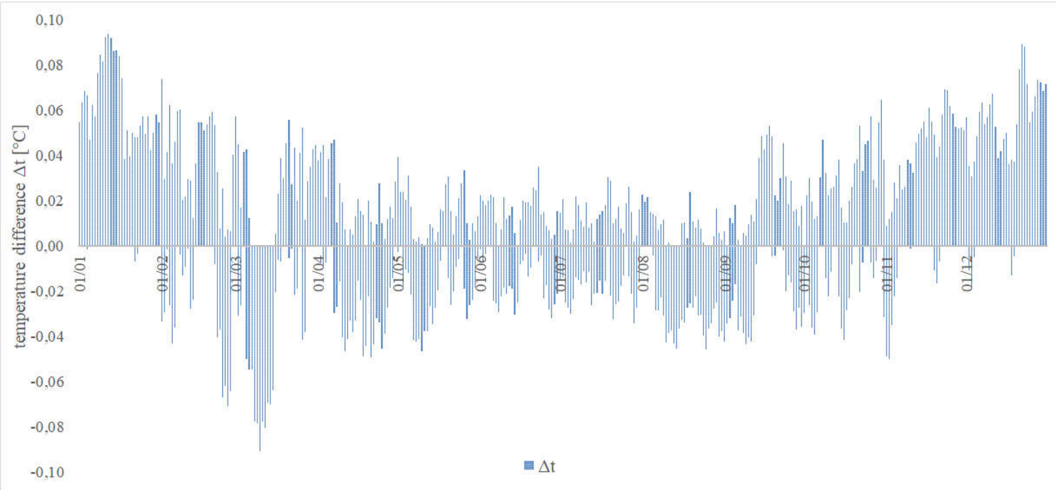

Figure 7. Temperature difference between baseline and Variant 1.

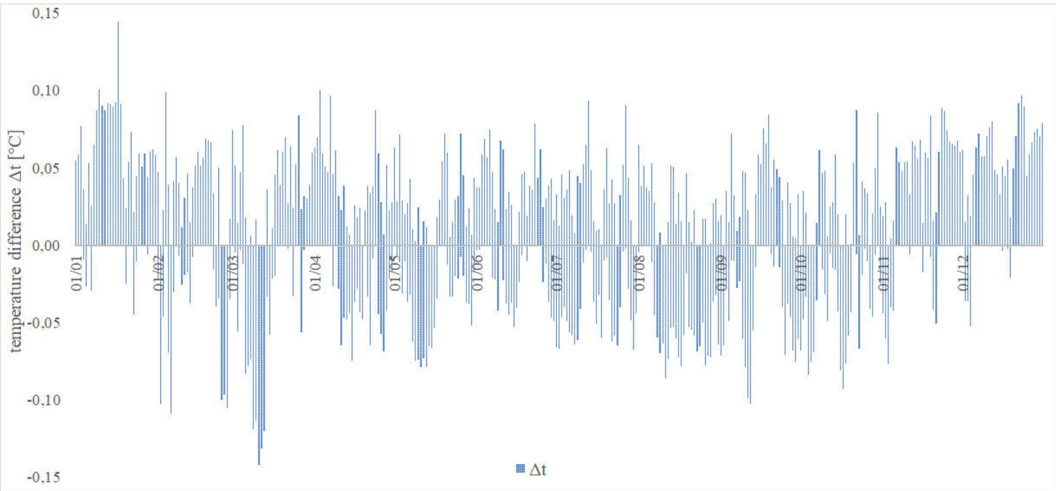

Figure 8. Temperature difference between baseline and Variant 2.

4. Conclusion

The aim of the study was to point on the direct and indirect connections in application of specific aims of sustainability in terms of regular criteria of methodology of BREEAM assessment. As has been introduced, the terminology of comprehensive assessment of buildings can be undertaken in different ways and extent. The analysis of thermal comfort done on the building influenced with BREEAM proved ability to create optimal indoor environment. Compared to the results from previous study [7], the simulation proved good accumulation features of the high-mass envelope. In the comparison of proposed variants were found just slight deviations in surface temperatures, therefore no further evaluation of thermal comfort was observed. Results were influenced by the type of the building with high percentage of glazing and the fact, that the alternative variants were high-mass construction compositions. The variants were selected with respect on previous findings [7] and also to keep in line with building's skeleton system. Assuming a lower ratio of glazed areas, the results of surface temperatures and PMV/PPD indices would be more significant. The analysis pointed on connection of energy efficiency of building's envelope and thermal comfort.

5. Acknowledgments

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