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Air, contaminant and heat transport models: integration and application

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Abstract

Comfort evaluations cover air quality, thermal, visual and acoustic comfort. Today, only few computer programs allow for the integrated evaluation of several or all relevant parameters. Heat transport, ventilation as well as lighting in a room are influenced by each other. Therefore they should be integrally modelled. As a part of the IEA-ECBCS Annex 23 'Multizone Airflow Modelling', such a coupling has been realised by integrating the air flow and contaminant transport simulation code of COMIS into the building and systems simulation code TRNSYS. This paper gives a short description of the concept used for the coupling. Then, two application examples typical for a building design study situation are presented, the first being a multi-storey school building which was passively cooled at night due to natural stack airflow. In the second example the façade of the same building was retrofitted with a glazed outer façade. Ventilation was provided by naturally driven shaft ventilation through the façade spaces. For such cases as described in the examples, it may be necessary due to the complex interactions, to study many configurations to find optimum control strategies for the openings and the blinds with respect to overheating risk as well as to air quality. For the upper floors, the risk of overheating and low air quality may be difficult to minimize without extending the shaft above roof level. © 1999 Elsevier Science S.A. All rights reserved.

Keywords: Multizone air flow modelling; Building simulation; Integration; Passive cooling; Double face façade

1. Introduction

In the integral planning process the facade, the structure and the equipment of a building are integrally designed. Energy consumption as well as occupant comfort are the relevant criteria which are studied using computer simulation programs. Comfort evaluations cover air quality, thermal, visual and acoustical comfort.

For all these individual aspects, specific simulation programs are available today, but very few programs allow for the integrated evaluation of several or all relevant parameters (Fig. 1). Heat transport, ventilation as well as lighting are influenced by each other. Hence they must be integrally considered in the simulation process.

Not many building simulation models are very well adapted to the simulation of natural ventilation. On the other hand, multizone air flow models normally require the room air temperatures as input values. Therefore the modelling of thermally induced driving forces is limited because in many applications the room air temperatures are not known a priori. In such cases, the coupling of a thermal and an air flow model is needed.

Several concepts exist for establishing this coupling, ranging from user directed parameter transfer to a complete merging of the two model codes [1]. Quite a few attempts to integrate an air flow model into a thermal model have already been made [2].

2. Integration of COMVEN as a TRNSYS type

2.1. The multizone air flow simulation code COMIS

COMIS [3] is a multizone air flow and contaminant transport computer simulation program. Its development started during the one-year COMIS workshop at the LBNL, USA, and then has continued within the IEA-ECBCS Annex 23 'Multizone Air Flow Modelling'. The actual simulation code, written in Fortran77, is named COMVEN. Two user interfaces are available for PCs: COMERL, a simple text editor based user interface with an integrated database, and IISIBÂT-COMIS, a graphical, sophisticated user interface, developed within Annex 23 on the basis of IISIBÂT for TRNSYS.

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2.2. *The building and system simulation code* TRNSYS

TRNSYS [4] is a modular building and systems simulation code, developed at the University of Wisconsin, USA. The simulation code consists of a controller and solver part and the so-called 'Types', routines representing individual system or building components. Such Types can be easily added or modified by the user and many such contributions have been included into the official TRNSYS version. PRESIM and IISIBÂT are the graphical user interfaces available for this program. A link to AUTOCAD has also been developed recently.

2.3. *Integration of* COMVEN *into* TRNSYS

Within Annex 23 'Multizone Air flow Modelling', the simulation code COMVEN of the COMIS model has been integrated into TRNSYS [4].

The simulation program COMVEN has been adapted as a TRNSYS Type (Type 57 COMV-TRNS) and is to be used in combination with Type 56, which is the thermal multizone building model of TRNSYS. This allows for the integral determination of the heat fluxes due to transmission, radiation and convection. Interactions between building mass, equipment and air flows due to natural and mechanical ventilation can be studied.

At each time step in the dynamic simulation a solution is iteratively determined. In each iteration loop, the room air temperature values are passed from the thermal building model Type 56 to Type 57 COMV-TRNS, which returns the respective air flow rates to Type 56. The calculated air flow rates per room are assigned to the interzonal flows or to the flows from outside to the ventilation system, which all are required by Type 56.

At this stage of the code development, the building data are basically input separately for the two Types. Thus, there is a certain risk of redundancy. Nevertheless, schedule values, as, e.g., the meteorological data and the window opening schedules, are defined as a TRNSYS schedule only and passed to the two Types internally.

Fig. 2 shows the TRNSYS program with the two Types mentioned, the parameters of their data connection, as well as the related input and output files.

