AIVC 12030

15 . 1

EUROPEAN STUDIES ON NATURAL VENTILATION

K. Limam, F. Allard, E. Dascalaki and M. Abadie

Natural ventilation is very attractive for architects because it offers robust solutions capable of providing acceptable indoor air quality and comfort throughout the full range of climate conditions. During the European Commission's ZEPHYR architectural competition,[1] organized by the Energy Research Group at University College, Dublin in 1994, it soon became very clear that most of the projects used natural ventilation as the principal technique for passive cooling and to provide an acceptable indoor environment.

In most cases, the minimum ventilation rates needed for indoor air quality can easily be reached, and the maximum ventilation rates needed for summer thermal control of the building can readily be identified. Natural ventilation is a logical and suitable strategy for many types of buildings, such as low-rise dwellings, schools, small or medium size offices and recreational and public buildings in moderate or mild climates. The open-window environment associated with natural ventilation is often popular and offers a wide range of design possibilities to architects. Natural ventilation can also be very cost-effective solution, when compared to the capital, maintenance and operational costs of mechanical systems and does not need any plant-room space. In such an environment, short periods of summer discomfort, if any, will be easily tolerated by the users of the building.

However, natural behaviour also means random airflow behaviour and less rigid control of the building's performance. The physical phenomena to be taken into account usually correspond to simple concepts such as thermal mass, but they are not easy to handle because of many uncertainties, for example the randomness of indoor airflow patterns or the difficulty of determining the surface heat transfer between the air and the walls. Furthermore, in many urban environments, outdoor air conditions and acoustics may not be acceptable because of air pollution and noise.[2] In these conditions, natural ventilation can be unsuitable or will need special attention during the design phase in order to avoid a direct link between the indoor and outdoor environments. In order to be effective, natural ventilation also requires a high degree of permeability within the building. In some buildings this can lead to security risks and conflicts with fire or safety regulations. In the case of deep-plan or multi-roomed buildings, fresh air delivery or good mixing may not be possible without some special design measures. These few examples show that while natural ventilation is very attractive, good design of naturally ventilated buildings needs to take into account many phenomena and criteria which are not necessarily easy to handle.

This article is largely aimed at architects, policy-makers and engineers who need to acquire a broad background knowledge about natural ventilation. In Europe, research on this topic within the frame of the PASCOOL[3] and AIOLOS[4] projects has included experimental and modelling work intended to fill existing gaps in our knowledge of indoor air conditions in naturally ventilated buildings. The co-ordinated efforts of research groups from Belgium (BBRI), France (LEPTAB in La Rochelle, ENTPE/LASH in Lyon), Greece (University of Athens), Italy (Comphoebus and University of Milan), Portugal (University of Porto) and Spain (University of Seville) have made these projects some of the most significant contributions to natural ventilation studies in the recent years.

PREDICTION METHODS

The physical processes that are involved in natural ventilation are very complex and the interpretation of their role in ventilation effectiveness is a difficult task. Classical fluid dynamics has described airflow phenomena under well defined boundary conditions in a quite satisfactory way. Description of the phenomena is achieved by solving the well known Navier–Stokes equations, combined with equations describing turbulence effects, under specific boundary and initial conditions. However, if the chaotic, random character of the wind is taken into account, a full knowledge of the boundary and initial conditions is almost impossible. Knowledge of the specific airflow characteristics in a space, as well as of the global airflow rates in buildings, is necessary for both comfort and energy design. Designers often wish to know the airflow rate through large openings in order to size building windows appropriately, while engineers are often more interested in the distribution of the air velocity in a zone to size ventilation inlets and outlets. Comfort experts may wish to know the air velocity values in a zone to calculate heat convection from or to the human body, while air-quality experts are interested in the flow rate, the dispersion of contaminants and the ventilation efficiency. According to the type of information required, various models and tools may be used. Models range from very simple empirical algorithms to calculate the global airflow rate to sophisticated computerized fluid dynamic techniques to solve the Navier–Stokes equations. In general, depending on the level of modelling complexity required, four different approaches can be distinguished for the description of the airflow in the case of natural ventilation of buildings:

