Evaluation of energy consumption and indoor air quality of a low energy row house

TOMAS HLAVACKA
Department of Building Structures
Brno University of Technology
Veveri 95, 602 00 Brno
CZECH REPUBLIC

Abstract: - The article deals with the student evaluation project of energy consumption and indoor air quality in a low energy row house, in the Moravian town Kuřim , Czech Republic in the Central Europe. The reference house was chosen from the set of four row houses built from recycled materials. For evaluation of energy consumption several calculation models were used, i.e. computer simulation models, calculation models based on the local standards and measurements in the building premises. For quality of indoor climate the measurements of indoor parameters such a humidity, temperature and CO_2were carried out.

Key-Words: - Low energy house, indoor air quality, energy consumption, recycled materials

1 Low energy row house in Kuřim

The reference low energy row house used for the evaluation of energy consumption and indoor climate is situated in the town Kurim, Czech Republic. The building is situated in the area with Central European climate with average temperatures in January around -2,5ºC and 18,5ºC in July. The building we focused on is a corner house of four row houses built up in 2005 and it is inhabited by family with two children.

For the constructions of the houses the following recycled materials were used:

- the wooden-cement blocks filled with concrete and polystyrene thermal insulation for vertical perimeter load bearing walls (filled with concrete and polystyrene thermal insulation)

- the thermal horizontal insulation for the ceiling.

The perimeter walls are additionally insulated by contact thermal insulation with surface plaster coating.

The choice of building materials was done according to laboratory tests and software numerical simulations by the scientific project MSM 26100008 on the Brno University of Technology. The wood cement blocks are made of residual wood produced as a waste in the wooden manufactory, and the defibering cellulose is the product of waste paper with special material modification.

For air exchange is used the forced ventilation machine, providing 75 percent of heat recovery, which is equipped by 1,67kW heating coil. The additional heating is covered by 1,2-2kW electrical heating coils situated in each room, running on the low cost night energy.

The domestic hot water is heated in electric boiler and 4m^2 solar thermal collectors are supporting the heating and decreasing the energy consumption of boiler by 40% per year.

2 Energy consumption evaluation

Energy consumption of the house in Kurim was evaluated in two ways. The first was the simulation procedure by advanced simulation program B-Sim with use of a local climatic data. The second verification was done according to calculation based on the local standards. These calculations aren't such accurate as the simulation method, but can verify the overall energy consumption and energy gains by months and due to this the outputs from the simulation can be validated.

2.1 Computer simulation of energy consumption

For computer simulation method was used the Danish simulation software B-Sim with use of local Czech climatic data in the location Kucharovice, measured by Czech meteorological institute and the chief of the project associated professor Jiri Sedlak on the research of Czech grant academy no. 103/97/1199 called the Reference climatic years for simulation and evaluation of energy demand of buildings. At first was the inner space of the house divided into the zones according to the operation of heating and ventilation and the simulation model was prepared. After that was inserted the set of technical parameters of inner space such as material properties, operating schedules of technical equipments and people load.

The simulation software provides the calculation of the time behavior of the interior climate condition according to real climatic data both for the inner temperature, humidity, CO_2 concentration and total energetic stability of building.

2.2 Calculation based on local standards

The calculations by local standards are based on monthly average climatic data with steady state temperature and humidity. The local regulation for calculation corresponds to European and ISO standard and is modified for specific Czech conditions.

These calculations included the computations of the building energy balance, this means the temperature losses caused by infiltration, ventilation, technical equipment and domestic hot water heating, as well as the temperature gains due to the heating, solar radiation, metabolic heat and domestic appliance. The calculation deals also with the heat recovery. The thermal stability of the building is shown on the mathematical equation(1)., where the Q_r means the returned heat, Q_h the energy need for heating, Q_w the energy need for the domestic hot water warming and the Q_t the total energy loss of the building.

$$Q + Q_r = Q_h + Q_w + Q_t$$

(1) The thermal stability of the building

The output of the calculation is a protocol which gives adequate information about the purpose of calculation, the reference of used standard, description of the building, construction materials, and the location, description of the zone divisions and so the assignment of rooms to the zones, information about the dimensions and method of the calculation and also the information about heating and ventilation.

2.3 Results acquired by means of computer simulation

The results acquired by means of computer simulation were verified with the results calculated on local standards. After the formation of complete model and the implementation of the building and neighborhood parameters the time behavior of the temperature, humidity, CO_2 concentration as well as energy gains and losses are issued.

