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NUMERICAL DATABASE APPLICATION TO BUILDING MODELS

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ABSTRACT

Increasing design standards within the building industry mean that some form of pre-construction testing of the building envelope is required. Expensive and time consuming field tests are becoming more impractical whereas the cost-effectiveness and greater flexibility of computer simulations will allow them to play an increasing role in building design. An expanding database of actual construction properties is needed to assist the use and advancement of existing models.

The present work program of the International Energy Agency's Air Infiltration and Ventilation Centre focuses on this problem with the development of an interactive numerical database alongside a comprehensive study of existing and future models. The model survey is presently investigating the capabilities of computer analysis techniques involving the combination of flow codes and heat transfer properties. The primary concerns of this database are air leakage properties, wind pressure distributions and climatic parameters.

AIMS

The aim of the paper is to demonstrate the present on-going work program of the International Energy Agency's Air Infiltration and Ventilation Centre in the field of modelling and building data. It is clear that to connect the available data with mathematical applications a comprehensive study has to be made of the codes available and their potential limitations in a cost-efficient environment. In turn, the models available are only useful if the input data applied to create the initial conditions are reliable and are in a form which is readily manipulated.

The large range of models means that the user needs a guideline as to the model which best suits his/her requirements and expertise, both in the input stage and the interpretation of results.

INTRODUCTION

Advances in both experimental techniques and mathematical modelling have resulted in a greater understanding of the air and heat flow patterns in and around buildings. The extensive use of tracer gas techniques to determine building infiltration has meant that the investigation of potential flows has become relatively straightforward. The pressurisation tests for measuring the airtightness and leakage flows within the building envelope is also becoming routine. Unfortunately these measurement techniques suffer from several drawbacks. The tracer gas method requires many discrete measurements to be made over a relatively long period of time. The measurements made are of little use in the design stages as they can only be used to assess the performance of existing structures or simplified scale models.

In spite of its importance, the analysis of air flows has not been developed fully due to the lack of consistent input data, computational difficulties and the restrictions imposed by the incompatible methods for analysing different flows (Walton 1989). Methods have been developed to analyse airflow in ducts (ASHRAE 1985) and to estimate infiltration (Liddament 1989a) and ventilation (ASHRAE 1985) but the relationship between these processes has rarely been studied.

The modelling of airflow within buildings requires: Determination of the boundary conditions (primarily wind pressure), the location and mathematical representation of the critical airflow paths, calculation of the resulting airflows and a user system which is easy to manipulate. The aim of this project is to analyse the potential flow codes in order to focus on their points of application and the development of numerical databases to take full advantage of the models.

AIR FLOW AND HEAT TRANSFER MODEL REVIEW

There is a wide range of calculation methods currently being used to tackle the problem of airflow and related phenomena (Hammond 1988). These range from low-level methods through intermediate-level (zonal) models to high-level (field) computer codes. The current survey is investigating the applicability of these codes in a working environment. There is a need for combined heat and flow codes to complement present testing systems. The ability to predict the indoor environment in the initial stages of design is of increasing importance, to save both time and money. The validity of the codes is greatly dependent on the information required and supplied to the model. The complex models developed to model the whole building envelope (Clarke 1990, Walton 1983) require complex initialisation parameters. For an inexperienced user the high level of information required may limit the effectiveness of the code.

Input parameters include: Climatic information, Building design and terrain characteristics, building materials and their properties, leakage data, external wind pressure coefficient (Cp) values, the design of the heating/cooling system, occupancy behaviour and the presence of internal sources. It is possible to collate a large proportion of this data in a single numerical database to be used in the application of the codes. To review the codes available it is necessary to look at the potential users if the systems. The practitioner is looking towards quick solutions to relatively simple problems whereas the designer needs a accurate appraisal of the situation to support the design decisions.