- empirical models:
  - British Standard method;[5]

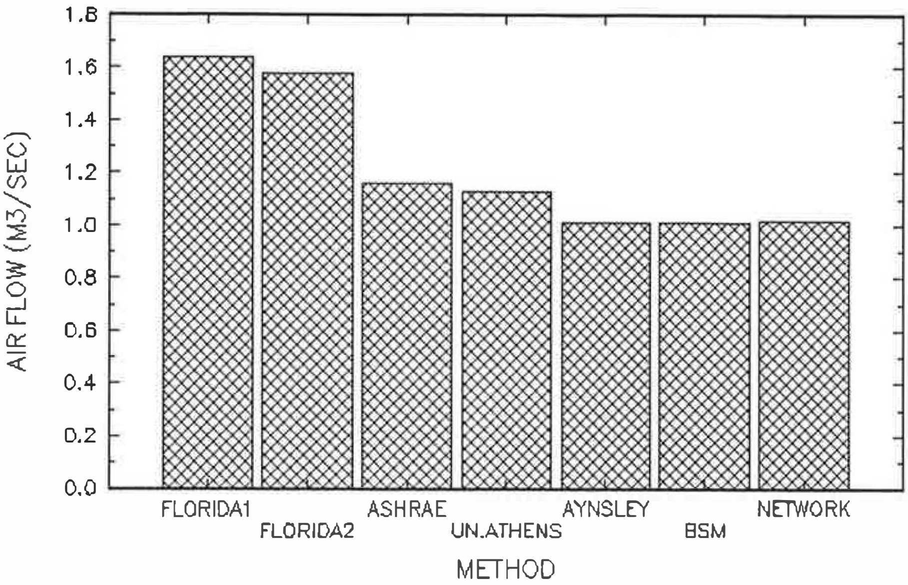

Figure 1. Predicted airflow values[4]

- ASHRAE;[6]
- Aynsley;[7]
- De Gidds;[8]
- Givonni;[9]
- Melaragno;[10]
- CSTB methodology;[11]
- Ernest methodology;[12]

• network models (Pascool[3]):
- PASSPORT-AIR
- COMIS

• zonal (opening-sizing) models;
- the Florida solar energy methods I and II;
- ASHRAE;
- Aynsley;
- British Standard method;
- computerized network method;

• CFD (computational fluid dynamic) models, which will not be discussed in this article.

Comparison between some of these models is given in Figure 1 (for a naturally ventilated building of 700 m^3); the calculated standard deviation is 0.27.

THE AIOLOS SOFTWARE[4]

Specific software for the calculation of the airflow rate in natural ventilation configurations has been developed at the Universities of Athens and La Rochelle. Based on the principles of network modelling, this tool offers the user many simulation possibilities, which can either be used for

