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SIMULATION OF ENERGY DEMANDS FOR THE INTERNAL MICROCLIMATE FORMATION IN BSIM SOFTWARE AND ITS VERIFICATION

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ABSTRACT

This article deals with the description and verifying energy model building in BSim software. Results of energy demands simulation for the internal microclimate formation in a real dwelling house carried out on the basis of actual hourly interval climatic data during a whole year are presented. The results are subsequently confronted with other calculation programs, possibly simplified methods, and particularly real measuring during a whole year. The aim is to verify reliability of BSim software and accuracy of various approaches to the calculation of building's energy demands for the internal climate formation.

Keywords: energy model, internal microclimate, climatic data

SIMULACE POTŘEB ENERGIÍ NA TVORBU VNITŘNÍHO KLIMATU BUDOVY V SOFTWARU BSIM A JEJÍ OVĚŘENÍ

Příspěvek se zabývá popisem tvorby energetického modelu budovy v programu BSim a jeho ověřením. Jsou prezentovány výsledky simulace potřeb energií na tvorbu vnitřního mikroklimatu konkrétního bytového domu prováděné na základě skutečných hodinových klimatických dat v průběhu celého roku. Výsledky jsou následně konfrontovány s jinými výpočetními nástroji, případně zjednodušenými metodami, a především s reálným měřením v průběhu celého roku. Cílem je dílčím způsobem ověřit věrohodnost softwaru BSim a přesnost různých přístupů k výpočtu energetických potřeb budovy na tvorbu vnitřního klimatu.

Klíčová slova: energetický model, vnitřní mikroklima, klimatická data

INTRODUCTION

This article confronts some of the computing methods for building energy consumption assessment both mutually and with the actual energy consumption. Danish software Bsim 2000, Czech National Calculation Tool NKN 2.03 and simplified manual calculation based on DOS T 3.07 were among chosen computing methods.

A dwelling house in Lucerne, which is a city in Switzerland, was chosen for the comparison of above-mentioned methods. Along with the actual energy consumption for building services operation, energy components influence on total annual demand of energy is also monitored.

BSIM 2000

The Building Simulation program 2000 (BSim 2000) was created by Danish Building and Urban Research Company. The program serves for thermal and energetic building simulation during the whole year.

During a 3D model formation individual rooms are step by step inserted. Construction material including its surface is assorted to each room a construction surface. Individual rooms are arranged into groups so-called "temperature zones" after model formation.

The operative temperature, way of heating and cooling, air-conditioning operation, lighting and number of occupants during the whole day are entered for the each individual temperature zone.

Before the starting computation building location with its latitude, longitude, altitude and time zone are entered.

For more accurate simulation it is possible to use actual measuring climatic data in form: day, month and hour, outdoor air temperature, relative humidity, direct and diffused solar radiation, total duration of sunshine, wind direction and its velocity.

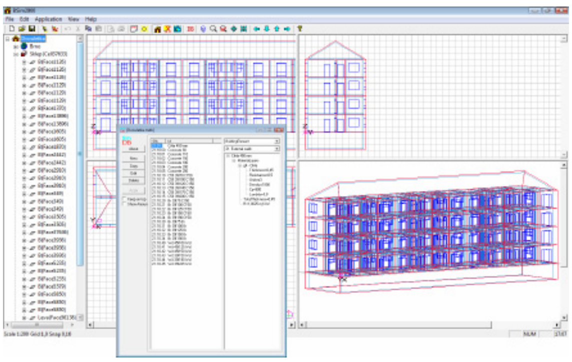

Fig. 1 – BSim 2000 program appearance

The time and stereometric diskretization step for the numerical solution of the heat conduction transmittance is chosen for the year-round simulation. In the calculation a time step length of 4,7 seconds (which means 786 time steps per hour) is applied. The stereometric diskretization step is chosen automatically. After the calculation initialization the year-round simulation is accomplished with inserted climatic data, required technical building services operation and building exploitation model during the typical day for every month of the year. The tabular and graphic recapitulation forms the output of all the energies needed for individual parts of building services operation.

