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MODELING AND SIMULATION OF INDOOR ENVIRONMENT AND BUILDING ENERGY PERFORMANCE

Karel KABELE

CTU in Prague, Faculty of Civil Engineering, Department of Microenvironmnetal and Builiding Services Engineering, Thakurova 7, Praha 6, Czech Republic
Email: kabele@fsv.cvut.cz

Summary: Contemporary development of architectural engineering and building services providing building operation is related to energy supply and use. The level of building dependence on energy is given by architect's priorities during conceptual design phase. Within existing traditional buildings it is possible to predict energy and environmental performance using empirical formulas, experience and simplified models, while within modern buildings it is difficult to describe synergy performance of particular building energy systems and its impact on indoor environment quality and energy performance. For these and other cases it is possible to use numerical modelling of building energy systems and create virtual laboratory to perform experiments with the building and to optimise building design. Different viewpoints are used to classify tools for building simulation. According to the method, detail level and model purpose following classes are classified: static models, simplified dynamic models, response function models, numerical methods models, analogy with electrical circuits and CFD (computational fluid dynamics) models.

Keywords: performance simulation, low-energy building.

1. INTRODUCTION

The development of engineering and architecture in recent years can be characterized as a search for attractive and successful solutions to the criteria reflect the current level of globalization and interconnection of cultures. One of the driving forces of development in this area are still rising energy prices resulting from increasing dependence on energy of our civilization and the resulting trends in the search for solutions with a strong emphasis on the economics of the operation, quality of indoor environment and its impact on health and work performance. This development is reflected in ways that technical systems of buildings - from the height of buildings surpassing records using the latest technology over structures based on natural principles to the construction and low cost.

Example of „hi-tech" building is in 2010 opened Burj Khalifa in Dubai with a height of 828 m to create a vertical city. (Fig. 1).
Example of structures based on natural principles can be a school Eastgate Harare in Zimbabwe [12], where the author utilized the principles of natural air conditioning termite (Fig. 2) and appropriate orientation of buildings, location of storage walls and channels for natural ventilation due to buoyant forces created by an object with a low energy consumption and the climatic conditions favourable internal environment.
Examples of low-energy buildings with low investment costs may be a pilot project recently completed residential building in Sušice [13] (Fig. 3), which offers housing for 12 families in apartments with controlled ventilation and energy saving solutions disposition.

Fig. 1 Burj Khalifa, Dubai

Certainly this list is not exhaustive, but the unifying element in all existing buildings is the energy required to operate the building. It is the energy required for

• ensuring the required parameters of the internal environment of buildings (interior temperature, air quality, artificial lighting);
• meeting the needs of human health (sanitary, domestic hot water);
• distribution of energy and media (electrical, gas, industrial gases);

• management and control systems of buildings (fire, intrusion, regulation, security, smart buildings);
• transport systems (elevators, escalators, travelators, tube-mail);
• technological equipment (central vacuum, kitchen, laundry, swimming pools, etc.).