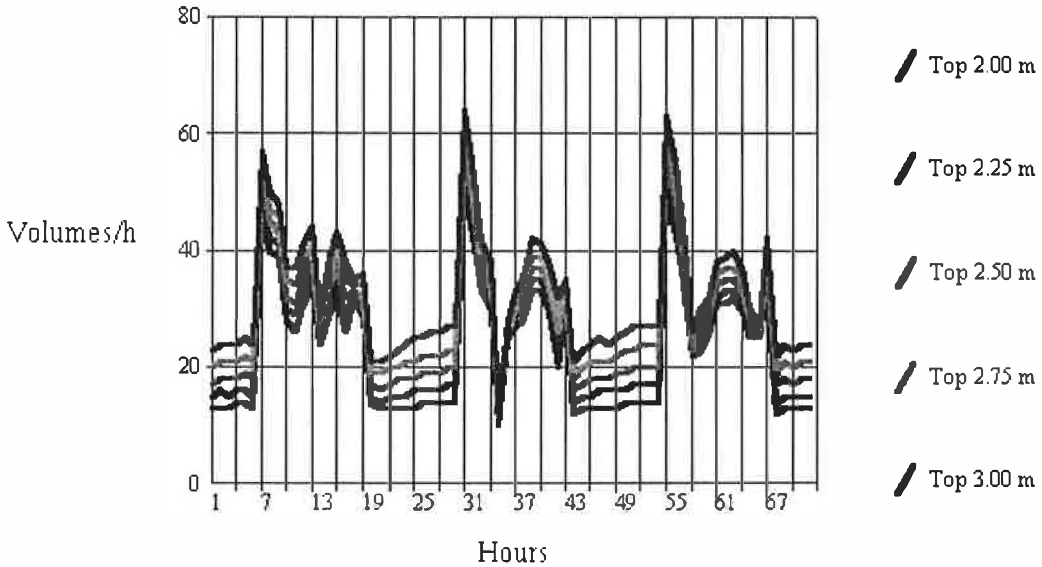

Figure 2. Sensitivity analysis on the height of the top of the eastern window (zone 2)[4]

Natural Ventilation in Buildings

A DESIGN HANDBOOK

The benefits – environmental, economic, and for occupants' comfort and health – of ventilating buildings naturally, rather than mechanically, are becoming increasingly recognised and sought after.

Approaches can be high-tech or low-tech, but always need to be part of an integrated design approach. A range of technical barriers, such as building codes, fire regulations and acoustics, also need to be taken into account.

This new handbook describes the real potential of natural ventilation, its appropriate use, the design and dimensioning methodologies, the need for an integrated design approach, and how to overcome barriers.

The book will provide essential design information for all architects, building engineers and other building design professionals.

Natural Ventilation in Buildings – A Design Handbook is written by the AIOLOS project participants, whose task has been putting into design-tool form the findings from various recent Europe-wide studies on natural ventilation and cooling.

EDITOR
The book was edited by Francis Allard of the University of La Rochelle, France based on the contributions of participants in AIOLOS, a European-funded project. The work was coordinated by Mat Santamouris from the University of Athens, Greece and involved experts in numerous European Countries.

£50.00/$75.00 • Hardcover • ISBN: 1-873936-72-9
c.400pp • 234 x 156 mm • March 1998

Available from:
James & James (Science Publishers) Ltd
35–37 William Road, London NW1 3ER, UK
Tel +44 171 387 8558
Fax +44 171 387 8998
email orders@jxj.com

JAMES X JAMES

design purposes or simply be explored to provide a deeper insight into the mechanisms involved in natural ventilation. The AIOLOS software is focused on calculation of the airflow rates in multiroom buildings. The following functions are offered:

- calculation of global airflow rates in each simulated zone;
- calculation of airflow rates through each of the openings in the building structure;
- sensitivity analyses for investigation of the impact of specific parameters of natural ventilation;
- an optimization process for the derivation of appropriate opening sizes to achieve optimum airflow rates within the required room configurations;
- a thermal model for assessment of the impact of various natural ventilation strategies on the thermal behaviour of the building.

These calculations can be run for a short (one day) or an extended (up to one year) time period. Climatic data can be treated statistically through an in-built climatic preprocessor. This feature allows the user to receive a rapid assessment of the prevailing climatic characteristics in the region in which the building is located. The results are reported in tabular or graphical form. For a better understanding of the results, statistical treatment is also possible. The above features are combined in a user-friendly interface. To facilitate use, the software is provided with an online help facility. An example of results is given in Figure 2. As shown, the resulting global air exchange rates increase with increasing height of the eastern window.

DIAGNOSTIC TECHNIQUES

To judge the performance of a building, a system or a particular technology, we need a set of evaluation tools: diagnostic techniques. In the case of buildings designed for passive ventilation, such diagnostic techniques aim to facilitate a good understanding of the physical behaviour of the building and/or the comfort conditions that will be provided. Diagnostic techniques can be applied in different situations:

- In existing buildings, before retrofitting, the main aim is to obtain a better understanding of the building performances.
- In new or retrofitted buildings, the typical aim is to evaluate to what extent the building functions as predicted.

There may be several reasons for carrying out diagnostic studies:

- To evaluate the performance of a range of buildings during summer. The sample will then be either the complete building set or a representative sample of the population of buildings. Physical parameters as well as users' satisfaction can be included.