A nonstationary hygrothermal building behaviour is transferred by the program in very short time interval on a stationary hygrothermal behaviour according to the Fourier heat equation. BSim 2000 software uses iterative methods to solve these dynamic states.

NKN 2.03 – 2007

NKN 2.03 program from 2007 was created at the Department of Microenvironmental and Building Services Engineering, CTU Prague, Faculty of Civil Engineering. The computing process of the National Calculation Tool (NKN) is in accordance with the Directive 2002/92/EC of the European Parliament about the energy intensity of buildings and valid national legislation of the Czech Republic.

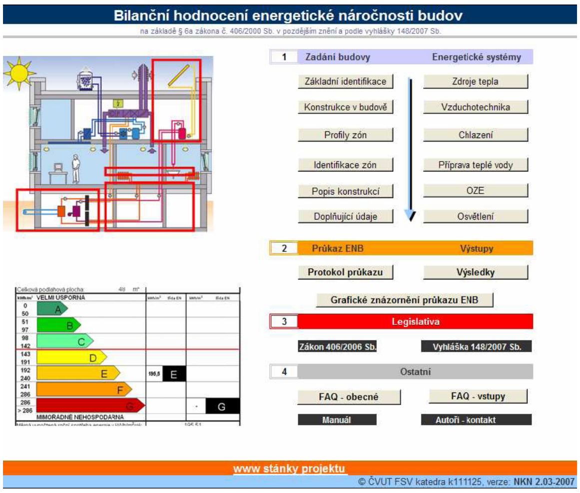

Fig. 2 – NKN 2.03 program appearance

A required data summary and a calculation of energy consumption in [MJ] both for each month of the year and for all the years form the program output. In the annual summary each energy demands are particularized according to the percentage distribution. Specific energy demand in [kWh/(m^2·yr)] is also calculated in there. According to the specific energy demand, the building is categorized into the class of the building energy intensity A to G. NKN program primary pursues computing of loads of delivery building energy a year. The delivered energy is inclusive of the energy demand for heating, cooling, air-conditioning, hot water preparation, lighting and individual subsystems operation.

The methodic of energy intensity of buildings represents a balance building classification method at a standardized usage. This method of classification is dependent on boundary conditions. For that reason the degree-day model was selected with hourly time interval. The evaluation is according to calculated data in [kWh/(m^2·yr)].

DOS T 3.07

The simplified manual calculation was accomplished in conformity with recommended technical standard no.7 from 2000, which was published by the Czech Chamber of Authorized Engineers and Technicians Working in the Field of Building Constructions (CCAET). In this standard reference conditions for the energy intensity of buildings are summarized.

The annual energy consumption assessment E_h [GJ/yr] for building heating is based on a total building heat loss calculation Q_t [kW] for heating. This calculation is accomplished according to the Czech technical standard with the designation CTS 06 0210 [4]. The annual heating energy consumption is due to the relation (1).

$$E_h = f_c \cdot Q_t \cdot \left(\frac{t_{si} - t_{se}}{t_i - t_e} \right) \cdot \tau \qquad (1)$$

The total corrective coefficient f_c [-] takes into account a building operation, a way of heating and a regulation system in the calculation. In parentheses there is a count from computing temperatures on moderate temperatures and a length of a heating period comes after.

DWELLING HOUSE IN LUCERNE

The analysed dwelling house in Swiss city Lucerne with proportions 31,4 x 11,1 meters is situated 477 meters above sea level as a detached building. The dwelling house is a three-storey, brick building with a basement and a saddle roof. The object is composed of two separate mirrored sections with 12 flats and with 794 m^2 of floorage. In each dwelling unit with size of 2+1, where the floorage is circa 66 m^2, 2 persons live there on an average.

The heat source for warm-water central heating is a furnace oil boiler which also serves for a hot water preparation. The designed temperature gradient is 70/50°C. In the building a forced air system isn't applied and the suppose fresh air supply is 30 m^3/hr for each person. That means the air change n = 0,30 hr^{-1}. Brick constructions have the coefficient of heat transmission approximately U = 1,40 W/(m^2·K) and window fillers have double glazing with U = 2,50 W/(m^2·K). The object appearance is in the picture *Fig. 3*. The object usage is defined in [6]. The average monthly climatic data for Lucerne and Brno are presented in the following table *Tab.1*.