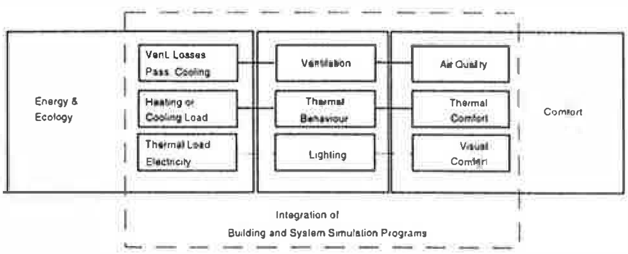

Fig. 1. Evaluation of energy and comfort aspects.

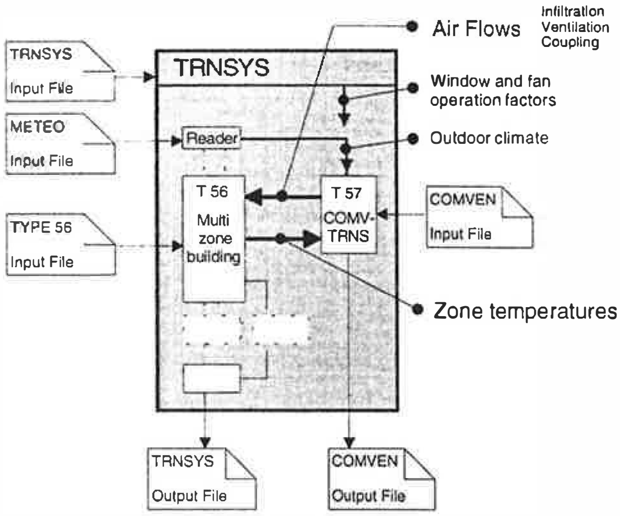

Fig. 2. Integration of COMVEN as Type 57 into TRNSYS. Air flow and zone temperature data are transferred between the thermal and the ventilation model. Building data must be input separately for the two Types, but not meteorological and window opening schedules.

The data link and the use of COMV-TRNS are described in more detail in [5], together with an example case. In the two application examples given below, additional modelling details are given.

3. Passive night cooling by natural ventilation

3.1. *Description of the building and the simulation cases*

The effect of passive cooling by natural night ventilation was studied for a four-storey building of the ZTL engineering school located close to Lucerne in central Switzerland (see Fig. 3) [6]. Fig. 4 shows a section of the building with the respective air flow paths through the gaps in the internal room doors which are always closed and through the openable tilted windows to the outside.

Two operation modes are compared: in mode 1 the windows are fully opened at night and during lesson breaks, and are in a tilted position during lessons; in mode 2 the windows are closed at night, tilted during lessons and fully opened only for one h before the morning and the afternoon lessons, respectively.

3.2. *Simulation results*

Fig. 5 shows, for mode 1 and 2, respectively, the outside and room air temperatures as well as the outdoor air exchange values and the respective window opening schedule for one typical room during a hot summer period.

When the windows are fully opened in the morning, the room temperature rapidly falls to the outside temperature, but due to the higher temperature of the building mass, in mode 2, the room temperature rises quickly again during

