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Numerical Simulation of the Effect of Heat Gains in the Heating Season

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Abstract

This paper is concerned with the description and verification of an energy model of a building using the BSim software. The aim is to determine the effect of the basic heat gains on the energy consumption of a building. Simulations were performed on the basis of the actual hourly-interval climatic data over a whole year. It has been found, that the highest heat gain comes from solar radiation.

Keywords: energy simulations, energy consumption, heat gains, climatic data, measurements

1. Introduction

This paper applies a BSim 2000 software from Denmark [1] used here to simulate the state of the microclimate and the energy consumption in a building. A dwelling house in Lucerne, Switzerland, was chosen to compare the above-mentioned methods. In addition to the actual energy consumption for building services operation, energy components influence on the total annual demand of energy is also monitored.

Nomenclature

U	heat thermal transmittance coefficient [W/(m^2·K)]
E_h	the annual heating energy consumption [GJ/yr]

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1.1. BSim 2000

The Building Simulation program 2000 (BSim 2000) was developed by the Building Research Institute in Hørsholm, Denmark. The program can be used for thermal and energetic building simulation over the whole year. When a 3D model is built, individual rooms are inserted step by step. Each wall of a room is assigned materials characteristics and its surface properties relevant for heat sharing by radiation. After the model is built, rooms are arranged into groups called "temperature zones". For each temperature zone, the operative temperature, the way of heating and cooling, the air-conditioning operation, the lighting and number of occupants during the whole day are entered. Before starting the computation, the building location with its latitude, longitude, altitude, and time zone are entered. For more accurate simulation, the actual climatic data measured may also be used in the following format: day, month, and hour, outdoor air temperature, relative humidity, direct and diffused solar radiation, total duration of sunshine, wind direction and its velocity.

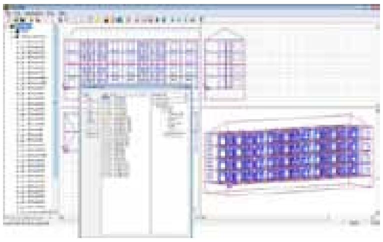

Fig. 1. Geometry of the building in software BSim

The time and space discretization steps for the numerical solution of the heat conduction transmittance are chosen for a year-round simulation. In the calculation, a time step length of 4.7 seconds (which means 786 time steps per hour) is used. The space discretization step is chosen automatically. After initializing the calculation, a year-round simulation is accomplished using the climatic data inserted, the technical building services operation required, and the building exploitation model during the typical day for every month of the year. A tabular and graphic recapitulation forms the output of all the energies needed for each part of the building services operation.

The software calculates the transient hygrothermal behaviour of the building in a very short time interval using the Fourier heat equation. The BSim 2000 software uses iterative methods to solve these dynamic states.

2. Investigated building description

The dwelling house analyzed in Lucerne was sized 31.4 by 11.1 meters being situated 477 meters above the sea level as a detached building. It is a three-storey brick building with a basement and a saddle roof. It is composed of two separate mirrored sections with 12 flats and 794 m^2 of floorage. In each dwelling unit sized 2+1 where the floorage is about 66 m^2, two persons live on an average.

The heat source for warm-water central heating is a furnace oil boiler, which also is also used to prepare hot water. The temperature gradient designed is 70/50°C. In the building, a forced air system is not applied and the assumed fresh air supply is 30 m^3/(hr, person). That means that ACH = 0.3. The heat transmission coefficient of brick structures is approximately U = 1.40 W/(m^2·K) and the windows have double-glazing with U = 2.50 W/(m^2·K). The house can be seen in Figure 3. Its usage is defined in [5]. The below table lists the average monthly climatic data for Lucerne and Brno.

Table 1. Comparison of average temperatures. [°C]

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

3. Comparison of simulation and measurement

In the dwelling house analyzed, the actual annual energy consumption for heating E_h [GJ/yr] was calculated at549 GJ/yr. The climatic data for Brno were used. The air exchange was taken to be 0.5 1/h. The building was occupied by 24 persons.

An identical calculation was also made for Lucerne, Switzerland. There, the value of E_h calculated was only 416 GJ/yr. The difference of 133 GJ/yr is due to the warmer climate in Switzerland.

In the Swiss dwelling house in Lucerne, the annual energy consumption for heating and hot water preparation was measured. The comparison between the actual consumption and that computed by the BSim 2000 program is presented in *Table 5*. The energy consumption for hot water preparation (100 GJ/yr) was determined on the basis of the actual total energy consumption. Then, the model deviation in BSim 2000 from the actual energy consumption in 2007 is about 8 %.

3.1. Influence of multiple air change (ACH)

The percentage share of a particular influence entering in the calculation may be verified using the energy model of the dwelling house created by the BSim 2000 program. In the previous calculations, the multiplicity of the $ACH = 0.5$was applied, but according to the "Swiss way of usage", the air change multiplicity is only $ACH = 0.3$. The influence of the air change multiplicity on the actual energy consumption for the heating is presented in the following *Table2* for different climatic data.