Tab. 1 – Comparison of average temperatures. [°C]

Month	Brno (CZ)	Lucerne (CH)
January	-2,10	0,50
February	-0,90	1,80
March	3,10	5,70
April	7,10	8,80
May	12,6	13,9
June	17,3	16,7
July	19,9	19,0
August	19,7	18,8
September	13,0	14,4
October	8,40	10,2
November	3,00	4,50
December	-0,10	2,00

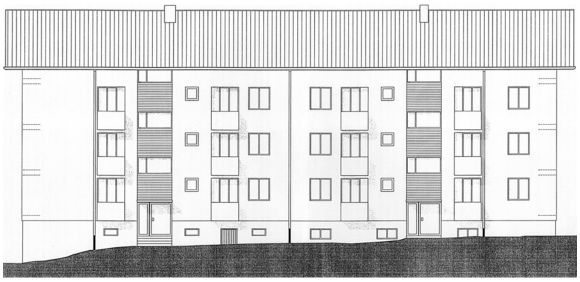

Fig. 3 – Appearance of the dwelling house in Lucerne city [6]

COMPARISON OF CALCULATION METHODS

In the analysed dwelling house the actual annual energy consumption for heating E_h [GJ/yr] was calculated with the chosen calculated methods vide *Tab. 3*. Input data are equal because of the results comparison.

Tab. 2 – Required input data

Climatic data	Brno
Multiplicity of air change	n = 0,50 hod^{-1}
Building occupancy	24 persons

Tab. 3 – Energy demands for heating

Calculation method	E_h
BSim 2000	549 GJ/yr
NKN 2.03 – 2007	654 GJ/yr
DOS T 3.07	624 GJ/yr

The distinction between NKN 2.03 – 2007 and the manual calculation based on Czech technical standard CTS 06 0210 and DOS T 3.07 is approximately 5 %. This difference is insignificant. On the other hand the results from BSim 2000 software are about 13 % lesser in comparison with the others methods. The course of energy needed for the heating during a whole year in single months is in *Fig. 4*.

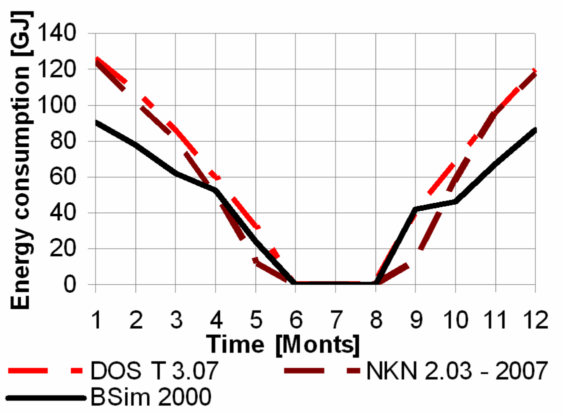

Fig. 4 – The course of the energy consumption for a dwelling house heating in Brno during a whore year

CALCULATION OF HEAT DEMAND FOR HEATING

The same calculation was made in BSim 2000 program for Swiss climatic data. While for the heating of the same dwelling house Brno the necessary heat energy demand was E_h = 549 GJ/yr, in Lucerne city in Switzerland there was sufficient only E_h = 416 GJ/yr. The difference with value 133 GJ/yr is caused by different climatic conditions in Switzerland.

INFLUENCE OF MULTIPLE AIR CHANGE

Percentage share of a particular influence entering in the calculation is possible to check out on the created energy model of the dwelling house in BSim 2000 program. In the previous calculations the multiplicity of the air change $n = 0{,}50$ yr^{-1} was applied, but according to the “Swiss way of usage” the air change multiplicity is only $n = 0{,}30$ hod^{-1}. The influence of the air change multiplicity on the actual energy consumption for the heating is presented in the following *Tab. 4* for different climatic data.

