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Simulation for (Sustainable) Building Design: Czech Experiences

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ABSTRACT

This paper attempts to outline the current state-of-the-art in the Czech Republic regarding the use of integrated building performance simulation as a design tool. Integrated performance simulation for reducing the environmental impact of buildings is illustrated by means of three recent HVAC selection and design studies for the new "Indonesian Jungle" pavilion in the Prague Zoo, for conversion of a historical building (water mill) into a museum, and for a city center office with thermal comfort complaints.

The paper elaborates the modeling and simulation work that was carried out to support the design teams of the above projects. This includes a discussion on how the simulation results were transformed in relevant design information.

The paper finishes by indicating directions for future work that is needed to be better equipped in order to address design problems such as the one indicated above.

1. INTRODUCTION

Many buildings are still constructed or remodeled without consideration of energy conserving strategies or other sustainability aspects. To provide substantial improvements in energy consumption and comfort levels, there is a need to treat buildings as complete optimized entities not as the sum of a number of separately optimized components.

Simulation is ideal for this because it is not restricted to the building structure itself but can include the indoor environment, while simultaneously taking into account the outdoor environment, mechanical, electrical or structural systems, and traditional and renewable energy supply systems. By assessing equipment and system integration ideas, it can aid building analysis and design in order to achieve a good indoor environment in a sustainable manner, and in that sense to care for people now and in the future.

Many heating, ventilation and air-conditioning (HVAC) design practitioners are already aware of building simulation technologies and its benefits in terms of environmental performance assessment of building designs. However, as yet, few (Czech) practitioners have expertise in using these technologies. This will quickly change due the introduction of:

performance based standards; societies such as the International Building Performance Simulation Association[1] (IBPSA); and appropriate training and continuing education.

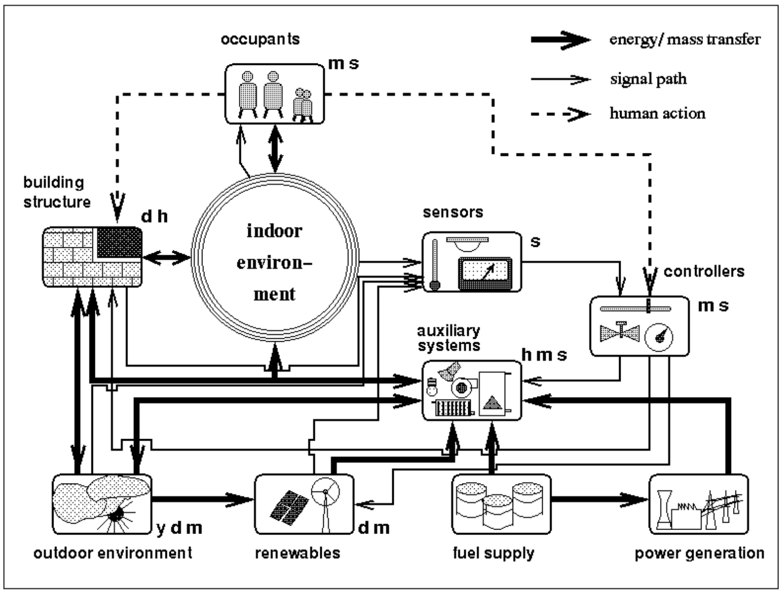

Figure 1. The building as an integration of energy systems.

The use of computer modeling and simulation for the design and/ or evaluation of buildings and HVAC is quickly moving from the research and development stage into everyday engineering practice (see [1]). In contrast to the traditional simplified calculating methods (not considering the system dynamics), computer based modeling approaches reality much closer.

Computer simulations are demanding more input information and data processing than ordinary design work. On the other hand, once the model is prepared, simulation techniques allow quick and detailed analysis of various solutions for the building geometry and construction as well as for the design and operation of HVAC systems. The aim of computer modeling is to optimize the design of a building and its service system according to the requirements for indoor air quality while keeping energy consumption at minimum levels.