The complete results are shown on the table, after the period is chosen. The evaluation of energy gains and losses for low energy house in Kurim, Czech Republic was done for year 2006.

2.4 Results taken out by calculation based on local standards

The results of calculations by local standards were prepared on standard computer excel calculation software, with use of the formulas given. These calculations are based on the average computational temperature and humidity values based on a long time monitoring of the climate in the given location prepared by the National standards institute. The calculations are not as accurate as the simulation method by computer program, but overall it gives approximately the same values of total energy balance as the simulation method.

3 Indoor air quality evaluation

For the indoor air quality evaluation was carried out the long time measurement of indoor temperature and humidity by several data loggers fixed in the internal space of the rooms, measurement of the air flow on the forced ventilation air outlets and the ion amount and charge.

3.1 Temperature and humidity measurements

The observation of indoor temperature was at first done by the calibrated thermal and humidity data loggers, activated at synchronized adjustment on start and observed for a winter period 2006.

3.2 Indoor ventilation outlet air flow measurements

Recording of the airflow at the ventilation outlets was done by the monitoring device equipped with the air-screw anemometer. The values of airflow were measured on all of the ventilation outlets and were compared with the values proposed by design. The indoor ventilation outlet measurements are necessary for investigation of hygienic behavior of the interior air.

3.3 Indoor ion observation

Observation of ion concentration of indoor space was done by measuring with cylindrical aspiration capacitor. These measurements were done by cooperation with the Faculty of Electrical Engineering and Communication. This observation was not made properly due to the system error and the results haven't been accurate, so the measurement has to be repeated again. The ion observation should be done for the analysis of the ion concentration. The positive influence of the negative ion concentration has been proved and is presumed for the children illness recovery in the natural caves in Czech Republic. The use and influence of building materials in low energy buildings on the ion charge is a complete research done on the Department of Building Structures of the Faculty of Civil Engineering.

4 Practical measurements

The final practical measurement is continuously in progress and the output of the central measuring station is permanently recorded. The observation is focused on the material thermal and humidity properties as the interior climate conditions. The external climatic data are collected by external measuring devices connected to central measuring unit.

4.1 Central measuring unit

The central measuring unit is built up with the central unit Adam 6500 and four isolated data flow converters Adam 4520. The measuring sensors are calibrated and are used for the monitoring of internal air properties and the local external meteorological data.

4.2 Calibration of sensors

The temperature and humidity sensors have been calibrated before the measurements started. The calibration of the thermal sensors was done by exact mercury thermometer with the accuracy on decimals. The humidity sensors were calibrated with use of the two exicators with saturated saline solution in the distilled water, providing the steady humid state environment. For the humidity of 88% was used the saturated solution of KCl salt and for humidity 33% the solution of $CaCl_2{\cdot}2H_2O$.

4.3 Connected devices

On the central unit Adam 6500 are connected devices both for inside air properties and outside meteorological data measurement. The inside thermal-humidity properties were measured by thermal resistor sensors and humidity sensors. The concentration of CO_2 is measured with help of the CO2 sensor and special data logging machine.

On the external constructions are measured the surface temperatures for verification of the multi-layer construction properties.

In the exterior the main meteorological data are collected by means of use of the thermal and humidity sensors, anemometer and the sensor for solar radiation.

5 Summary

For evaluation of the energy consumption of the low energy house have to be prepared the local measurements and also the simulation and computations with help of software to avoid the errors and verify the used procedures. The output of the measurements and calculations need to be presented in complete protocol containing all main data as it is mentioned in local regulation.

Focusing on measurements and simulation done on the low energy house in Kurim, the results simulated by computer software and the results of measurements were compared with the observation of the energy consumption done by inhabitants. It can be said that the results approximately corresponds to each other, when concentrating on a long time period. Some differences between simulated and measured values are caused by nonconforming realization of the external building constructions recently.

For the measurements of indoor air it can be said, that the forced ventilation system used in the low energy house is a great device for creation and maintenance of its quality.