The model survey includes the investigation of the transfer mechanisms involved in the modelling of single and multi-zone problems. The transfer of properties from heated to unheated zones and the characteristics of airborne moisture transport within and between related zones are considered. The heat conduction of solids has to be appreciated alongside the properties of the transport medium. All this information needs to stored in such a way as to be readily accessible to the model user.

Combined heat and air flow models have been developed from the interaction of separate codes with a similar model base. This technique also allows for the inclusion of other considerations such as moisture (Cunningham 1988) and contaminant dispersal.

Initially multizone simulation techniques were confined to mainframe computer systems. Now, however, they are available for operation on pc based systems on which quite complex networks can be investigated. This has resulted in wider availability but many still lack 'user friendliness'. Other problems include the lack of suitable input data and inadequate validation through a lack of supporting measurement data. The IEA annex 23, Multizone Airflow Modelling, has been created to address these points in order to provide a method which may be reliably used for research and design applications.

The annex is divided into three subtasks: Model development with a user friendly front end, data acquisition for model evaluation and model evaluation. The first subtask is an extension of the COMIS project (AIVC TN29, 1990) in which an 'intelligent simulation environment' (ISE) is to be developed to assist a user in setting the critical model parameters and developing a flow network. The work also includes the incorporation of pollutant transport and demonstrating the coupling of a multizone model with a thermal building simulation model. An outline of the ISE is illustrated in Figure 1. The essential feature is to couple to a model via a series of graphic data input screens. Data is then provided by the user or retrieved from internal databases. An expert system is also available to assist the user in selecting the best information.

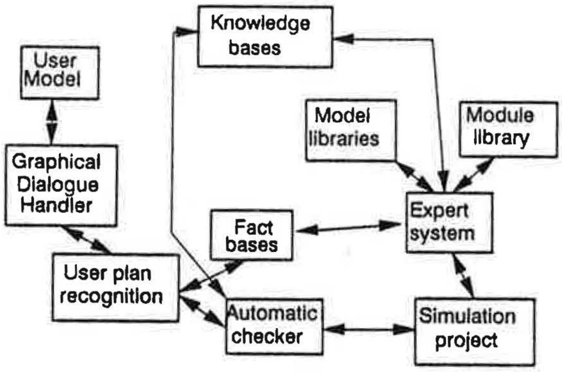

Figure 1. An Outline of ISE

The aim, therefore is to provide the user with the necessary knowledge and tools to use a model. Essential to all this work is the development of a suitable algorithm for the simulation of multizonal air flow. Modules for incorporation in this algorithm include flow through large openings, single sided flow, and crack flow. The addition of recent research, reviewing building air flow simulation techniques (Liddament 1991), allows for a comprehensive study of the methods available.

Model Evaluation

The objective of the second subtask along with the present research work is the data acquisition for model evaluation. The aims are to identify input requirements, assess the quality or accuracy needed for input data and to obtain appropriate datasets based on these needs. Much data are already available but do not necessarily meet the needs of existing models. Where existing data are used, emphasis is being placed on quality assessment, dealing with missing data items, establishing rules for any interpolation requirements and carefully discriminating between actual measured data and derived values. To support existing data an extensive investigation is underway of the current measurement programs in which clearly defined examples will be selected for analysis.

In providing new datasets, emphasis has been directed at clearly defining the objectives of each measurement in the context of evaluation needs, standardising the format of data collection and standardising procedures for estimating errors (AIVC 1991). The annex experimental program will include measurements on isolated systems within the laboratory, the use of test cells, field measurements on 'simple' buildings of different constructional techniques and field measurements on more complex buildings such as multi-storey office buildings. Also a wide range of exposure and climatic conditions are being applied. The advantage of the international collaboration in the research is that it enables the widest range of construction, ventilation and climatic conditions to be included within the study.