- To evaluate a specific building to obtain a better understanding of its performance without any specific aim to solve or improve certain aspects of the building.
- To evaluate a specific building problem with the aim of obtaining good indications of how to improve the performance of the building.

CRITICAL BARRIERS

Natural ventilation can play an important role in the control of indoor air quality and indoor temperature in summer, contributing to the prevention of overheating when an adequate ventilation strategy is adopted. However, the success of natural ventilation strategies can be affected by other factors in the design and use of the building, which must be anticipated if natural ventilation is to work effectively:

- building operation issues (safety, air pollution, shading, draught prevention, ignorance of the occupants);
- building design issues (fire regulations, acoustic regulations, pattern of use, need to provide shading, privacy and daylighting, automatic controls, lack of suitable, reliable design tools);
- other issues: architecture, acceptance of a certain degree of fluctuation of the indoor conditions, compliance with or absence of suitable regulations.

Thus, naturally ventilated buildings face many hurdles and they will be the exception rather than the rule as long as most of these barriers are not overcome with good, inexpensive, robust solutions. This project aims to guide designers in the search for good alternatives, as far as the current state of the art allows.

DESIGN GUIDELINES AND TECHNICAL SOLUTIONS

The effectiveness of natural ventilation, i.e., its capacity to provide good indoor air quality and passive cooling in a building, depends greatly on design decisions. Mechanical ventilation systems can be designed separately from the design of the buildings in which they are installed; they can also be installed in existing buildings after a few modifications. In contrast, ventilation systems using only natural mechanisms, such as wind and thermal buoyancy, need to be designed together with the building, since the building itself and its components are the elements which can reduce or increase air movement as well as influence the air quality (dust, pollution, etc.). Architects and engineers need to acquire qualitative and quantitative information about the interactions between the building and its environment in order to design buildings and systems consistent with a passive low-energy approach. Such qualitative information includes: design context; background; design concepts; and design criteria. Quantitative information includes: the results of calculation techniques for defining climate parameters, sizes of openings and estimates of

Swiss quality products

- HEAT PUMPS
- DIGITAL CONTROL FOR HEATING EQUIPMENT

SAURER
THERMOTECHNIK

Heat Pumps for Heating (Natura) or Hot Water (Eco Boiler), Electronic Control Systems

SAURER THERMOTECHNICS Inc.
P.O.Box 196
CH-9320 Arbon
Switzerland
Tel: 41 71 446 92 12
Fax: 41 71 446 67 05

ICEC

ECOSOLAR® Hybrid Solar Panels
– makes zero-energy house possible –
– fully roof and facade integrated –
– world solar efficiency record –

ECOLUX® Energy Saving Lamps
– 80% energy saving –
– supercompact –
– electronic –
– long life –

Ask for local contact of international network

International Clean Energy Consortium
ICEC AG, POB 928, CH-8055 Zurich
Phone: +411-463-9252
Fax: +411-463-0252
e-mail: icecag@zik.ch

Figure 3. The building occupied by Meletitiki Ltd in Athens[4]

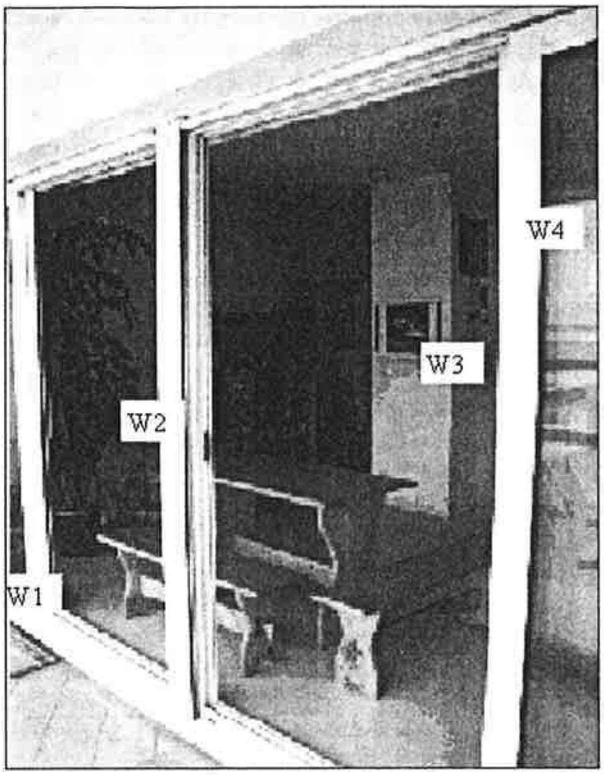

Figure 4. Apartment in La Rochelle[4]

airflow rates; and the results of other evaluation methods assist the selection and incorporation of proper technologies.

