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Preface

Energy and building performance simulation: current state and future issues

This special issue is devoted to simulating physical processes in buildings. Simulating energy and airflows in buildings is perhaps the best-known activity, but simulation of light, smoke, moisture, noise and the quality of the indoor environment are often just as important. This special issue gives different perspectives on the state of the art in building performance simulation.

Simulation-based information has the potential to improve competitiveness, productivity, quality and efficiency in the construction industry as well as facilitating future innovation and technological progress. In that respect, successful implementation of software tools and applications in practice will be crucial for Architecture, Engineering and Construction organisations to gain and maintain a competitive edge in the global construction market.

It is particularly appropriate to devote a special issue to this topic because the techniques of building performance simulation are undergoing rapid change. Dramatic improvements in computing power, algorithms and physical data make it possible to simulate physical processes at levels of detail and time scales that were not feasible only a few years ago.

Most practitioners are aware of the emerging building simulation technologies but, as yet, few are able to claim expertise in its application. This situation is expected to change significantly in the next few years in response to developments such as the introduction of performance-based building standards. Training in simulation is increasingly being offered as continuing education and as part of the regular curricula of higher educational institutes. The increasing interest in, and use of, simulation is also a result of the activities of societies dedicated to promotion and the effective deployment of simulation, such as the International Building Performance Simulation Association.[1] IBPSA was founded in 1986 to advance and promote the science of building performance simulation in order to improve the design, construction, operation and maintenance of new and existing buildings worldwide.

IBPSA covers broad areas of building environmental and building services engineering. Typical topics include building physics (including heat, air and moisture flow, electric and day lighting, acoustics, smoke transport); heating, ventilation and air-conditioning systems; energy supply systems (including renewable energy systems, thermal storage systems, district heating and cooling, combined heating and power systems); human factors (including health, productivity, thermal comfort, visual comfort, acoustical comfort, indoor air quality); building services; and advances and recent modelling and simulation developments in modelling and simulation such as coupling with CAD, product modelling, software interoperability, user interface issues, validation and calibration techniques.

All these topics may be addressed at different levels of resolution (from microscopic to the urban scale) and for different stages in the building life cycle (from early sketch design, via detailed design to construction, commissioning, operation, control and maintenance) of new and existing buildings worldwide (Fig. 1).

One of IBPSA's main activities is the organisation of a series of bi-annual international conferences. The most recent was Building Simulation 1999 in Kyoto. The next one will be Building Simulation 2001 in Rio de Janeiro (see http://www.ibpsa.org).

The proceedings of Building Simulation 1999 in Kyoto comprise a total of 183 papers from all over the world and are available as three printed volumes and on CD-ROM. A number of papers have been selected for this special issue of Energy and Buildings in order to provide an overview of the ''state of the field'' in terms of the scope of this journal. The papers, which follow, are expanded and improved versions of the conference papers. The process of selection, plus the opportunities for discussions at the conference, has encouraged the authors to revise their papers. In addition, the journal allows more pages than the conference, which allowed for expansions, clarifications, additional references, figures, etc.

The first two papers are of a general nature. The first paper addresses the extraordinary progress in building simulation, which is not always apparent to the researchers and developers working in their own, often narrow, field. In his paper, Kusuda recalls early simulation efforts and speculates on directions for future activities. In the second paper, Clarke

[1] IBPSA details are available at http://www.ibpsa.org.

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Fig. 1. Yasaka shrine in Kyoto.

argues that, to facilitate integrated multi-variate performance appraisal, all aspects of a building must be treated simultaneously. His paper gives examples of how the principal technical domains relating to a building's environmental performance can be coupled within an integrated simulation package.

The following two papers both concern new-generation building simulation software. Sowell and Haves focus on the relative efficiency of some methods employed in solution of building simulation models. The paper shows that graph-theoretic techniques offer significant speed advantages over other methods for significantly reducible problems and that by using sparse methods in combination with graph theoretic methods even problem portions with little reduction potential can be solved efficiently.

The next paper by Crawley et al. describes a major US effort to create a new-generation building simulation environment based on two existing simulation packages, which originate from the days of mainframe computers. Expansion of the capabilities of the 'legacy' codes had become difficult, time-consuming and expensive. At the same time, in the last 30 years there have seen significant advances in analysis and computational methods and power — providing an opportunity for significant improvement in these tools.

Each of the next four papers describes a specific building modelling issue currently of interest. The first is that, the inclusion of photovoltaic facades and other local heat and electrical power sources within building designs has given rise to the concept of embedded generation, in which some or all of the heat and power required are produced close to the point of use. The paper by Clarke and Kelly describes recent work to simulate the heat and power flows associated with both an embedded generation system and the building it serves. The second issue concerns coupled heat and moisture transfer, which is very relevant to many building applications. The paper by Ozaki et al. introduces a numerical model of combined heat and water transfer using the thermodynamic water potential. The third issue is the treatment of convective heat transfer at internal building surfaces, which has a significant impact on the simulation of heat and airflow. The paper by Beausoleil–Morrison describes a new approach — drawing upon previously published methods — for modelling mixed convection within mechanically ventilated rooms.

The fourth issue is related to the widely used ice-on-coil thermal storage tanks. In their paper, Zhu and Zhang describe how to model the charge/discharge process, in particular, the effect of ice–water density differences.

The final four papers are all concerned with building systems. Since, these systems are the actual energy consumers, system simulation is a very important issue. The first two of these papers are related to control of primary and secondary plant. The paper by Ahn and Mitchell describes how to use simulation for the optimisation of supervisory control strategies that generate the set points of the controlled variables in central cooling plants. The next paper by Liu and Dexter describes a supervisory control scheme that adapts to the presence of degradation faults and minimises any resulting increase in energy consumption or deterioration in occupant comfort. Their fuzzy logic approach is used for supervisory control of VAV air-conditioning systems. The final two papers both concern on-line fault detection, a technique which, when incorporated in a building management system, can save enormous amounts of energy and expenses. In their paper, Yoshida et al. describe the application of the very efficient Recursive Autoregressive Exogenous Algorithm modelling for on-line fault detection and diagnosis in VAV systems. In the last paper, Salsbury and Diamond describe how a model-based, feed-forward control scheme can improve control performance over traditional PID and also detect faults in the controlled process. They also discuss recent experiences of implementing the control

scheme in a real building using the BACnet communication protocol.

It is our hope that this special issue provides a good overview of the current state of building simulation. It is important to realise, however, that the current state represents only a point on our path towards truly powerful and easy-to-use tools for building and systems design and operation. As has been noted before, hopefully todays state-of-the-art can become the foundation of tomorrows promise.

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