Air Infiltration Review

a quarterly newsletter from the IEA Air Infiltration and Ventilation Centre

International Energy Agency - AIVC

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Ventilation: The Situation in Switzerland

Viktor Dorer, R. Meierhans, U. Steinemann, EMPA, Switzerland

Switzerland

Surface total 41'284 km^2
Population: 6'936'000 (1990)
Regions : Jura, Midlands, Alps, South side of the Alps
Housing: From 200 to 2100 m above sea level
Number of cantons (states): 26

Climatic conditions and available data

The Swiss topography is dominated by the Alps and the Jura in the north-west part and the most dense populated 'Midlands' between these two mountain regions. The climatic conditions vary in a very wide range both in temperature and solar radiation due to the different altitudes and the different climatic conditions north and south of the Alps. Accordingly there are roughly three climatic regions:

Region	Average daily maximum July	January
Midland (all major cities like Zuerich, Bern, Geneva)	18 oC	0 oC
Southern parts (Tessin, Wallis)	22 oC	+3 oC
Highest Jura and alpine region (values are typical for an altitude of 1500 msl)	12 oC	-7 oC

Meteo data are available as hourly values from over 70 automatic meteo stations. Derived values for hand calculation methods (like degree days) are regularly published in Swiss technical journals. Design reference years 1981-90 for 16 typical stations are prepared and distributed by EMPA for several building simulation programs.

Building stock

In Switzerland, there exist about 2.2 million buildings with the following characteristics:

In this issue

Building Stock Switzerland (1990)		
Type of building	Number	Volume [mio m^3]
Residential buildings	1087500	1260
• For residential use only	924800	990
• mixed residential use	144700	270
Non-residential buildings	1068900	1430
• office buildings	127500	540
• industrial buildings	107000	420
• agricultural buildings	454500	400
• other buildings	379900	70
Total	2156400	2690

Leakage and average ventilation rates

Quite few building air tightness data (nL50-values) are available. Measurements have been performed mainly in four types of buildings:

- Low energy research or P&D residential buildings.
- Wood construction residential buildings (representing less than 5% of the building stock).
- Dwellings and apartments fully or in many cases only partly measured due to occupant complaints concerning excessive heating demands and/or draft problems.
- Typical residential and office buildings measured in the frame of the Swiss project NEFF 226 (see AIR Vol 7, No 3 May 1986 and new publication available mid 1994). Flow rates in naturally ventilated buildings have been measured just in a few houses and no reliable overall figures on the actual situation can be given.

Taking into account the building construction practices and the results of a few long term tracer gas measurements, it can be concluded that the ventilation rates from background and unintentional openings is in general very marginal and that the resulting ventilation rate is mainly governed by the occupant's window opening behaviour. Nevertheless mechanical extracts in kitchen and wet rooms are now often required and thus very common in newer houses.

In many exposed areas the installation of soundproof windows in older and thus rather poor insulated buildings lead to low ventilation rates, mould grow and other moisture related problems. Ventilation strategies and systems

There are no statistics available about the ventilation strategy used and the systems installed in the different buildings. A rough estimation is given below:

	Approx. % of buildings with		
Type of building	Natural Ventilation	Mechanical extract	Balanced system
Residential buildings			
• residential use only	85	13	2
• mixed residential use	70	26	4
Non-residential buildings			
• office buildings	30	30	40
• industrial buildings	30	30	40
• agricultural buildings	70	26	4
• other buildings	80	17	3
Total	64	22	14

Legislation in regard to heating, ventilation and indoor environment

Building and energy codes are issued on cantonal level. Many of them are based on the building and energy standards and guidelines of the SIA (Swiss Engineers and Architects Association). In 1990 an amendment to the constitution concerning energy has been accepted by public vote, on the basis of which an energy law is now drafted. The introduction of CO_2 taxes and fossil and electric energy consumption limits are evaluated. This should lead to less complicated regulations.

Most buildings in Switzerland are of stable value and thus high pay back times up to 15 years are accepted and allow for the installation of energy efficient equipment even at quite low energy prices. Innovation by legislation: The new requirements and their stringent enforcement pushed the design and construction companies to perform integral planning and the manufacturers to develop new equipment. As a result, innovative designs and products are realised, thus making the industry more competitive.

Standards and guidelines in regard to ventilation and indoor environment Building standards are issued by

Air Infiltration Review

Editor: Janet Blacknell

Air Infiltration Review has a quarterly circulation of 3,500 copies and is currently distributed to organisations in 40 countries. Short articles or correspondence of a general technical nature related to the subject of air infiltration and ventilation are welcome for possible inclusion in AIR. Articles intended for publication must be written in English and should not exceed 1,500 words in length. If you wish to contribute to AIR, please contact the Air Infiltration and Ventilation Centre. Please note that all submitted papers should use SI units.

the SIA. The normative bodies in Switzerland are also involved in the CEN standardisation work and thus SIA does release new standards only in draft form.

Design of buildings: Recommendations for the overall building air tightness are given in SIA 180 for four different ventilation types as upper as well as lower limits in order to account for energy as well as for indoor air quality aspects. Insulation requirements for the building envelope are set out by the cantons, most of them are based on SIA 380/1.

Design of HVAC-Systems and ventilation rates: Principles for the design, commissioning and maintenance of HVAC-systems are defined in the SIA guidelines SIA V 382/1-3. In regard to ventilation rates and energy, the following requirements are defined:

- Outside air flow rates per person (smoking permitted/ not permitted)
- Maximum total pressure loss (supply and extract)
- Total fan efficiencies at design condition

Values are stated for the general case as well as for energy efficient systems.

There are additional requirements for special cases such as kitchens, windowless rooms, restaurants, garages etc.

The need for mechanical cooling must be proven and therefore the impact of the energy legislation on the design of energy efficient office buildings can be noticed. Key design issues are:

- Sufficient thermal mass
- Efficient and flexible external blinds
- Multiple glazing with coatings
- Optimum daylight design
- Heat recovery systems, designed on the basis of yearly net gains
- Well insulated, tight and low resistance ventilation ductwork

Requirements for products and materials

Source control is a very basic principle of the Swiss policy to ensure a good indoor air quality at thus a low energy consumption.

Even there is still a lack of knowledge about emission characteristic and also of control legislation, we are well aware of the problems and some steps have already been made:

- Ban of use of asbestos in occupied zones
- Limitation of the allowed formaldehyde emission of chipboard to a maximum of 10mg/100g (Lignum CH 10)
- Guidelines for protection measures against radon in buildings
- General recommendations for separating smoking and non-smoking areas.

Recent activities of the SIA are aiming at the establishment of a general declaration scheme for the ecologically relevant characteristics of building materials.

Research and demonstration programs

In order to disseminate the knowledge on new and promising techniques among practitioners of the building industry as wide and as soon as possible, so-called 'Impuls'-programs are initiated on a regular time basis, covering specific topics.

Currently, the following three programs are carried out:

PACER: Renewable energies

IP BAU: Conservation and renovation

RAVEL Efficient use of electricity

Specific courses are offered and an impressive list of guidelines and other publications is available.