The following case studies serve both to illustrate the current state of the art in the Czech Republic, and to illustrate different options for energy conservation. All simulations were done with the integrated building performance modeling and simulation environment ESP-r [2]. Different ways of energy saving are given:

2. EXAMPLE APPLICATIONS

2.1 Evaporative cooling of the Indonesian Jungle pavilion in the Prague Zoo

The computer model of the Indonesian Jungle pavilion in the Prague Zoo was used as a primary information source for the estimation of the energy demand in this highly unusual building [4].

[1] http://www.ibpsa.org

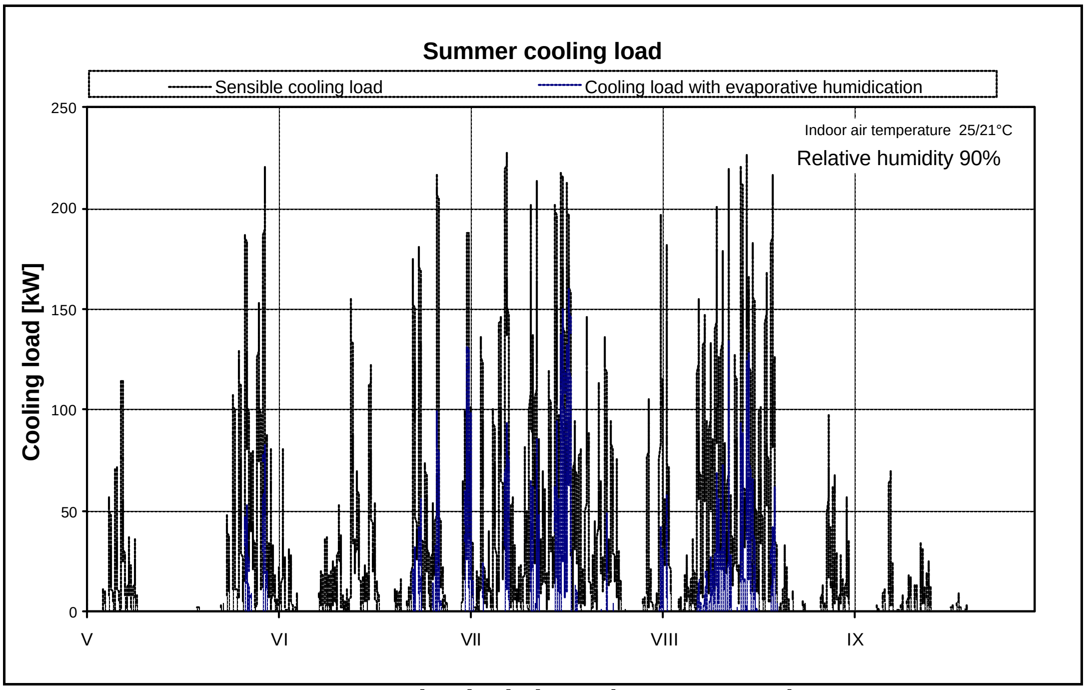

Figure 2. Cooling loads during the summer months

In view of the required indoor relative humidity, which was very high (70 to 90%), an alternative cooling technique was introduced using water sprayed into the pavilion interior. As can be seen in Figure 2 and Figure 3, this decreased the maximum cooling capacity demand from 215 kW to 160 kW. The time when the cooling system would be in use was reduced from 2000 hrs to about 1000 hours per year. The simulations predicted also the number of operating hours with high cooling loads, for example cooling loads higher than 120 kW will occur during only 80 hours per year.