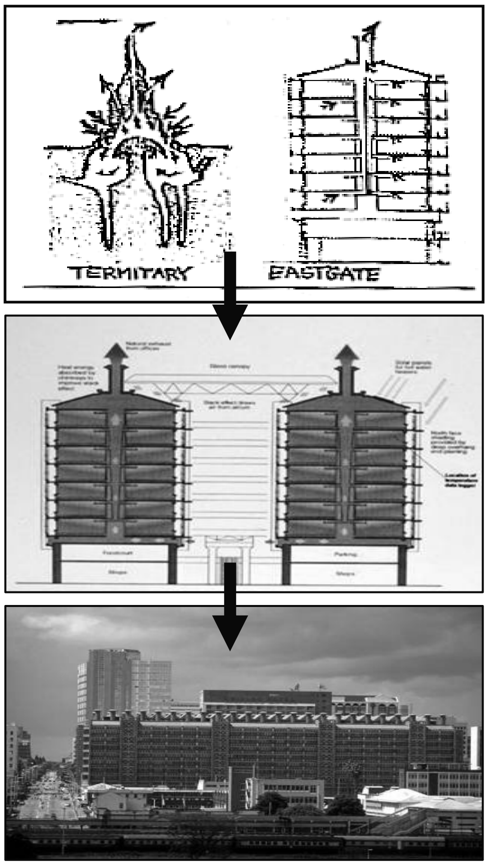

Fig. 2 Eastgate Harare -Zimbabwe

Description of the energy and environmental performance of buildings, which is a comprehensive expression of the energy flows in the various subsystems, their interactions, the resulting flow of energy in the measured image points and spatio- temporal parameters produced by the internal environment is the foundation for building and optimizing system performance in terms of energy [1].
For existing buildings can be, based on the measurement of energy supplied flow rate and temperature of heat transfer materials and the chosen parameters of the internal environment of an energy audit to determine potential energy savings, space, and propose to implement measures to reduce energy needs and consumption. However, this procedure is not applicable to the proposed building at the design stage. For standard and simple objects can be in determining the expected energy consumption based on empirical relationships and analogies, used since the beginning of the European School HVAC (building services), which dates back to 19th century 80s. For a modern, technology-equipped building with sophisticated building structures and strict requirements for the definition of indoor environment, however, a conventional computational tool are not sufficiently sensitive and accurate, and therefore since the 80 dates the beginning of the 20th century the development of applications of numerical methods for modelling and simulation of energy and environmental performance of buildings. The group around the prof. Joseph Clarke from the University of Strathclyde, Glasgow, founded the international organization IBPSA (International Building Performance Simulation Association), which brings together experts in the simulation of buildings since 1985 and regularly organizes the biennial Conference Building Simulation. Since then, the methods of numerical modelling and simulation gradually come to practice and develop their use.

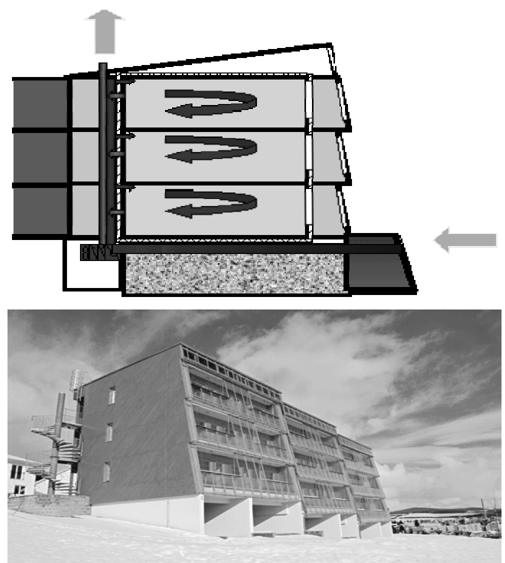

Fig. 3 Low energy and low cost residential house Sušice, Czech Republic

2. BUILDING ENERGY AND ENVIRONMENTAL PERFORMANCE NUMERICAL MODELING

The development of computer technology in recent years enabled the development of new methods and devices that support the design of buildings and technical equipment. Besides the very handsome and commercially successful graphic resources to support the process design (CAD programs) in the field of energy systems for buildings started to have computer programs that can describe the building energy and environmental performance, under variable climatic and operating conditions, known collectively building performance simulation programs. Behind the expression of building performance term we can expect such as temperature.

versus time courses, thermal comfort evaluation or the immediate needs of the energy and annual heat balance, two- or three- dimensional display of air flow patterns in rooms. The programs are used in the design phase of the building to verify its expected behaviour under different conditions and give the background to optimize the design [6]. Using computer simulation methods can be likened to a virtual laboratory in which to create a certain extent, a simplified model of a building or part. This model is loaded by different climatic and operating conditions and "measured" as observed the feedback of n the model going places. This way is possible with minimal cost compared to actual physical model and measurements to verify tens to hundreds of different variants of design elements and create such an optimization function to determine i.e. the size of this element.

On the other hand, it should be noted that working with a computer model of the energy and environmental performance of buildings is very demanding in terms of both the hardware and software, in terms of its use. For such a complex system, such as building and its technical equipment, it is a major problem in determining the input values, which are physical and geometric properties of the components and materials used. A computer model is in fact depending on the method of calculating very sensitive to different parameters and could easily happen that the result is in relation to reality completely irrelevant, just because of minor oversights or ordinary typo somewhere in the beginning. For this reason, any serious simulation program subjected to very intensive testing and verification, and each created a computer model should be tested in familiar conditions. For these reasons, it is necessary to look at the practical application of these methods. Just like doing a real model for each building and the design is based on the experience and the simplified calculation methods (heat loss degree-day method etc.), does not make sense to process for each building computer models. Using these methods is absolutely the place where they lack experience with similar problems and where the solved problem is atypical. This group is undoubtedly the most glass buildings, patio construction, assembly rooms, low energy buildings, where experience with the implementation of buildings designed using traditional methods are often very painful - the standard proposed by the heating or cooling is not sufficient in extreme conditions, residents complain of uncomfortable indoor environment and this could be mentioned further.