The aim of the national research and demonstration program Energie-2000 is until the year 2000 to

- stabilise the fossil energy consumption and the CO_2 production on the level of the year 1990,
- to stabilise the electrical energy consumption,
- to reach a proportion of renewable energy production of 0.5% for electricity and 3% for heating,
- to increase the efficiency of existing power plants.

E2000 action groups are concerned with fossil energy for heating and transport, electricity and renewable energy.

In regard to buildings many demonstration objects are currently realised and ten centres deal with specific types of buildings which have a great potentials for energy savings (e.g. hospitals).

In the frame of this program many support programs and demonstration projects have been initiated for dwellings as well as for office buildings. The construction of energy efficient houses, namely those based on renewable energy, are subsidised on national and cantonal levels.

Innovative features for commercial buildings are amongst other:

- Minimum ventilation rate and displacement ventilation
- Demand controlled ventilation
- Radiant and slab cooling, free cooling
- Earth coupling (storage, air heat exchanger, hot water coils)
- Mechanical residential ventilation with heat recovery
- Cogeneration (heat load controlled)

The research program ERL (Energy relevant air movements in buildings) started in 1986 and has terminated recently. It comprised more than 25 individual projects, grouped into three sub task:

A Single zone air flow modelling (CFD) and measurement techniques (LDA).

B Multizone airflow modelling and measurements; validation work.

C Innovative ventilation systems (displacement ventilation): Measurements and design guidelines.

Sub tasks A and B were closely linked to the IEA-ECB Annex 20 'Air Flows in Buildings'.

Detailed technical reports as well as summary publications are available.

For more information please contact the Swiss AIVC representative.

Air Infiltration and Ventilation Centre Information Services and Library

by Janet Blacknell, AIVC Information Specialist

Introduction

The AIVC Information Centre is a busy distribution centre for information on a wide variety of subjects. It deals with clients from all over the world, particularly in the member countries, and handles around 100 enquiries from individuals and organisations per month. Items of literature despatched in one year currently approach 7,000. These include Technical Notes on a variety of subjects (the latest ones include relevant standards and numerical database information), literature lists, searches performed on the Centre's bibliographic database, Airbase (which is also available to clients as a software package), and library items which are requested as a result of searches or scanning of the quarterly abstracting journal, "Recent Additions to Airbase".

Newsletter - Air Infiltration Review

Welcome to Air Infiltration Review, the quarterly newsletter of the Air Infiltration and Ventilation Centre (AIVC). For those who may be unacquainted with it, the newsletter regularly features three or four articles of topical interest in the field of air infiltration and ventilation in buildings. It is intended to present articles of general interest with the aim of demystifying the more technical aspects of our subject, and to give a brief overview of developments in this area. The articles range widely in scope; recent subject areas have included:

- Duct cleaning - a literature survey,
- Indoor air quality in dwellings before and after renovation,
- Demand controlled ventilation systems - sensor tests,
- Using CFD techniques to evaluate wind pressure for air infiltration analysis,

and contributions are received from a wide range of member countries (In recent issues, articles have been published from UK, Italy, Netherlands, Belgium, Sweden, Finland and France). The newsletter is published in December, March, June and September, and the last date for contributions will be the last week of October, January, April, and July for the relevant edition. Items are not formally refereed, in compliance with the immediate and up-to-date nature of the publication, although representatives of the member countries have some influence over what is included. Contributions of 1500-2000 words are welcome, whose technical content is of a nature to be understood by a wide range of researchers in the field. Other regular items in Air Infiltration Review are book reviews, conference reports and items featuring new publications and research work from the AIVC. Each year a detailed report is featured about the annual AIVC Conference. This report is intended as a review and journal of the most important papers and events, for those who have been unable to attend. A list of forthcoming conferences is to be found towards the back with details of relevant upcoming events, together with contact addresses.

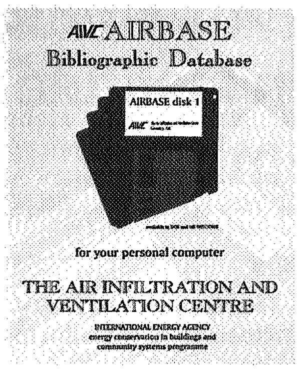
Air Infiltration and Ventilation Centre

The Air Infiltration and Ventilation Centre is Annex 5 of the IEA Energy Conservation in Buildings and Community Systems Programme, and was established in 1979. The aims of the centre are the standardisation of techniques, the validation of models, the catalogue and transfer of information, and the encouragement of research. It is intended to be a review body for current world research, to ensure full dissemination of this research and based on a knowledge of work already done to give direction and firm basis for future research in the participating countries. Its role has changed gradually over time and it has broadened its original subject base to include ventilation aspects in the energy conservation and environmental sphere. AIVC publishes a range of documents in the form of technical notes, guides, handbooks and conference proceedings. Recent technical notes are as follows:

- TN 41'Infiltration data from the Alberta Home Heating Research Facility'
- TN 42 'Current ventilation and air conditioning systems and strategies'
- TN 43 'Ventilation and building airtightness: an international comparison of standards, codes of practice and regulations'
- TN 44 'An analysis and data summary of the AIVC's numerical database'

The Centre's present role is to act as an information centre for members of Annex 5, and to a certain extent, to gather and distribute information to members of the many other annexes of the International Energy Agency Energy Conservation in Buildings and Community Systems programme. The Centre holds a growing 'bookshop' collection of publications and final reports from all the annexes, which are available for purchase (A publications booklet is available from the AIVC).

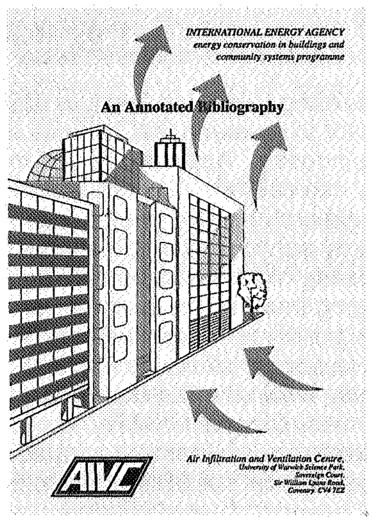
Airbase



"Airbase" software package

The hub of the work of the Centre is undoubtedly the AIVC's bibliographical database, 'Airbase', which is a finely targeted source of information on all aspects of infiltration and ventilation in buildings, and is used by around a thousand enquirers every year. There are currently over 7,000 records available for searching, and the database grows at a rate of approximately 1,000 items per year. Items are carefully selected to be of use to clients in the AIVC member countries, and the relatively small size of the database (in comparison to other more general ones) lends itself to material which is unique to the AIVC's information centre. Sources for the material, which is stored in the AIVC library and can be readily consulted by using the library services, include conference proceedings, technical reports, journal articles, and so-called 'grey' literature, including internal reports which may not be available elsewhere. Material is actively sought by AIVC staff, by attendance at conferences, and regular information gathering visits to organisations around the world. Clients of the AIVC Information Services are encouraged to supply recent papers and other publications for inclusion in the database, and for distribution among other interested parties. In this way the information centre is limited in scope and size only by the number of clients or enquirers who avail themselves of its services.