*Table 3*shows that the percentage share of the heat ventilation loss ranges from 5 % to 9 % in the chillier months in Lucerne and is even 18 % in January in Brno. The percentage share of the heat ventilation loss depends on the specific air change value.

3.2. Comparison between the reality and the BSim 2000 program

In the Lucerne dwelling house, the annual energy consumption for heating and hot water preparation was measured. The comparison between the actual consumption and that computed by the BSim 2000 program follows. The energy consumption for hot water preparation (100 GJ/yr) was determined on the basis of the actual total energy consumption. The actual energy consumption for heating in 2007 is 418 GJ/yr. The one simulated by BSim 2000 is 387 GJ/yr, which is a deviation of8 %.

3.3. Influence of night heating decrement influence

The night heating decrement influence was tested using the same house model in BSim 2000. 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 savings varied ranging from 4 % in colder months up to 16 % in the warm month of September.

Table 2. Energy demands for heating [GJ/yr]

Month	Brno (CZ)		Lucerne (CH)	
ACH	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
June	7	15	6	14
July	9	17	8	16
August	10	17	8	16
September	10	18	9	16
October	9	17	8	15
November	8	15	6	13
December	5	12	5	11

3.4. Influence of solar radiation

The climatic data entered to the BSim 2000 software also included solar radiation. Hence, it is possible to test the solar radiation influence on the building heating. The results are shown in Table 3.

Table 3. Solar radiation influence in [%]

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

From this table, it is evident that the solar radiation share of the total heating energy consumption has a major importance. In winter months, the percentage share ranges about 3 %, but in the spring and autumn months, the solar radiation share has the larger significance – up to 21 % in Brno and 25 % in Lucerne.

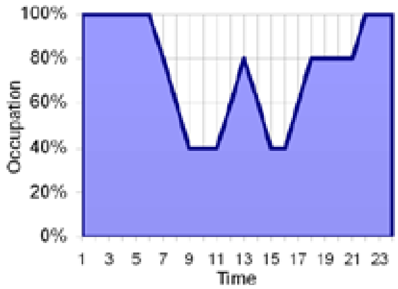

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Fig. 2. Dwelling building occupancy during the day

3.5. Influence of heat produce from occupants

In the previous energy calculation, a model with 24 persons in the whole building was considered. These persons were entered to the calculation as the inner heat sources with a value of 70 W/person. The influences of the heat production of persons were thought of as corresponding to the room occupancy behaviour determined experimentally and depicted in Figure2.

3.6. Influence of heat production from lighting

The next influence, which can affect the total energy demand for heating, is the heat gained from lighting. Based on [2], in every dwelling unit, a lighting heating capacity of 9.4 W/m^2 is considered with the capacity being distributed in time as shown in Figure 3(a).

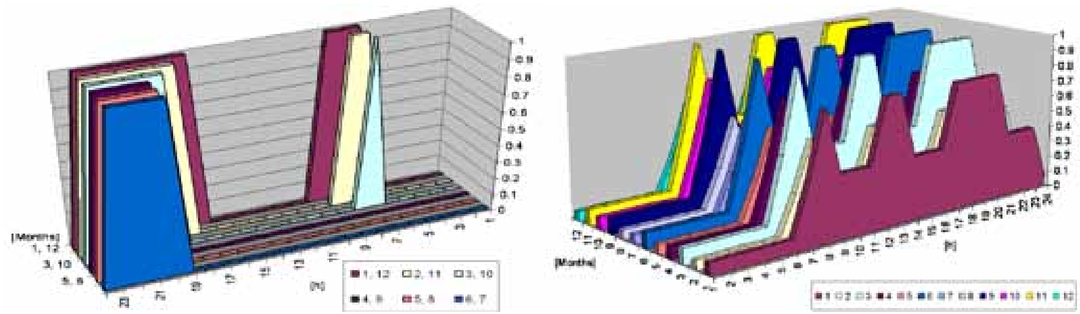

Fig. 3. (a)Relative heat gains from lighting in time; (b) Relative heat gain from electric appliances in time

3.7. Influence of electric appliances

Various electric appliances are placed in each flat of the house. The heat capacity and service time of these appliances are variable. Based on [2], a heat capacity of 3 $W/m^2$was used, relatively distributed in time as shown in Figure3(b). The percentage share of the total heat demand is from 3 % in colder months up to 6 % in the warm month.

Table 4. Influence of heat gains from lighting in [%]

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

4. Evaluation of the influences listed

Above, some of the influences on the calculation of the total energy demand for heating are listed. A summary of particular percentage shares is given by Table 8.

It is evident from Table 5, that the heat loss due to transmission and the heat loss due to ventilation have the highest shares of the total energy demand for heating. The highest heat gain comes from 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.

Table 5. Percentage share of particular influences

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

5. Conclusion

It has been found that the simulation carried out by the energy model in the BSim software most approximates the realistic heat demand. As the only one from of the methods selected, this simulation program works with detailed climatic data. From the simulations in BSim 2000 described above, it follows that the heat losses due to transmission and ventilation have the highest percentage share of the total energy needed for the actual building operation. The effect of night decrement is about 5 % of the reduction of the energy consumption. The heat gain effect is approximately 20 %.

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