For the modelling of energy systems for buildings, there are two approaches, sequential and simultaneous.

In the sequential model, each element of the replacement of the relationship between input and output values so that when plugged into the system, becomes the output value of the element input value for another element. Thus, at some point in time, can start the simulation with the known boundary conditions - such as outside temperature or the temperature in the building already generated by the model building - with the calculation advancing the whole system. The individual components are therefore replaced by a "black box" - an algorithm that can be either simple or complex. This technique has certain advantages - for each element can use a different method for the modelling and advancing technical knowledge models can still improve. The problem occurs when the required input data has not yet been counted or we want the dynamic system control.

For simultaneous access to the system is replaced by a nodal scheme. Power flows between nodes are expressed as a set of equations derived in time and space. This matrix is incorporated into the matrix describing the building and created a matrix is solved once and re-elected as the final time step. An approach based on complexity is moderated in order to formulate the matrix system in relation to single node element and then to depend on the algorithm "black box", working in parallel to express the internal behaviour of the elements. The heat capacity of elements is included, the method remains the simultaneous modelling, but the task is less complex. And the model of each component can use just the current theory. The system matrix system is a system combining protocol and the problems associated with the sequential approach eliminated. Matrix building and integrating the whole system greatly simplifies the problem because it uses a single tool for their solution, which is implicit finite difference method.

3. CLASSIFICATION OF MODELLING APPROACHES AND TOOLS

The purpose of modelling energy flow is by no means an absolute agreement of model with reality, since in this case it is necessary to "optimize" money and energy to build simulation models and then depending on the expected benefits.

Because the optimization of indoor environment is a complex problem with many links, it is often necessary to first obtain a basic understanding of the problem and only after finding the weight of individual factors can continue processing the detailed model [1].

The basic classification of models results from the methods used:

- static models;
- simplified dynamic models;
- models build on the principle of function, describing the response of the system;
- model formulated on the basis of numerical methods;
- analogy with electrical circuits
- Computational Fluid Dynamics

The second criterion of classification models, the energy behaviour of indoor environment is a measure of the complexity of the model. They are mainly:

- models of buildings;
- models energy system or its components;

- integrated models of buildings and systems.

Another classification criterion is the purpose of modelling

- indoor environment;
- system behaviour;
- interaction and building systems.

4. CONCLUSION

Modelling and simulation of energy and environmental performance of buildings is a modern tool that allows you to analyze the building in terms of energy needs and predict their behaviour under various operating conditions. This tool can be used on existing and proposed buildings. For existing buildings, it is used mainly for energy audits; the simulation is to evaluate the impact of the proposed austerity measures. Other possible areas of use of existing buildings, HVAC systems, fault prediction supported by simultaneous simulation of the energy and environmental performance of buildings and compare simulated and real values of energy consumption.

The proposed building is to use the model given by the time the computer model set up and use. Utilization is the conceptual decision-architectural studies, where it is possible to change the basic parameters such as building shape, window size, design and conceptual design of HVAC systems [3] through a more detailed look at non-standard solution of the circuit elements of buildings [5] and its impact on energy and environmental performance of buildings (such as double facades, Trombe walls, transparent insulation) in the conceptual design of the building after optimizing operational control heating and ventilation in the building [4]. In addition to evaluating the proposed solutions in terms of energy consumption is often also possible to analyze the outcome of the internal environment in terms of thermal microclimate [2]. Computer modelling and simulation of energy and environmental performance of buildings should be used primarily in the following cases:

• Creation of data for strategic decision-making at the level of architectural studies (integrated models of buildings, energy systems and operations) [1];

• Modelling of non-standard solution of the circuit elements of buildings (building glass, double facades, building lightweight, low energy buildings, building details, address) on the energy and environmental performance of buildings [7];

• Modelling of non-standard solution of the elements of technical building equipment (natural cooling of buildings, heat pumps, under floor heating, hypocaustenic heating, cooling ceiling [9];

• Optimization of operational settings of heating and ventilation of buildings [1];

• Analysis of energy-saving measures to balance the energy audits [6];

• Modelling the internal environment of space - the flow of images, the resulting temperature distribution [10], [8];

• Calculation of the distribution of the operating costs of complex operational units [11].

5. ACKNOWLEDGMENT

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