The database itself is available for purchase (see order form at the back of this newsletter) for use with a personal computer, in DOS or Windows format. Sample copies (including the latest 250 records, i.e., Recent Additions for the relevant quarter, or a search of your choice) are also available free of charge. Approximately 7,000 items of literature are requested each year from the AIVC library, which equates to the distribution of the entire library each year. Although items from the latest update of the database are most often requested, there is a good deal of interest in the earlier items as well, as researchers seek out the necessary background information to their subject. The library staff are happy to respond to specific requests for information, and if necessary, the material can be ordered and added to the library for a specific case. For example, a recent project involved collecting information on ventilation strategies in mortuary buildings. An initial search generated a limited number of items in 'Airbase', so further research was conducted using external databases, and the resultant information added to Airbase and distributed to the client in the form of an information pack. These types of searches are likely to be of interest to others, and a list of recent requests can be provided on request. Popular searches are made available for distribution in the form of literature reviews, recent examples of which include items on duct cleaning, garage ventilation and natural ventilation.



A range of annotated bibliographies are available from AIVC

Recent Additions

In close relation to Airbase is 'Recent Additions to Airbase', which is the quarterly abstracting journal of the AIVC. Records entered in Airbase are listed in Recent Additions in full, and an order form is included for items from the library. In general, Airbase is of use to those who wish to perform a search of the whole database in a specific subject area, while Recent Additions is a useful aid for researchers who wish to keep abreast of the latest papers written by colleagues in the field. Recent Additions has a circulation of approximately 2,000, and a large proportion of the enquiries dealt with by the Centre are generated by this publication. The format of records for Airbase (and Recent Additions) follows the traditional layout, i.e., title, author, bibliographical information, abstract, keywords. The abstracts are normally fairly detailed, and if present, the author's abstract is used. Otherwise an abstract will be created at the AIVC. Keywords are taken from a restricted list, and are intended as pointers to subject areas dealt with which may not be cited in the title or abstract. For searching the database, the software (Blackwell's IdeaList) uses a speedy free text process which can perform searches of varying levels of complexity. Other features include:

- recording of searches for repetition at a later date (i.e., when Airbase has been updated),
- a number of macros, which maximise the scope of search terms,
- and an adaptable format for printing out results.

Other Services

AIVC publications are available to clients in member countries, usually free of charge. Certain items are available to non-participating enquirers for purchase. The AIVC publishes its annual conference proceedings soon after the event in September each year and these can be purchased in hard copy or as a microfichewith a CD ROM version likely to be available in the near future. Proceedings for the years 1980 to 1989 arestill available in limited numbers, and these can be supplied free of charge, subject to a small charge for postage. Recent searches and bibliographies cover ventilation of dissection rooms, analysis of tracer gas data and others as already listed.

For more information, contact the AIVC (details on back page of this newsletter).

Current and Recent Research at the Division of Building Physics and Indoor Climate, Belgian Building Research Institute, Limelette, Belgium

by Malcolm Orme, AIVC Scientist

The Belgian Building Research Institute (BBRI) is a major contributor to research that benefits all aspects of the building industry. Applications and methods, which industry can use, are major objectives of the fundamental research being carried out there. An example of a key service that BBRI supplies is airtightness testing of both components and whole buildings, ranging from factory-built window frames to large industrial buildings. Also, methods of controlled ventilation (in dwellings, offices, and schools) are subjects of study within the Division of Building Physics and Indoor Climate at BBRI. For instance, a mechanical ventilation system with infrared control has been installed in one of BBRI's own office buildings. It is intended to evaluate this system for its energy consumption; the indoor air quality that it gives rise to; also the reaction it produces from the users of the building.

Whilst maintaining close contact with other research centres both in Belgium and elsewhere, the direction of research at BBRI is managed by means of Technical Committees. These enable the Belgian building industry to guarantee that the funding, which they provide, is used to fulfil their needs. The Technical Committees most relevant to the ventilation of buildings are "Chauffage et Climatisation" (heating and air conditioning), and "Hygrothermie" (heat and moisture transfer).

BBRI and Europe

BBRI often works with other organisations on international projects, as well as its research and services specific to Belgium. A recent item of such work was the identification of radon gas sources, studies of suitable models for predicting its movement through soil and the inside of buildings, and techniques for reducing the presence of radon gas in buildings. This took place in association with the National Radiological Protection Board (NRPB) of the UK and groups in five other European countries. Predictions of the effectiveness of various ventilation strategies for the solution of radon problems are described in reference [1].

Also, BBRI is assisting in a European audit to optimise indoor air quality and energy consumption in office buildings. Moreover, it is one of the main organisations responsible for the Belgian contribution to the setting of building-related European standards, on behalf of the Comité Européen de Normalisation (CEN).

The following European projects are described below:

(i) Eurokobra - the European Thermal Bridge Atlas,

(ii) Passys and Related Projects, and

(iii) the Aereco Humidity-Controlled Natural Ventilation System.

(i) Eurokobra - The European Thermal Bridge Atlas

A thermal bridge can occur between the heated space inside a building envelope and either the unheated space inside the envelope or the outside air. This happens when parts of the envelope are not correctly insulated resulting in mould, severe condensation and large energy losses. To avoid or minimise the effects of thermal bridges, information regarding heat flow through building details is being collected throughout Europe. BBRI is co-ordinating the production of Kobra, a computer programme that has been designed to interrogate a database of building components known as Eurokobra. This database is a thermal bridge atlas for 2-dimensional details. It is intended to include more than 500 different items by the end of 1994 and over 750 by the end of the project. Kobra has the flexibility to allow individual details to be edited. The resulting heat flow through the building detail is then calculated, together with its new temperature field. More information about Kobra is contained in reference [2].

(ii) Passys and Related Projects

The research phase of the Passys (Passive Solar Components and Systems Testing) project operated from 1986 to 1993. (Details given in reference [3].) This project was conducted by the Commission of the European Communities (CEC), with 60 researchers from 28 institutes in 10 European countries taking part. Funding was provided by the CEC, several national governments and participating institutes. Its objective was to develop reliable and affordable procedures for the testing of passive solar components in a building system. Another aim was to increase confidence in passive solar simulation and simplified design tools through validation and further improvements. The experimental side was conducted by using highly insulated test cells, of external dimensions 8.4 m x 3.8 m x 3.6 m. These cells are subdivided into 2 sections, a test room of internal volume 38 m^3 and a service room. Each cell contains a computer controlled heating and cooling system. It is possible to test a building component of dimensions 2.75 m x 2.75 m by placing it into an insulated frame in the south face of a test cell. The Limelette research centre is the Belgian location for four purpose-built Passys test cells (shown in Figure 1). The second phase, Passys II, dealt with the testing of all types of building components, using the same test method as the one applied to passive solar components. Passys Newsletters were published every 6 months throughout the duration of the project until it ended. (See reference [4].). Now that the Passys test method has been developed, an operational structure, Paslink, has been organised for the purpose of maintaining high quality assurance and sharing new developments and findings.