References:

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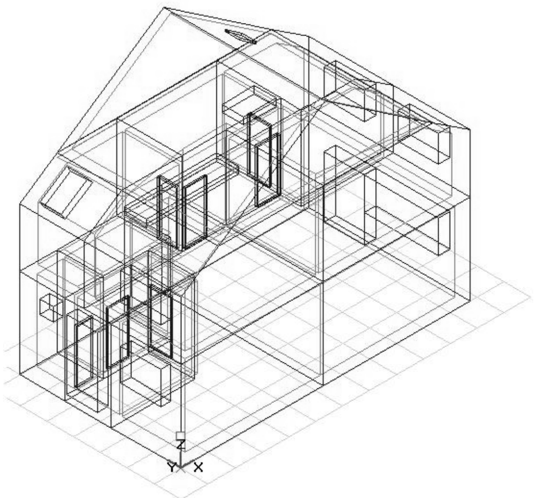
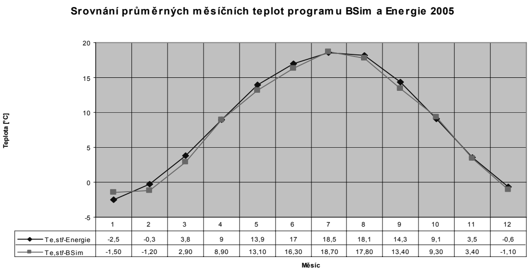


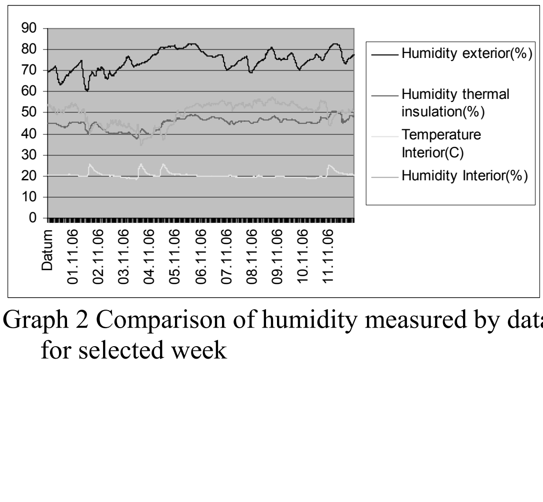
Fig.1 The zone model of a low energy house in Kurim prepared in the building simulation software B-Sim

(KURIM)	Q Heating	Q Infiltration	Q SunRad	Q People	Q Transmission	Q Ventilation	Co2 (ppm)
Sum/Mean	5133,17	-1866,38	3251,73	2336,00	-6368,02	-1618,23	499,40
1	795,56	-18,95	113,86	198,40	-1048,05	-182,40	498,10
2	712,37	-19,61	158,53	179,20	-938,60	-219,31	497,60
3	730,98	-146,90	260,32	198,40	-866,78	-293,83	488,60
4	623,92	-336,59	337,56	192,00	-603,79	-284,33	467,50
5	161,01	-277,31	403,58	198,40	-129,21	-88,12	514,20
6	0,00	-157,08	418,97	192,00	-156,00	0,00	497,90
7	0,00	-106,46	461,02	198,40	6,02	0,00	441,30
8	0,00	-121,66	397,57	198,40	-44,59	0,00	481,10
9	0,00	-200,14	300,38	192,00	-179,11	0,00	639,50
10	618,86	-311,77	208,35	198,40	-646,72	-150,66	483,20
11	700,38	-129,23	118,55	192,00	-793,68	-207,96	488,60
12	790,08	-40,68	73,03	198,40	-967,52	-191,62	495,90

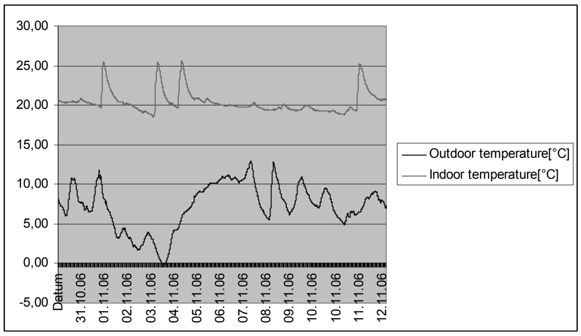
Table 1 The monthly energy stability of a building calculated with use of simulation software B-Sim



Graph 1 Comparison of average monthly temperatures calculated by software B-Sim and given by a national standard



Graph 2 Comparison of humidity measured by data logger for selected week



Graph 4 Interior and outdoor temperatures measured by data logger with visible extremes of indoor temperature after usage of stove wood heating