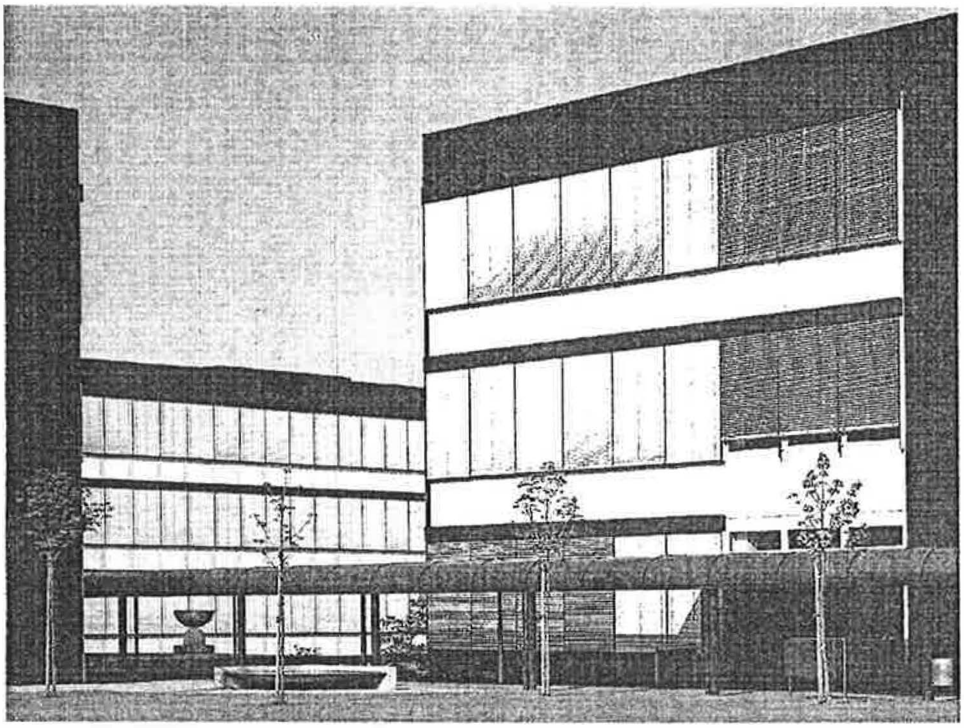

Fig. 3. The building of the ZTL school.

the lesson, while in mode 1 the temperature remains on a moderate level. Peak room temperatures differ by about 4K from mode 1 (night cooling) to mode 2.

4. Retrofit with a glazed double face façade

For the same building, a retrofit is planned and respective concepts have been worked out. One proposal is for a glazed double face façade, built up over the original structure which remains practically unchanged. This approach is effective in respect of construction costs and ecological aspects. Fig. 6 shows one of the proposed constructions. On the side of a room, the double face façade spaces are open in a vertical direction, acting thus as a ventilation shaft. In the middle section, the original window is removed and replaced by a window in the outer face of the façade (Fig. 7).

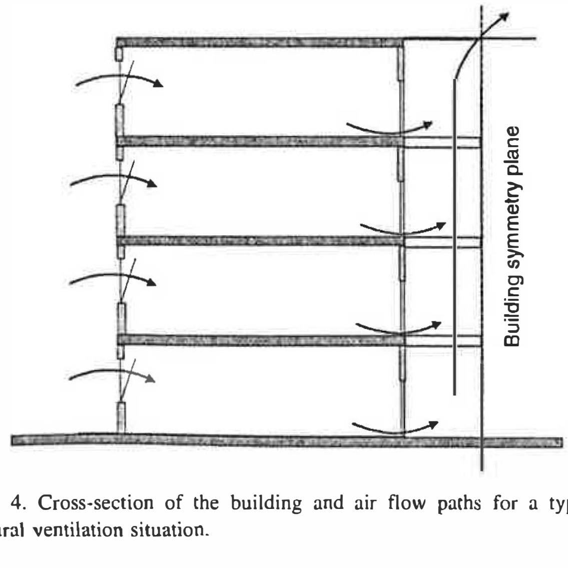

Fig. 4. Cross-section of the building and air flow paths for a typical natural ventilation situation.

While the potential for reduced transmission losses in winter time is quite obvious, more concern was related to the overheating risk in summer and thus to the possibilities of cooling and ventilating the building satisfactorily.

The aim of the simulation study presented in this paper was to provide data on the thermal comfort and the respective ventilation situation in the different rooms for a typical hot summer period, and to establish strategies for the operation of the different windows and openings for optimum indoor environment.

4.1. Modelling

A section over the entire building height of the southern part of the building was modelled with its double face façade and the adjacent rooms.

Wind effects as well as the influence of the second, north oriented building section have not been considered in this example.

4.1.1. Thermal model

The building is modelled using the TRNSYS Type 56 Multizone Building. Actually, Type 56 of TRNSYS 14.1