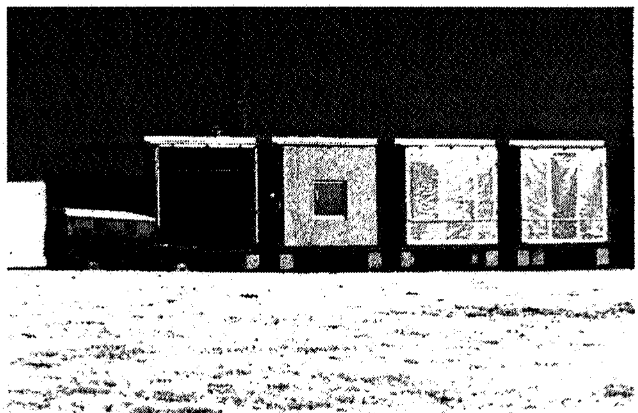


Figure 1 The Passys Test Cells at BBRI

"Compass" and "Pascool" are projects related to Passys. Compass uses special Passys test cells with removable roofs for testing roof components. The Passys, Paslink, and Compass projects have all been co-ordinated by BBRI. Pascool (Passive Cooling) is a current CEC research programme with which BBRI is involved. The intention is to study and improve passive cooling techniques, tools and design guidelines, with special emphasis on building design for southern European climates. The Pascool Newsletter, published every 6 months by the Department of Applied Physics, University of Athens, relates the latest developments about the continuing Pascool programme, and news of developments in Compass and Paslink.

(iii) The Aereco Humidity-Controlled Natural Ventilation System

A building in Namur, Belgium consisting of 18 apartments (17 of which were occupied) has been monitored by BBRI, as part of a CEC - Aereco demonstration project on a humidity-controlled natural ventilation system [5]. Standard natural ventilation systems were installed in one half of the apartments and humidity-controlled ventilation systems in the other half. Then the performance of the humidity-controlled system was evaluated with respect to energy consumption and air quality improvement. It was found that because of the humidity control, the ventilation energy losses were reduced. On the other hand, it was discovered that the building and duct characteristics have a major impact on the performance of the system.

International Energy Agency Projects

In addition to participating in CEC research programmes, BBRI also has links with the International Energy Agency (IEA). In particular it works with the IEA Energy Conservation in Buildings and Community Systems Programme, Annex V, the Air Infiltration and Ventilation Centre (AIVC), and Annex XXIII, Multizone Air Flow Modelling (Comis). (BBRI holds reserve copies of the entire AIVC library of papers abstracted in Airbase.)

BBRI takes part in Task XIII (Advanced Low Energy Buildings) of the IEA Solar Heating and Cooling Programme. The purpose of this activity is to design and construct low energy solar dwellings which should be technically and economically realistic in the period 2000-2010. The Pleiade (Passive and Low Energy Innovative Architecture Design) dwelling is Belgium's response to this challenging proposal and BBRI is one of many Belgian groups involved in its design and monitoring. Details of this work can be found in reference [6].

Contact Address

For further information about any of the above projects, please contact Peter Wouters at:

Belgian Building Research Institute, Violetstraat 21-23, B-1000, Brussels, Belgium

References

[1] Prediction of the performance of various strategies of subfloor ventilation as remedial actions for radon problems. Cohilis P., Wouters P., L'Heureux D.; Air Infiltration and Ventilation Centre, UK; Proceedings of 11th AIVC Conference, "Ventilation System Performance". Lake Maggiore, Italy 18-21 September, 1990. Volume 2, p17-39.

[2] Eurokobra: International collaboration on a computerized thermal bridge atlas for designers. Wouters P., Schietecat J., Standaert P., Houthuys P.; Proceedings of BEP 94, 2nd BEPAC Conference, "Building Environmental Performance: Facing the Future". University of York, UK 6-8. April 1994. p67-72.

[3] The contribution of Passys with regard to future building performance evaluation. Wouters P., Vandaele L., Geerinckx B.; Proceedings of Bep 94, 2nd BEPAC Conference, "Building Environmental Performance: Facing the Future". University of York, UK. 6-8 April 1994. p1-6.

[4] Passys Newsletter. Final Issue, May 1993. (Available from BBRI.)

[5] Natural Ventilation in 18 Belgian Apartments: Final Results of Longterm Monitoring. Wouters P., Geerinckx B., L'Heureux D.; Air Infiltration and Ventilation Centre, UK; Proceedings of 14th AIVC Conference, "Energy Impact of Ventilation and Air Infiltration". Copenhagen, Denmark. 21-23 September 1993. p369-377.

[6] The Pleiade Dwelling: an IEA Task XIII Low Energy Dwelling with Emphasis on IAQ and Thermal Comfort. Wouters P., L'Heureux D., De Herde A., Gratia E.; Air Infiltration and Ventilation Centre, UK; Proceedings of 14th AIVC Conference, "Energy Impact of Ventilation and Air Infiltration". Copenhagen, Denmark. 21-23 September 1993. p215-224.

15th AIVC Conference, Buxton, UK
27-29 September, 1994
Preliminary Programme

Tuesday 27 September

Welcome & Keynote Presentation

SESSION 1: Ventilation Strategies

Efficiency of Ventilation in Office Buildings.*R R Walker (UK)*

Annex 27 - Domestic ventilation, occupant habits' influence on ventilation need.*L-G Mansson (SWE)*

A study of various passive stack ventilation systems in a test house.*L M Parkins (UK)*

Passive ventilators in New Zealand homes: Part 1 Numerical studies and Part 2 Experimental trials .*M R Bassett (N.Z.)*

Ventilation by the Windows in Classrooms: A Case Study.*V. Richalet (FRANCE)*

Single Sided Ventilation : A Comparison of Measured Air Change Rates with Tracer Gas and with the Heat Balance Approach.*D.Ducarme et al (BELGIUM)*

Natural ventilation through a single opening - the effects of headwind.*G M J Davies et al (UK)*

Investigation of Ventilation Conditions in Naturally Ventilated Single Family Houses.*Niels Bergsoe (DK)*

Demand controlled ventilation system for houses.*J Heinonen et al (FIN)*

SESSION 2: Indoor air quality - Posters

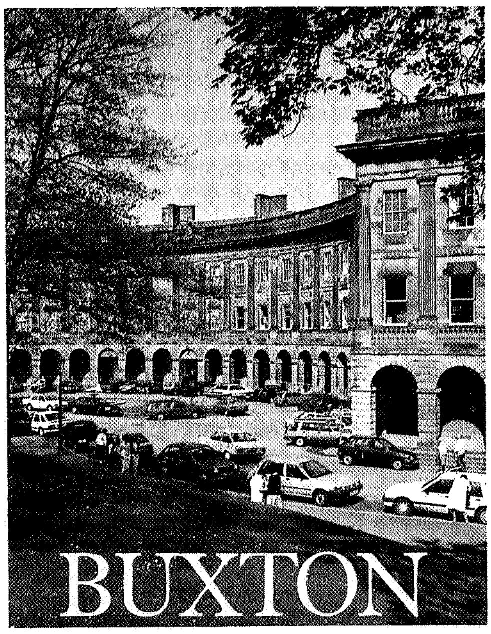
5 minute oral presentation by each author, followed by general viewing of posters and discussion.