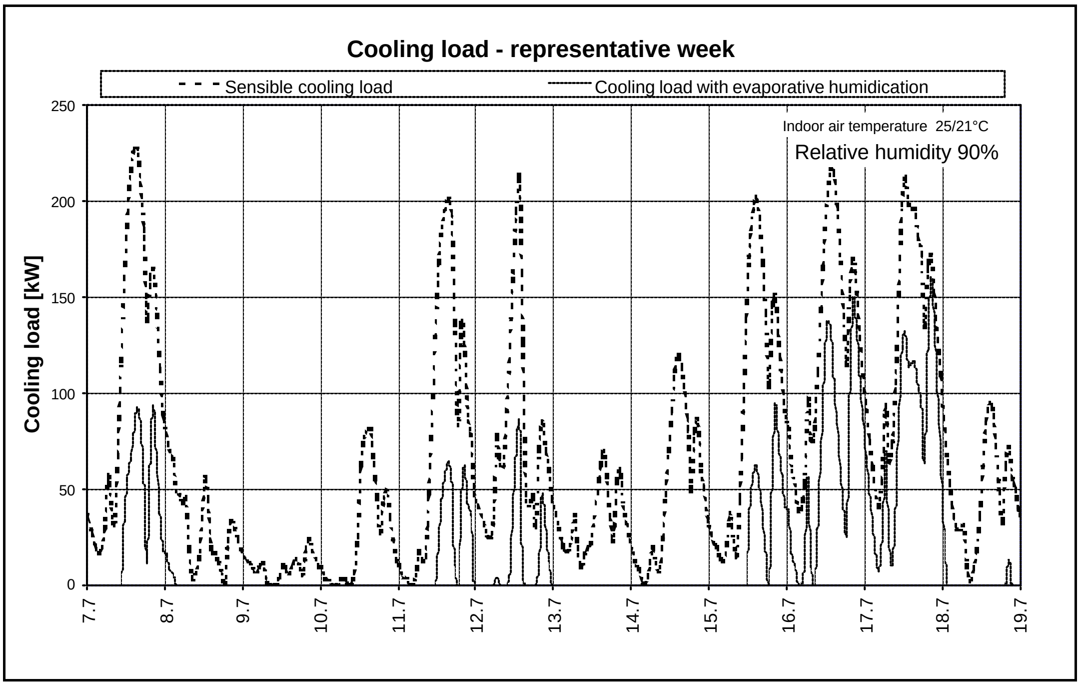

Figure 3. Cooling loads during a representative week

Based on the simulation results the primary parameters for HVAV plant design were specified. An air flow rate of 48 000 m^3/h (3 ACH) will be used in the summer. Fresh air will be cooled and humidified in he AC unit. The second step adiabatic cooling (humidifying) will be done in the pavilion. Pneumatic nozzles will spray a maximum of 100 kg/h of water. In winter only 8 000 m^3/h of fresh air will be used. The rest will be circulated. To minimize the water condensation on the roof, local heating close to the roof is recommended. The maximum cooling capacity of 100 kW will be used only a few times during the year. A small source with storage is recommended.

2.2 Influence on cooling energy demand of stored heat in heavy constructions

One of the main disadvantages of traditional calculating and design methods for HVAC systems is the underestimation of the impact of the heat capacity of the building. In the design of the new galleries in the historical Sovovy Mlýny (watermills) in Prague, computer simulations were used to predict the required capacity of the cooling system.

The initial design made by a standard calculation estimated the cooling capacity about 100 kW. The cooling system was dimensioned accordingly. The simulation showed that for an indoor air temperature of 24°C a cooling capacity of 20 kW would be enough to remove both the external heat load and the internal heat gains from occupants and lights.

The study helped not only to lower investment costs for cooling system but most of all to minimize changes in the construction of a valuable historical building.