Tab. 4 – Influence of multiple air change in [%]

Month	Brno (CZ)		Lucerne (CH)	
n [hr^{-1}]	0,30	0,50	0,30	0,50
January	10	18	9	16
February	9	17	8	15
March	8	15	6	13
April	5	12	5	11
May	6	12	5	11
October	7	15	6	14
November	9	17	8	16
December	10	17	8	16

In the table *Tab. 4* can be seen, that the percentage share of the heat ventilation loss ranges from 5 % to 9 % in chillier months in Lucerne and even 18 % in January in Brno. The percentage share of the heat ventilation loss depends on a specific air change value.

CONFRONTATION OF THE REALITY AND BSIM 2000 PROGRAM

In the analysed Swiss dwelling house in Lucerne city the annual energy consumption for heating and the hot water preparation was measured. The confrontation of the actual consumption and the BSim 2000 program is presented in *Tab. 5.* The energy consumption for the hot water preparation (100 GJ/yr) was taken off the actual total energy consumption. The model deviation in BSim 2000 program from the actual energy consumption in 2007 is then circa 8 %.

Tab. 5 – The confrontation of the reality and Bsim 2000 program

	Period	Energy GJ/yr
Reality	1. 5. 2004 – 1. 5. 2005	894
	1. 5. 2005 – 1. 5. 2006	782r
	1. 5. 2006 – 1. 5. 2007	418
Calculation	BSim 2000 *(Lucerne, n = 0,30 hr^{-1}, Climatic data in 2007)*	387

INFLUENCE OF SOLAR RADIATION

In climatic data for BSim 2000 software the solar radiation is listed as well. Hence it is possible to test the solar radiation influence on the building heating. The results are mentioned in the table *Tab. 6.*

Tab. 6 – Solar radiation influence in [%]

Month	Brno (CZ)	Lucerne (CH)
January	3	4
February	5	7
March	9	15
April	17	19
September	21	25
October	11	14
November	4	6
December	2	4

It is evident from Tab. 6, that the solar radiation share on total heating energy consumption has a major importance. In winter months the percentage share ranges about 3 %, but in spring and autumn months the solar radiation share has the larger significance, respectively up to 21 % in Brno and 25 % in Lucerne.

INFLUENCE OF NIGHT HEATING DECREMENT

The night heating decrement influence was tested on the same object model in BSim 2000 software. The night decrement during the real heating system operation was carried out in the evaluated time period from 10 p.m. to 6 a.m. The heating energy saving ranges from 4 % in chillier months up to 16 % in warm month of September.

INFLUENCE OF HEAT PRODUCE FROM OCCUPANTS

In the previous calculation in the energy object a model with 24 persons in the whole building was ratiocinated. These persons were entered to the calculation as the inner heat sources with value 70 W/person. The influences of the heat produce from persons according to the building occupancy from *Fig. 5.*

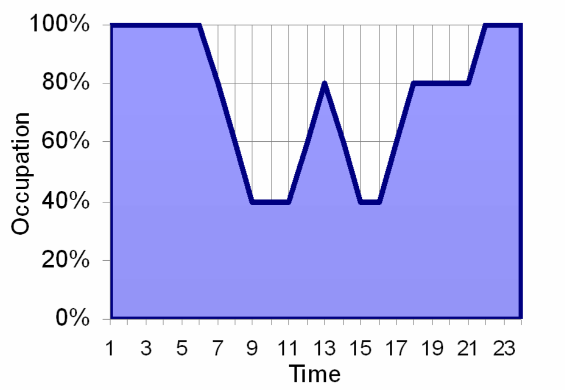

Fig. 5 – Dwelling building occupancy during the day in Lucerne, Switzerland

The heat produce from occupants depends on climatic conditions. While in Brno the share of the heat gains from occupants is maximum 6 %, in Lucerne the share is higher due to the warmer climate, namely 7 % in September.