Indoor air quality and ventilation indices in multizone, transport-pollutant model.*A C Megri et al (FRA)*

Methods for investigating indoor air conditions of ventilated rooms. *P Vogel et al (GER)*

High quality ventilation systems - a tool to reduce SBS symptoms. *A Kumlin et al (SWE)*

Numerical assessment of thermal comfort and air quality in an office with displacement ventilation. *G Gan (UK)*



The role of infiltration for indoor air quality - a case study in multifamily dwelling houses in Poland. *A Baranowski (POL)*

Effectiveness of various means of extract ventilation at removing moisture from a kitchen. *T Shepherd et al (UK)*

Water evaporation of 5 common indoor plants under various climate conditions. *B Strickler (SWITZ)*

Role and tasks of ventilation in modern buildings: a case study for Silesian dwelling houses. *M B Nantka (POL)*

The role of ventilation in controlling the dispersion of radon gas from a cellar in a domestic house. *I C Ward et al (UK)*

Detection and mitigation of occupational radon exposure in underground workplaces. *K Pirjo et al (FIN)*

The mechanical ventilation of suspended timber floors for radon remediation - a simple analysis. *M Wooliscroft (UK)*

Using pressure extension tests to improve radon protection of UK housing. *P Bell et al (UK)*

Wednesday, 28 September

SESSION 3: Energy Impact of Ventilation. Building Design for Optimum Ventilation

Fluctuating air flows through cracks. *S Sharples et al (UK)*

Air-tightness of U.S. dwellings. *M Sherman et al (USA)*

Energy efficient ventilation of bathrooms. *M Sandberg et al (SWE)*

The relative energy use of passive stack ventilators and extract fans *M Wooliscroft (UK)*

Volume control of fans to reduce the energy demand of ventilation systems. *F Steimle (GER)*

A design guide for thermally induced ventilation.*C Filleux et al (SWITZ)*

Air movement in a re-clad medium rise building and its effect on energy usage. *I C Ward et al (UK)*

Use of cavity walls for combined thermal storage and heat exchange *D J Harris (UK)*

The Performance of Dynamic Insulation in Two Residential Buildings. *J T Brunsell (NORWAY)*

Ventilation and energy flow through large vertical openings in buildings. *J van der Maas et al (SWITZ)*

Lunch and FREE Afternoon

SESSION 4: Ventilation and Energy - Posters

5 minute oral presentation by each author, followed by general viewing of posters and discussion.

Survey of mechanical ventilation systems in 30 low energy dwellings in Germany. *J Werner et al (GER)*

Simple and reliable systems for demand controlled ventilation in apartments. *S Svennberg (SWE)*

Ventilation concept, indoor air quality and measurement results in the "Passivhaus Darmstadt Kranichstein" . *F Wolfgang (GER)*

Improvement of domestic ventilation systems. *J Heikkinen et al (FIN)*

The Capenhurst ventilation test house. *D A McIntyre et al (UK)*

Heat recovery ventilation and carbon emission abatement for UK dwellings.*K Broughton (UK)*

Effective ventilation strategies demands flexible system design. *A Svensson (SWE)*

Report on desiccative evaporative cooling (DEC). *F Dehli (GER)*

Development of HVAC system controlled by outdoor-indoor pressure adjustment. *T Keskirkuru et al (FIN)*

The testing and rating of terminals used on ventilation systems. *P Welsh (UK)*

Domestic Ventilation with Variable Volume Flows. *G Polenskie (GER)*

Heat losses from suspended timber floors with insulation. *D J Harris (UK)*

Reducing Air Infiltration Losses in Naturally Ventilation Industrial Buildings. *PJ Jones et al (UK)*

Passive stack ventilation. *J Palmer et al (UK)*

Comparing predicted and measured passive stack ventilation rates. *R Hartless et al (UK)*

Ventilation air flow through window openings in combination with shading devices. *A C Pitts et al (UK)*

Use of passive stack systems in multi-storey dwellings: assessment of performance. *Dr C Irwin et al (UK)*

Case studies of passive stack ventilation systems in occupied dwellings. *L M Parkins (UK)*

A Review of Weather Data for Natural Ventilation. *MJM Arif and GJ Levermore (UK)*

The Limits of Natural Ventilation in Deep Office Spaces. *Martin White and R R Walker (UK)*

Thursday, 29 September

SESSION 5: Calculation, Measurement and Design Tools

The evaluation of ventilation effectiveness measurements in a four zone laboratory test facility. *J R Waters et al (UK)*

Determination of local mean ages of air by the homogeneous injection tracer gas technique. *H Stymne et at (SWE)*

Tracking Air Movement in Rooms. *D K Alexander et al (UK)*

Application of a multi-zone airflow and contaminant dispersal model to indoor air quality control in residential buildings. *S J Emmerich et al (USA)*

Two-zones model for predicting passive stack ventilation in multi-storey dwellings. *J G Villenave et al (FRA)*

Practical methods for improving estimates of natural ventilation rates . *I S Walker et al (CAN)*

A suggested standard methodology for the assessment of the performance of domestic ventilation systems. *Dr R E Edwards et al (UK)*

Simulation of passive cooling and facade driven natural ventilation. *V Dorer et al (SWITZ)*

SESSION 6: Measurement and Modelling

Dare you risk designing without the best tools? *J Littler et al (UK)*

Design tool for optimizing the selection of ventilation plants. *G Wernstedt (SWE)*

AIVC POSTER *M Orme (UK)*

Air movement studies in a large parish church building. *I C Ward et al (UK)*

Particle-Streak-Velocimetry for Room Air Flows. *F. Scholzen et al (SWITZ)*

Thermal simulation of ambients with regard to ventilated attics. *E Kruger (GER)*

Flow paths in a Swedish single family house - a case study. *B Hedin (SWE)*

An attempt to model non-uniform zone air with a nodal network. *J L M Hens et al (UK) (NETH)*

Determination of k-factors of HVAC system components using measurements and CFD modelling. *S R Riffat et al (UK)*

Measurement and modelling of aerosol particle flow in an environmental chamber. *A N Cheong et al (UK)*

Full scale modelling of indoor air flows. *F Steimle et al (GER)*

Tracer gas mixing with air: Effect of tracer species. *Prof. S B Riffat et al (UK)*

Preliminary ventilation effectiveness measurements by a pulse tracer method. *M R Bassett et al (N.Z.)*

Ventilation and utility program incentives in the northwest U.S. *D T Stevens (USA)*

Checking the performance of ventilation systems. *P Granqvist (SWE)*

The effects of balancing the ventilation in office buildings. *J Teljonsalo et al (FIN)*

Climate-based analysis of residential ventilation systems. *N E Matson et al (USA)*

Measuring subfloor ventilation rates. *R Hartless et al (UK)*

Standardised measurements of the cooling performance of chilled ceilings.*Fritz Steimle (GER)*

The measured energy impact of air leakage on a house. *S Vaidya (USA)*

Air flow through smooth and rough cracks. *A Sharples et al (UK)*

Comparison of the accuracy of detailed and simple model of air infiltration. *J-M Furbinger (SWITZ)*

An experimental and theoretical investigation of airflow through large horizontal openings.*J S Kohal et al (UK)*

Algorithms for interzonal particle flow through large openings. *K W Cheong et al (UK)*

Conference Dinner

Friday, 30th September

SESSION 7: Ventilation Strategies

Occupant satisfaction and ventilation strategy - a case study of 20 public buildings.*G Donnini et al (CAN)*

Ventilation strategies to mitigate passive smoking in homes. *M D A E S Perera et al (UK)*

Protecting the indoor air against external external pollutants in the case of a sudden contamination of the outdoor air. *K E Siren et al (FIN)*

An indoor air quality model to determine residential ventilation rates for comfort. *T Hamlin (CAN)*

The Air Lock Floor. *J C Phaff and WF de Gids (NL)*

Summing up

End conference

Estimation of Air Infiltration and Building Thermal Performance

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Department of Physics, University of Siegen, Germany

**On leave from Department of Mechanical Engineering, Indian Institute of Technology, Bombay, India*

Abstract

This paper presents the estimation of air infiltration in a building using the COMIS multi-zone model. The applicability of this information in the design of buildings is demonstrated and the effect of air infiltration in the thermal performance of buildings is investigated. An integrated method incorporating both air infiltration estimation and building thermal simulation is proposed.