The final section of the research is concerned with establishing a protocol for model evaluation. This would be applicable to any multizone technique and hence has a wide application area by providing usable datasets for general validation purposes. The AIVC's own numerical database will draw on this work for application in future validation studies The goals of this area of research are to ensure that a model performs according to specific criteria, to determine the domain of application and, by means of feedback from the results, improve model performance. There are many criteria by which the model may be judged and the specific details have yet to be determined. Also, when comparing a model against measured data, the deviation of the measurements from the physical quantities being investigated must be understood.

NUMERICAL DATABASE

As part of its operating program, the Air Infiltration and Ventilation Centre has established a numerical database to be used in support of design studies and for the verification of numerical models (Fig. 2). The design data being gathered includes:

* component leakage values
* whole building leakages
* wind pressure coefficients and wind pressure algorithms
* basic climatic data
* key standards relating to ventilation and indoor air air quality requirements
* impact of occupant interaction on air change rates and energy use
* ventilation effectiveness and air flow patterns data

The validation data includes:

* air change rate measurements
* interzonal air flow
* air movement patterns
* pollutant transport

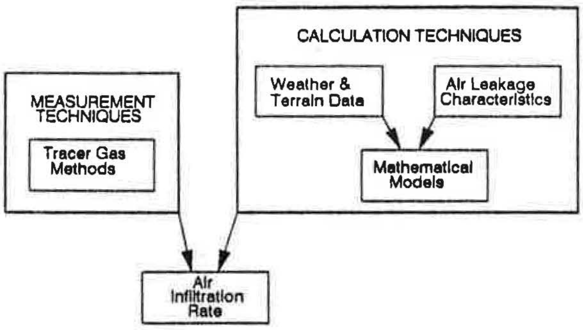

Figure 2. Alternative Routes to the Estimation of Air Change Rates.

In each case validation data has been drawn from selected studies including the IEA's annexes 20 and 23, in which careful measurement control has been introduced and in which the key parameters needed for data input have also been recorded (e.g. driving forces, leakage distribution, fan, duct and diffuser characteristics, pollutant sources, etc.)

Data Sources

Although the selection of data is very rigorous, but it is planned to represent in the database all building types and conditions for which suitable measurements were available. By combining data from many sources throughout the world it is possible for designers and numerical modellers to consider a far wider range of operating conditions than would be possible than using the results of a single set of measurements.

A key source of data has been the related air flow annexes of the International Energy Agency's Implementing Agreement on Energy Conservation in Building and Community Systems. Thus this approach will ensure the maximum dissemination of knowledge resulting from IEA activities. The associated annexes include:

* Annex 8: Inhabitant behaviour with regard to ventilation

* Annex 9:Minimum ventilation rates
* Annex 14:Condensation
* Annex 18:Demand control ventilation systems
* Annex 20:Air flow patterns within buildings
* Annex 23:Multizone air flow modelling

The COMIS (1990) project which took place at Lawrence Berkley Laboratories in the United States (Liddament 1989b) undertaken comprehensive multizone air flow measurements as part of the development of a building air infiltration and ventilation simulation code. These data will provide further input to the database. Other data sources include a new compilation by ASHRAE on air leakage characteristics of component openings and data located during the AIVC's present survey of current research.

Management System

In selecting a database management system, consideration had to be given to several requirements. For example, it is essential to ensure widespread availability of the database. Equally it is important that the system should offer maximum flexibility in relation to establishing and linking data fields. Another fundamental requirement is that it should be possible to introduce new parameters at a later date should it prove desirable to increase the scope of the database. The initial database is a pc based system using DBASE IV software.

CONCLUSIONS

The present research program provides an opportunity to evaluate air flow patterns within buildings. In addition to air flow analysis, such computer fluid dynamics techniques may be used to predict the propagation of pollutants, fire and smoke, and to evaluate flow velocities and temperature distributions. These methods therefore have potentially important applications in the prediction of the building environment. The advantages gained in such techniques are related to the quality and consistency of the information provided to the codes and the interpretation of the ensuing results. To make full use of the models and mathematical techniques a base of data is being prepared within the Centre, coupled with an research review of the available models to create a system of the greatest use to the user.

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