INFLUENCE OF HEAT GAINS FROM LIGHTING

The another influence, which can effect the total energy demand for heating, the heat gain from lighting is. In every dwelling unit the heating lighting capacity 9,4 W/m^2 based on [6] is considered and the capacity is distributed in time period according to the *Fig. 6.*

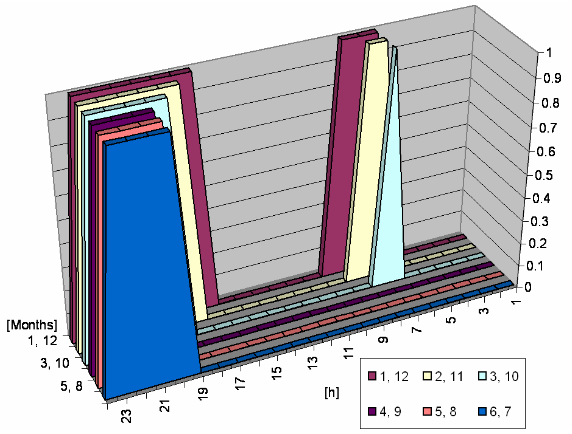

Fig. 6 – Relative heat gains from lighting in time

Tab. 7 – Influence of heat gains from lighting in [%]

Month	Brno (CZ)	Lucerne (CH)
January	4	4
February	4	4
March	4	5
April	6	6
September	8	9
October	7	7
November	5	5
December	4	4

INFLUENCE OF ELECTRIC APPLIANCES

Various electric appliances are placed in each flat of the whole object. A heat capacity and a service time of these appliances is changeable. Their heat capacity was used with value 3 W/m^2 based on [6] and the capacity is relatively distributed in time period pursuant to *Fig. 7*.

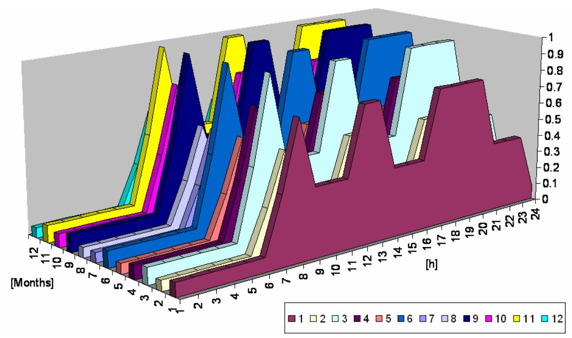

Fig. 7 – Relative heat gain from electric appliances in time

The percentage share on the total heat demand is from 3 % in chillier months up to 6 % in warm month.

EVALUATION OF LISTED INFLUENCES

In the text mentioned above some of the influences on the calculation of the total energy demand for heating are listed. The summary of the particular percentage shares are mentioned in *Tab. 8*.

Tab. 8 – Percentage share of particular influences

Influence	Share [%]	
Month	Brno	Lucerne
Heat transmission loss	59	56
Multiple air change	12	11
Solar radiation	14	16
Night decrement of heating	5	6
Heat produce from occupants	3	3
Electric appliances	3	3
Lighting	4	4

It is evident from the table *Tab. 8*, that the highest share on the total energy demand for heating has the heat loss due to transmission and the heat loss due to ventilation. The highest heat gain comes from the solar radiation. The influence of the night decrement is about 5 % and the inner heat gains from occupants, lighting and electric appliances are slightly lower.

HEAT GAINS ASSESSMENT FROM SOLAR RADIATION

The heat gains coming from the solar radiation have their inconsiderable share on the total heat demand for heating. The assessment of the heat gains depends on a building geographical position, a percentage share of an object glazing, an orientation due to point of the compass and many other factors.

The calculation correlation (2) for computing of the heat gains from the solar radiation during the whole heating period E_{zs} [kWhr] is specified in the public notice of Ministry of Industry and Trade No. 291/2001Coll. [2], §6 Heat gains, the clause (3), where V [m^3] is the building capacity. This correlation (2) is determined just for the Czech Republic and it doesn't take into account a building orientation due to point of the compass and a size of building glazing. In spite of that when this empirical correlation (2) is confronted with building energy model in BSim 2000 program it analyses relatively good accuracy. The results are mentioned in the following table *Tab. 9*.

$$E_{zs} = 3 \cdot V \qquad (2)$$

The dwelling house capacity is $V = 4531$ m^3, afterwards the heat gain from the solar radiation for the whole heating period should be $E_{zs} = 13593$ kWhr.