1. Introduction

The knowledge of airflow patterns in a building is necessary to determine the quality of air, to estimate space heating/-cooling loads and to make sizing calculations of air conditioning equipment. In this communication, we focus our attention on the airflows in a building occurring due to infiltration.

There are a number of experimental techniques used for measuring the infiltration of air in a building [1]. Also reported are mathematical approaches ranging from empirical techniques to rigorous multizone models [2,3]. The multizone models are well suited for buildings with internal partitions or having inhomogeneous concentrations in the living space. We have used a multi-zone infiltration model known as CO_(Conjunction of Multi-zone Infiltration Specialists) model [3] for estimating airflows in a building.

The currently most common practice of including the effect of air infiltration on building thermal simulation is to use a constant value for the air change rate. Its value is selected on the basis of thumb rules which lack proper theoretical justification. It would, however, be more appropriate to estimate this quantity according to building construction details and for given climatic conditions. It can then be used as an input for the thermal simulation of the building.

In this paper, the estimation of air infiltration in a building is presented and its applicability in building design is demonstrated. The effect of the infiltration on building thermal performance is investigated and a procedure for integrating the air infiltration calculations into the thermal simulation of buildings is proposed. The program SUNCODE [4] has been used for thermal simulation and calculations have been carried out for an example building corresponding to the climatic conditions of New Delhi (28.58 Deg N, 77.20 Deg E), India.

2. Description of the Building

A simple building has been considered as an example for the present investigation; the plan of which is shown in Figure 1. It is a typical middle-class small family residence in India. It consists of two rooms (zones 1 and 2), one kitchenette (zone 5), one toilet (zone 3) and a small entrance passage (zone 4); the volumes of these zones are 45.0 m^3, 45.0 m^3, 36.0 m^3, 18.0 m^3, and 21.6 m^3, respectively. The height of the building is 3.0 m.

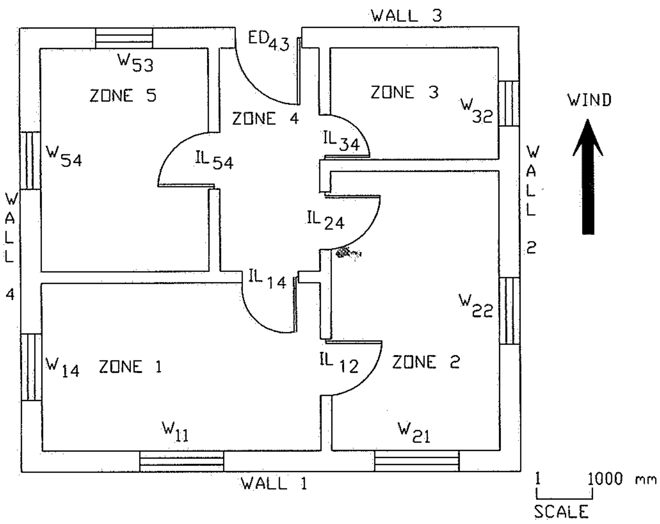

Figure 1: Plan of the building

There are seven windows on external walls and their sizes are:

W_{11} and W_{21}: (1.5 x 1.2) m^2; W_{14} and W_{22}: (2.1 x 1.2) m^2;

W_{32}: (0.8 x 0.8) m^2; W_{53} and W_{54} : (1.0 x 1.2) m^2.

The building has an external door (ED_{43}) of size (1.2 x 2.0) m^2. There are five interzonal doors and all are of the size (1.0 x 2.0) m^2, except that between zones 4 and 3, which is of (0.8 x 2.0) m^2.

The building is assumed to be an isolated one sitting on an open flat terrain wind direction is normal to the upwind wall. Consequently, the pressure coefficients on external surfaces have been used following e.g. Grosso [5]. Further, the leakages are considered to exist only around the perimeters of windows and doors. It may be mentioned that the recommended values for flow coefficients per unit length of various types of cracks corresponding to typical Indian building constructions were not available to us. It was also not possible to find measured values of air infiltration for buildings in India. Therefore, the flow coefficient per unit crack length has been estimated only with a value of 30 m^3/h-m-Pa 2/3 [6]. This corresponds to an air change rate of about 2 h^{-1}, which is considered to be typical for Indian buildings in view of the fact that they are relatively less airtight.

3. Infiltration Calculations

The calculations performed to investigate the various implications of air infiltration have been carried out with a resolution in time of one hour. The weather related data used for these calculations correspond to a typical day of month January in New Delhi [7].

Effect of Building Orientation:

The building with a given plan of doors and windows, both internal as well as external, needs to be oriented appropriately with reference to the prevailing wind direction so as to realize the desired air flow into the building. The best orientation would correspond to the situation for which there would be the required rate of fresh air exchange. At the same time, there should be no undesirable interzonal flow such as fumes or foul smell entering the living space from the kitchen or the toilet. For given internal as well as external leakages, the air infiltration calculations will help in fixing the orientation of the building with respect to the prevailing wind direction to satisfy these requirements.

With this in view, the calculations have been carried out for angles of wind direction 0 deg, 90 deg, 180 deg and 270 deg, respectively. Figure 2 shows the corresponding building plans. It may be noted that the physical situations for wind angles 90 deg, 180 deg and 270 deg are equivalent to corresponding rotations of the building anticlockwise by 90 deg, 180 deg,and 270 deg with respect to the wind direction at angle zero. In other words, for a given prevailing wind direction which is represented by the wind angle zero, these calculations would help in determining the best orientation for the building.

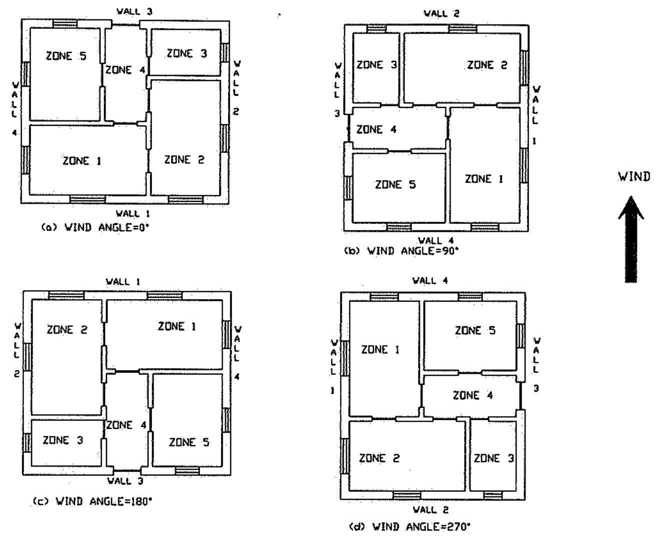

Figure 2: Building plans for various orientations

The total infiltration in the building corresponding to different wind angles remains more or less constant with a small variation depending on the crack length on the upwind wall. The maximum air exchange is about 2.24 h^{-1} occurring for the wind angle of 0 deg (that is, wall 1 is the upwind wall) and the maximum negative of 270 deg (that is, wall 2 is the upwind wall). This is due to the fact that the crack length on wall 1 of the building is the maximum whereas that on wall 2 is the minimum.