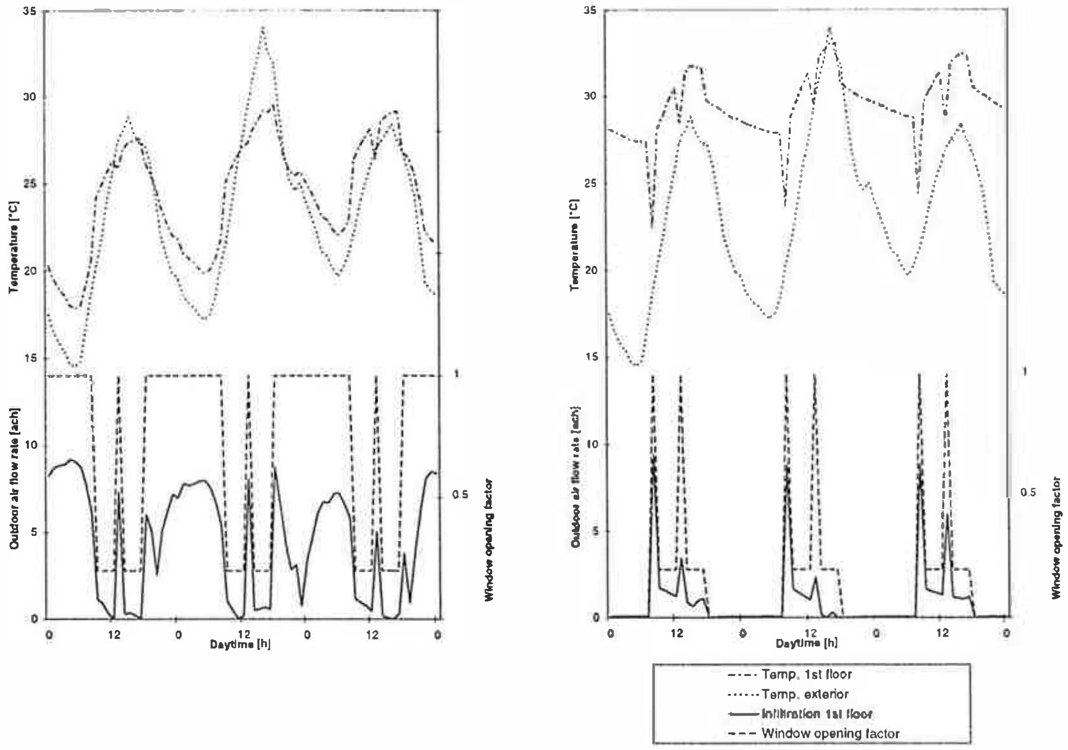

Fig. 5. Outside and room air temperatures, the outdoor air exchange and the window opening schedule for mode 1 (night ventilation, left) and for mode 2 (no night time ventilation, right).

(which was used for this study) is not very well suited to model this specific building configuration due the following limitations:

■ Solar radiation is considered only for windows and external walls. This means that radiation through the double face façade zone into the adjacent rooms behind can only be modelled by using the equation option of TRNSYS.

■ The model for windows in Type 56 is quite limited as it does not allow for defined glazing types with specific spectral characteristics. Also blinds are only considered as a geometrical aperture factor. Thus the energy transport aspects must be modelled by the user. Nevertheless the Type 56 of the TRNSYS version 14.2 contains a sophisticated window model [7].

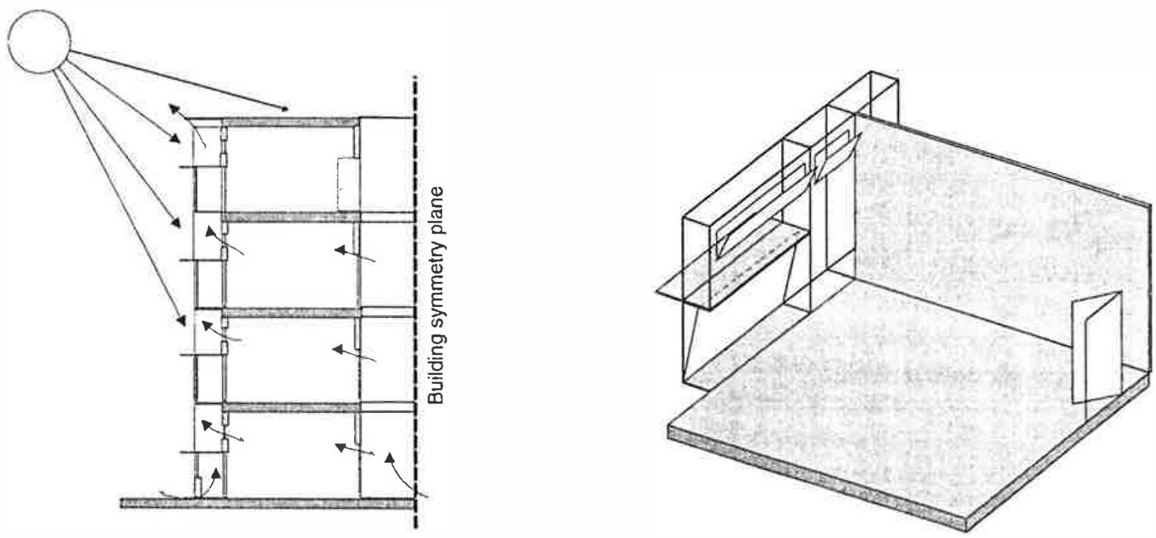

Fig. 6. Cross-section of the building section modelled and isometric drawing of one room with the double face façade spaces.