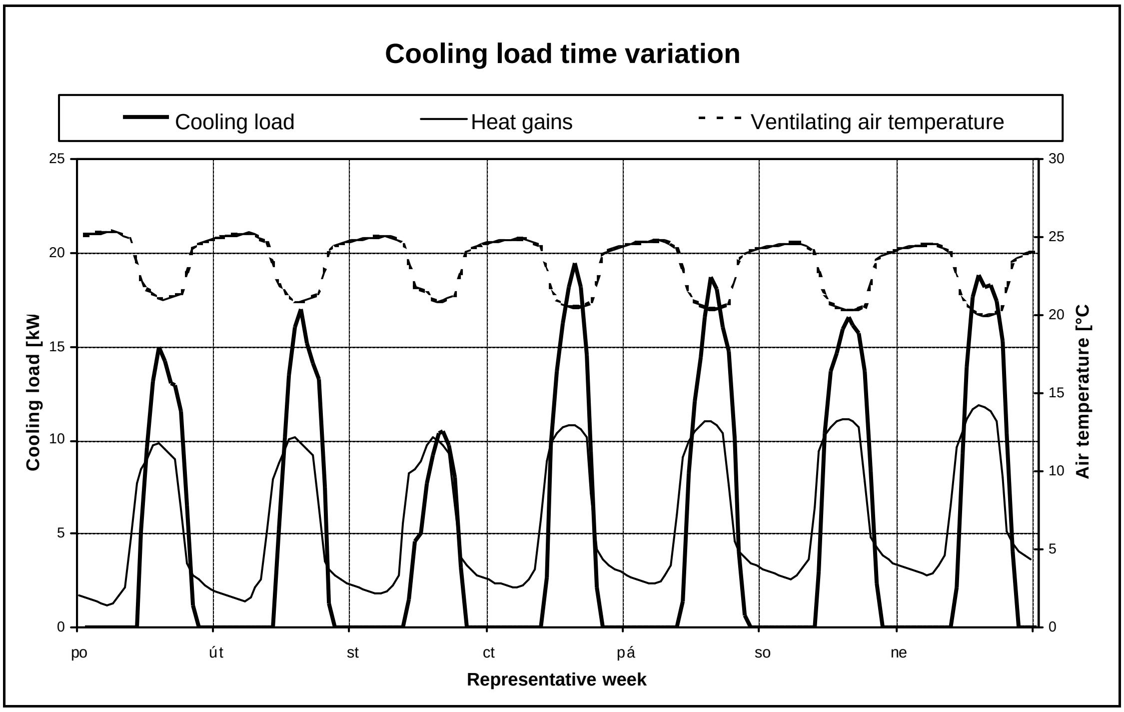

Figure 4. Cooling load variation during a representative week

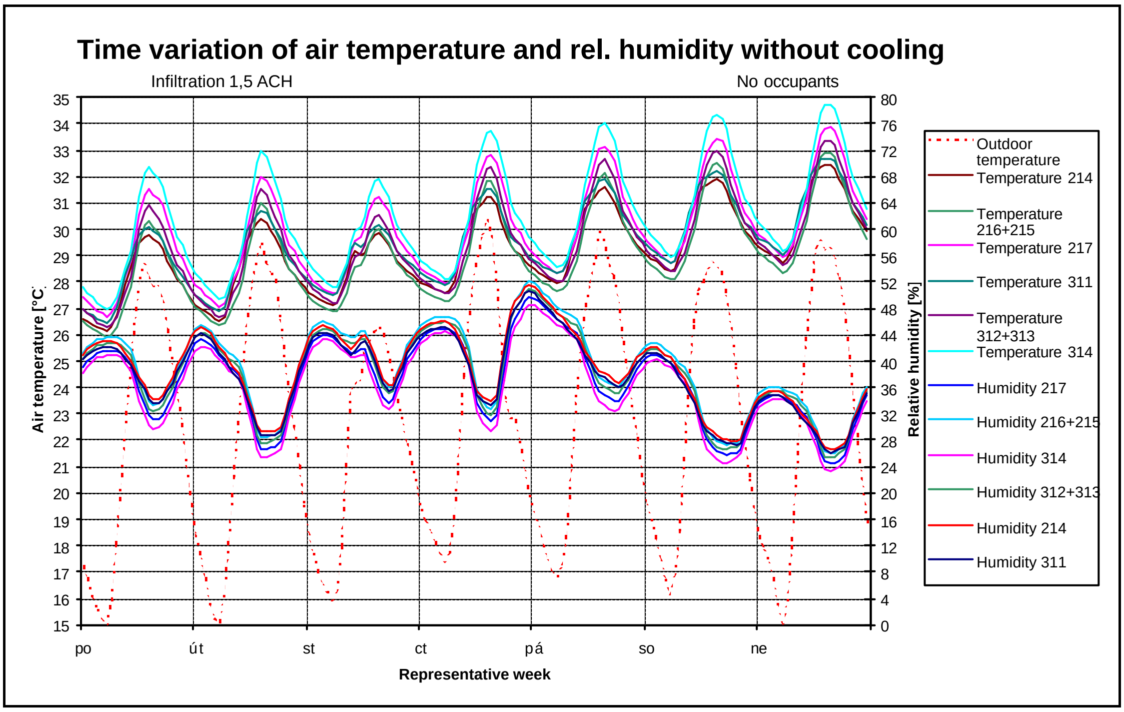

Figure 5. Air temperature and relative humidity during a representative week

The simulation was combined with measurements in the existing building and the indoor environment was assessed also for the case without any cooling device. The influence of number of visitors, the lighting and open or closed shutters was tested.

2.3 Control strategies and energy consumption of A/C device

The air-conditioning system for offices in Prague city center was assessed according to the current standards and using computer simulation. Both methods gave very similar results in cooling loads and air conditioner sizes. The orientation and slope of the garret windows caused relatively high solar heat gains during the whole day. Using computer simulation, several control strategies were analyzed yielding. This gave interesting results:

- When continuously operated, the air-conditioning device is capable to keep the indoor air temperature at 25 °C but the cooling energy consumption is very high.
- If the air conditioner operates only on working days from 6 a.m. to 7 p.m., the indoor air temperature oversteps the required level (25 °C) and even exceeds 31 °C.
- To operate the air-conditioning device also over night in a reduced-output mode (the temperature set-point is 32 °C over night) seemed to be the optimum cooling strategy. The indoor air temperatures are very close to the required level while the energy consumption is almost the same as in the previous case.

Table 1. Results of Computer Simulations – Comparison of Different Cooling Strategies

Cooling strategy	Maximum temperature in working hours [°C]	Maximum temperature [°C]	Maximum cooling load [W]	Annual cooling energy consumption [kWh]	Time when the temperature exceeds 25°C [hours]
1	25	25	3 570	3 330	0
2	31.4	43	3 780	2 905	214
3	26.7	32	3 780	2 975	82