Tab. 9 – Heat gains from solar radiation

Calculation method	E_{zs}
Public notice No. 291/2001 Coll.	13 593 kWh
BSim 2000 (for Brno)	14 777 kWh

The difference between the empirical correlation (2) and the accurate calculation in BSim 2000 program with measured hourly interval climatic data for Brno is up to 10 % (it was calculated besides shadowing windows components). It is possible to establish, that the empirical correlation (2) devaluates the actual (maximum) contribution of the heat solar gains in the total energy balance.

HEAT GAINS ASSESSMENT FROM OCCUPANTS

The heat production by occupants creates the other heat gain. A quantity of obtained heat depends on many factors. A number of occupants and a length of their stay in the building are the most significant. The correlation (3), mentioned in DOS T 3.07, which was published by the CCAET in 2000, takes into account these factors.

$$Q_l = 6{,}20 \cdot (36 - t_i) \cdot i_l \qquad (3)$$

Where i_l [°C] is the number of persons re-counted on men and Q_l [W] is the heat produce from occupants in interior. For the calculation of the persons heat gains in a total heating season it is necessary to multiple the actual heat gain Q_l [W] and the number of hours per total heating season,.

Tab. 10 – The calculation of persons heat gains

Internal environmental temperature	t_i = 20°C
Percentage stay of persons	m = 50%
Number of persons in the dwelling house	i_l = 24 persons
Number of heating days for Brno	d = 222 days
Actual heat gain from persons	Q_l = 2381 W
Heat gain from persons	E_{zo} = 6432 kWh

In BSim program the heat gain from persons re-counted on the value 2,2 W/m^2 is applied , which is distributed in a time period according to *Fig. 8*. The confrontation of the calculated heat gain from persons E_{zo} [kWhr] per total heating season based on DOS T 3.07 and BSim 2000 program is specified in the table *Tab. 14*. The difference between the results is 15 %.

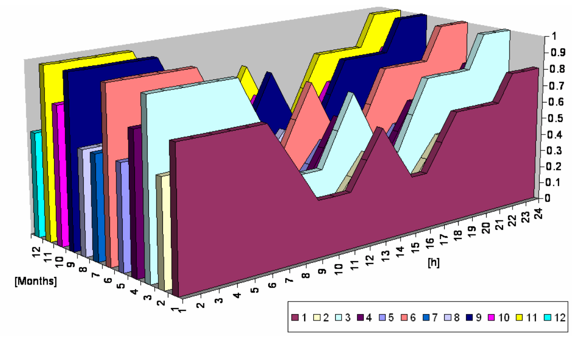

Fig. 8 – Relative heat gains from persons in time period (BSim)

Tab. 11 – Heat gains from persons in a heating season

Calculation method	E_{zo}
DOS T 3.07 – CCAET, year 2000	6 432 kWh
BSim 2000 (for Brno)	7 399 kWh

CONCLUSION

In the course of confrontation of selected calculation methods it has been found out that the simulation done with the energy model in BSim software most approximates to the realistic heat demand. This simulation program works with the detailed climatic data as the only one from the selected methods. BSim also takes into account the building geometry, the thermal inertia, the solar radiation effect and the inner heat gains. The other computing methods or tools are based on substantially easier methods of a building thermal behaviour.

From the simulations in BSim 2000 described above it arises, that the heat loss due to transmission and ventilation have the highest percentage share on the total energy needed for actual building operation. The effect of night decrement is circa 5 % on the reduction of the energy consumption. The heat gain effect is approximately 20 %. Further it has been found out, that the correlation (2) slightly devaluated the real heat gains from solar radiations.

In connection with the heat losses due to transmission, the thermal bridge influence will be further explored.

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LITERATURE

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