The interzonal flows for various wind angles have been shown in Figure 3. They demonstrate among others the following results: for a wind angle of 270 deg, the air flow takes place from zone 3 (toilet) to zone 4 (entrance passage). For wind angles of 90 deg and 180 deg, the flow occurs from zone 5 (kitchen) to zone 4 (passage). Consequently, there is flow from zone 4 to other zones, namely zones 1 and 2 (living space, bedroom). These types of interzonal air flows from kitchen or toilet to the living spaces are undesirable. On the other hand, there is no such unwanted interzonal flow for the case of wind angle zero. This, and the fact that the external air change is not significantly affected by a rotation of the building, leads to the conclusion that the best orientation corresponds to the case with wind angle zero, i.e. when wall 1 faces the wind.

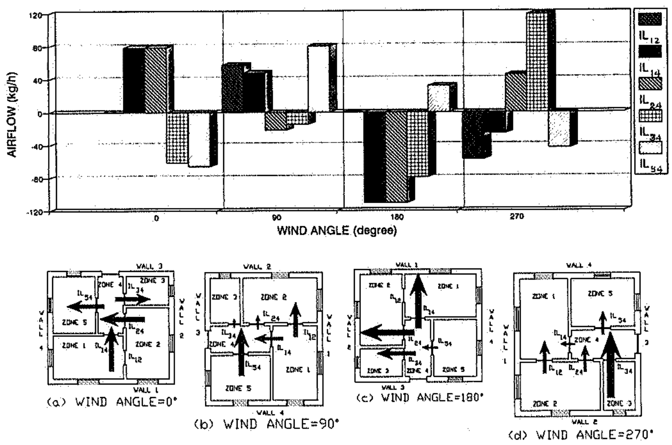

Figure 3: Interzonal airflows for various building orientations

Effect of Location and Size of Leakages:

For a fixed orientation of a building with respect to the prevailing wind direction, the infiltration calculations can also be used to identify the best location of doors and windows including their sizes so as to ensure appropriate interzonal air flows. In other words, for a given building plan, the estimation of air flows can be used to identify the openings which are to be removed or made airtight in order that fumes from the kitchen or foul smell from the toilet do not enter the living space or bedroom (zones 1 and 2) through the passage (zone 4). Consequently, the undesirable interzonal flows are avoided and the quality of indoor air is maintained good. For a fixed plan and orientation (with reference to the prevailing wind direction) of the building, these studies can be carried out for the external openings while the internal leakages are kept unchanged and vice versa.

In order to demonstrate this capability, calculations have been carried out for various locations and sizes of doors and windows different from those shown in the original building plan (Figure 1). Although many combinations could be possible, only a few examples have been discussed here for explaining the results. It is assumed that wall 1 is facing the wind, i.e., wall 1 is the upwind wall and its crack length remains constant for all calculations. Also, the sizes of each room are kept constant. The four cases that have been considered as examples differ mainly in the locations and sizes of doors and windows. The corresponding air supplies for zone 4 which would result in air flows to living space or bedroom have been indicated by the thickness and direction of interzonal arrows.

Case I: The building plan considered in this case is given in Figure 4(a). A comparison of it with that depicted in Figure 1 shows that the interzonal leakages are unchanged, but the external openings are modified. the windows W_{21} and W_{54} are assumed to be absent while (the leakage lengths of) the windows W_{11}, W_{14}, W_{22} and W_{53} are now of twice the sizes than those shown in Figure 1. The external door is relocated in zone 2 on wall 2. Under these conditions, it is seen that there is air flow from the kitchen to the living area resulting in an air change rate of about 0.34 h^{-1} for zone 4. This zone is for this case and the following ones a connecting passage instead of an entrance area (as in the base case). The flow can be reduced to an air change rate of 0.23 h^{-1} if a window W_{43} (half the size of the window W_{53}) is provided in zone 4 on wall 3. The flow can be reversed, however, if any one of the windows W_{14}, W_{22} and W_{53} is halved in size, or if W_{32} is relocated as W_{33}.

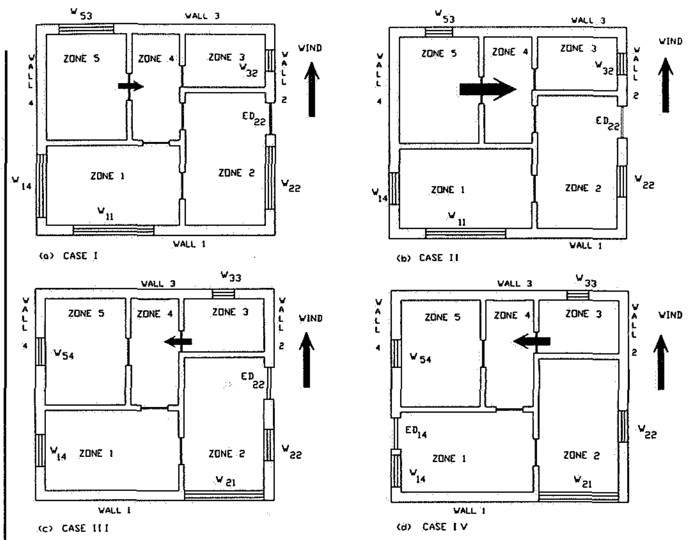

Figure 4: Building plans for different special cases

Case II: Figure 4(b) shows the building plan used for this example. Here, external openings and internal links have been changed both: Windows W_{21}, W_{54} and the internal door IL_{14} are removed while the window W_{11} is doubled. The external door ED_{22} is provided in zone 2 on wall 2 instead of that in zone 4 on wall 3. For this situation, an undesirable air flow pattern is observed: The flow occurs from zone 5 (kitchen) to zone 4 creating an internal air exchange of about 0.80 h^{-1} for this zone. Air exchange reduces to 0.54 h^{-1} if the window W_{43} mentioned in Case I is provided in zone 4 on wall 3. Air change stops completely if the external door ED_{43} of Figure 1 is present in zone 4 on wall 3 instead of the window. The flow can also be reduced to 0.26 h^{-1} if the window W_{32} of zone 3 on wall 2 is located on wall 3 as W_{33}. It reverses if a window W_{54} is provided or if the internal door IL_{14} is present.

Case III: In this case the following variations of the building plan compared to those ones shown in Figure 1 are considered: Windows W_{11}, W_{53} and the internal door IL_{24} are removed while the window W_{21} is doubled. The window of zone 3 is considered to be located on wall 3 instead of wall 2, i.e., W_{32} is replaced by W_{33}. An external door ED_{22} is provided in zone 2 on wall 2 in lieu of ED_{43}. The corresponding building plan is shown in Figure 4(c). For such a situation, the flow of air occurs from zone 3 (toilet) to zone 4, creating an air exchange of about 0.37 h^{-1} for zone 4 which is not desirable. If the window W_{53} is added again, the flow decreases. The flow can be stopped completely if an external door ED_{43} or a window W_{32}, instead of W_{33}, is provided.