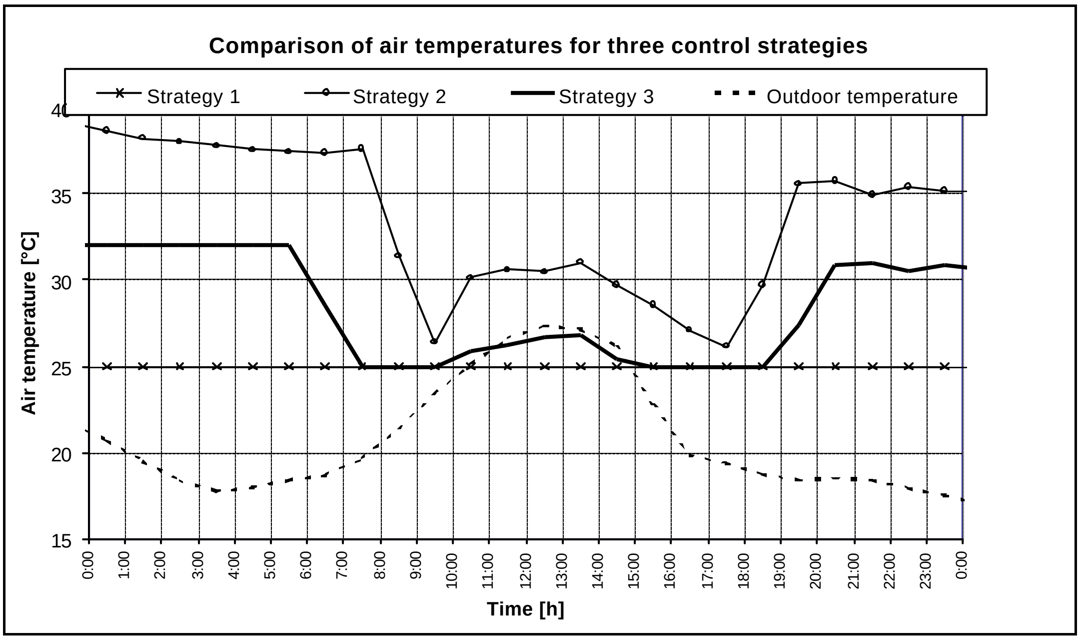

Figure 6. Air temperature variations for the three control strategies

2. CONCLUSIONS

The above case studies both illustrate the current state of the art in the Czech Republic in terms of modeling and simulation, as well as demonstrate different options for energy conservation in new and existing buildings.

It has been shown that lower investments and operational costs can be achieved by detailed analysis of the air-conditioning system and by application of a low-energy cooling technique, such as evaporative cooling, in case of the jungle pavilion of the Prague Zoo.

By considering the thermal storage capacity of building walls we can not only decrease the cooling energy costs but also minimize costs associated with modifying the building construction, in case of the Sovovy Mlyny historical building in Prague.

The operation and control strategy analysis of existing air-conditioning system can decrease operational costs while minimizing summertime overheating in case of some offices in the center of Prague.

The uptake and use of building simulation in the Czech Republic still lags behind other countries. This is caused by a number of interacting barriers:

- people in practice are not sufficiently aware of the advantages offered by building simulation;
- practitioners have little experience with modeling and simulation because there are only a few practical applications in the Czech Republic;
- language problems;
- lack of hardware.

However, engineers in the Czech Republic are quickly catching up by activities such as:

- demonstration of the methodology in detail with a case study including calibration;
- creation of a representative hourly weather database for Prague and a typical Czech construction properties database;
- working out of practical case studies demonstrating the applicability and value of modeling and simulation for solving typical Czech problems;
- incorporation of lectures on modeling and simulation in the undergraduate and postgraduate curricula at higher institutes of education in the Czech Republic;
- participation in international research projects and incorporation of modeling and simulation in Ph.D. research;
- foundation of IBPSA-Czech Republic.

There still remains a lot of work to be done to promote building simulation so that it will be generally recognized and accepted by practitioners in the Czech Republic as a powerful tool in the field of environmental engineering. This is a very challenging task for the future.

REFERENCES

[1] Nakahara, N. Yoshida, H. Udagawa, M. Hensen, J. 1999. *Proceedings of the 6th International IBPSA Conference Building Simulation'99*. Volume I,II,III, Kyoto

[2] ESP-r 1998. *A Building Energy Simulation Environment. ESRU Manual*. Energy Systems Research Unit. University of Strathclyde, Glasgow

[3] Lain, M. 1999. *Posouzení klimatizace kancelárí*. [Research report], CTU in Prague, Prgue

[4] Barták, M. Drkal, F. Hensen, J. Lain, M. 2000. *Analýza vnitrního prostredí pavilonu ZOO Praha Indonéská džungle.* [Research report], CTU in Prague, Prgue

[5] Barták, M. Drkal, F. Hensen, J. Lain, M. 2000. *Analýza tepelného stavu prostredí galerie v objektu Sovovy mlýny*. [Research report], CTU in Prague, Prgue