Case IV: The building plan considered for this case is shown in Figure 4(d). It is the same as that shown in Figure 4(c) except that the external door ED_{22} is relocated as ED_{14}. It is seen that the flow decreases. The flow can be stopped completely if an external door ED_{43} or a window W_{32}, instead of W_{33}, is provided.

These example cases clearly illustrate that the COMIS model can be used to locate and size external as well as internal leakages like windows, doors etc. of a building accordingly to examine and establish desirable interzonal air flows. For every given ground plan and configuration of leakages modifications and alternatives could be presented directing or sizing the air flows towards better indoor quality and better thermal comfort.

4. Integration of Infiltration and Thermal Simulations

The hourly variations of meteorological parameters, particularly wind speed and ambient temperature, cause a systematic variation of the infiltration rates in building. Therefore, the use of a constant infiltration rate - a usual practice in current building thermal simulations - is not appropriate. Thus, it is desirable to estimate air change rates for a building as function of time and to integrate calculation results into thermal simulations of this building.

For the purpose of its thermal simulation the building has been divided into five zones (Figure 1). With assumed values for zone temperatures, the air change rate is calculated for each zone. This is used as an input for the thermal simulation and the zone temperatures are calculated on this basis. The air change rate of each zone is then recalculated using these new zone temperatures. This iterative procedure is repeated till the successive results of zone temperatures are more or less the same (by 0.01 deg C). In order to carry out these calculations in an integrated fashion, suitable modifications have been made in the source codes of COMIS and SUNCODE programs.

The building is assumed to be non-conditioned and the results of integrated calculations are compared with those obtained from the simulation with a fixed air change rate of 2 h^{-1}. This value for the fixed air change rate of the example building has been estimated with the help of the COMIS model corresponding to yearly average wind speed and ambient temperature in New Dehli [7].

The various heat flows occurring in the building on a daily basis for winter conditions in New Delhi (month January) have been calculated and presented in Table 1 and Figure 5. The negative sign of heat flows in Table 1 indicates that they are actually heat losses from the building. The term "ambient" refers to the heat flows through all walls and the roof.

Table 1: Building Heat Flows

Climate	Type of calculation	Window (MJ/day)	Ambient (MJ/day)	Ground (MJ/day)	Infiltration (MJ/day)
winter	integrated	-19.1	-20.4	-0.1	-36.3
	fixed air change rate	-18.6	-16.4	+0.3	-41.3

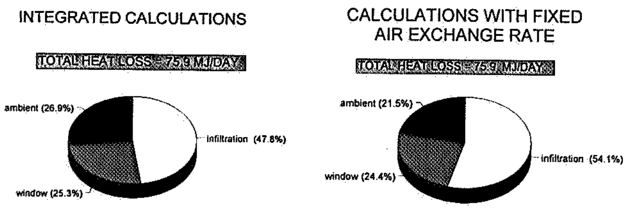

Figure 5:Building heat flows for a winter day in Delhi according to different calculation methods

The infiltration losses do not agree in both calculation methods because the hourly air change rates are - due to the climatic conditions of this day - quite different from the constant value of 2 h^{-1} for the fixed case. The indoor temperatures come out to be slightly higher in the case of integrated calculation and consequently the window and ambient losses are higher, too. For the same reason, the building then looses heat through the ground whereas it gains heat for the fixed case. Thus it is seen that the predictions for various losses by the simulation with fixed air change rate are different from those of the integrated model.

It may be mentioned that during summertime usually the windows are not kept closed throughout the day and are generally opened in the evening to reduce the indoor air temperature. Consequently, infiltration calculations for closed windows during summertime are not of much interest and are not reported.

With the help of a more realistic estimation of air infiltration using the COMIS model, a more reliable and accurate prediction can be made for the thermal performance of the building. Therefore, it is strongly recommended to use an integrated calculation method for thermal simulation of buildings incorporating the estimation of air infiltration, provided the required wind data are available.

5. Conclusions

The conclusions of the present investigation are summarized as follows:

(i) The air infiltration rate of a building is strongly influenced by building parameters and constructional properties of components such as orientation, distribution of leakages and their flow characteristics. Also, weather dependent variables such as wind speed and temperature significantly affect its value. Consequently, the air infiltration rate for a building cannot be guessed properly without the knowledge and right use of the corresponding information. It is, therefore, necessary to carry out integrated calculations for incorporating the effect of infiltration on building thermal simulation with correct or well-reasoned values.

(ii) For a given building plan and fixed external and internal leakage distributions, the best orientation for the building with reference to the prevailing wind direction can be selected so as to realize a desirable fresh air exchange and to ensure preferable interzonal airflows. Also, for a given building plan and fixed orientation of this building with respect to wind direction, it is possible to investigate the best location and size of exterior and interior openings to establish desirable interzonal airflows.

(iii) Predictions of building thermal simulations based on a fixed air infiltration rate can differ significantly from those with integrated simulations. The differences are more prominent for higher wind speeds and stronger variations of it. Therefore, it is essential to incorporate improved estimations of air infiltration into the thermal simulation of building, at least for the above-mentioned case.

Acknowledgements

The financial support of the International Office at the Forschungszentrum Juelich, Germany, for this project work is gratefully acknowledged.

Nomenclature

ED_{ij}	External door of i'th zone on j'th wall
i	integer variable for zone number
IL_{im}	internal link connecting i'th zone with m'th zone
j	integer variable for wall number
m	integer variable for zone number
W_{ij}	window of i'th zone on j'th wall

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AIVC CONFERENCE PROCEEDINGS

AIVC Conference Proceedings nos 1-9 are available as individual papers, or in microfiche form. Details of contents can be forwarded on request.
10th 'Progress and trends in air infiltration and ventilation research' Espoo, Finland, 1989;
11th 'Ventilation System Performance' Belgirate, Italy, 1990;
12th 'Air Movement and Ventilation Control within Buildings', Ottawa, Canada, 1991, 3 volumes.;
13th 'Ventilation for Energy Efficiency and Optimum Indoor Air Quality', France, 1992;
14th 'Energy Impact of Air Infiltration and Ventilation', Denmark, 1993

LITERATURE LISTS

1) Pressurisation - infiltration correlation: 1. Models.
2) Pressurisation - infiltration correlation: 2. Measurements.
3) Weatherstripping windows and doors.
4) Caulks and sealants.
5) Domestic air-to-air heat exchangers.
6) Air infiltration in industrial buildings.
7) Air flow through building entrances.
8) Air infiltration in commercial buildings.
9) Air infiltration in public buildings.
10) Carbon dioxide controlled ventilation.
11) Occupancy effects on air infiltration.
12) Windbreaks and shelterbelts.
13) Air infiltration measurement techniques.
14) Roofs and attics.
15) Identification of air leakage paths.
16) Sick buildings.
17) Flow through large openings.
18) Control of cross contamination from smokers.
19) Location of exhausts and inlets.

*For list of participating countries see back page.

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