NATURAL VENTILATED BUILDINGS – CASE STUDIES

Several types of buildings were studied:

- an office building (Athens, Greece) (Figure 3);
- a detached single-family residence (Porto, Portugal);
- a row-house single-family residence (in Louvain-la-Neuve, Belgium);
- two apartments in multifamily high-rise buildings (La Rochelle, France – Figure 4 – and Catania, Italy);
- a school building, in Lyon, France.

The effectiveness of natural ventilation, both as cross-ventilation and as single-sided ventilation, is demonstrated in each case by measurements of the performance of several buildings. Examples of results of the experiments carried in Athens and La Rochelle are given in Figure 5 and Table 1 respectively.

A closer look at the graphs in Figure 5 gives some insight into the impact of night ventilation on the performance of the building. During the night ventilation period, the temperature in the building drops and follows the variation of the ambient temperature. Night ventilation reduces the temperature in the building by 2°C.

In order to evaluate the impact of various natural ventilation strategies, multi-tracer gas measurements were carried out in La Rochelle.[4] From these experiments it was possible to define a natural ventilation efficiency index for each configuration as an average of the ratio of the local mean age and room mean age of the air. Table 1 gives the natural ventilation efficiency coefficients averaged for various experiments carried out in the La Rochelle building. It appears that natural single-sided ventilation can be very efficient. The comparison between Cases 1 and 3 shows that opening a double section in the middle of the window does not increase significantly the ventilation efficiency, which improves from 68.3 to 71.7. In contrast, when the same area is open, but located on the two opposite sides of the window (Case 3), it is possible to increase the efficiency significantly with a different airflow pattern. These results have been confirmed by flow visualization in a water channel.

CONCLUSION

A large research effort in the field of natural ventilation has been undertaken within various European projects during recent years. These projects have demonstrated how useful natural ventilation strategies can be in ensuring good indoor quality in European buildings. Nevertheless, these

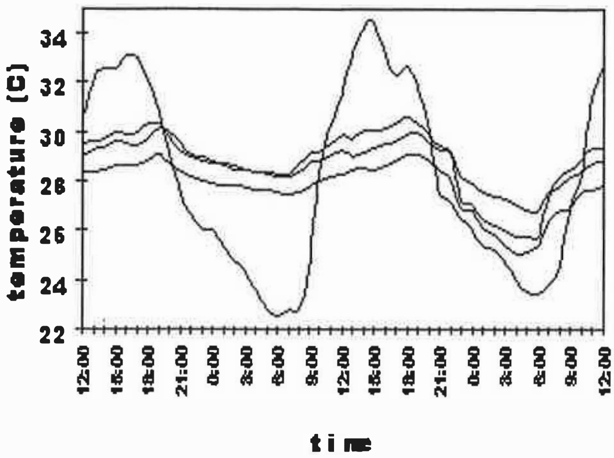

Figure 5. Impact of night ventilation (Meletitiki office building in Athens) 4. 7.8.95–9.8.95

projects have also pointed out critical barriers to the effective use of such technical solutions and the difficulties in designing and dimensioning efficient systems for natural ventilation. Our work has aimed to fill these existing gaps by providing designers with a synthesis of scientific knowledge acquired in recent European projects and transforming it into efficient design tools and guidelines for architects and engineers.

REFERENCES

1. ZEPHYR European Architectural Ideas Competition (1994). Energy Research Group, School of Architecture, University College Dublin for European Commission DGXII.
2. Maldonado E (1996). Syntheses of barrier and challenges: why natural ventilation?, AIOLOS Workshop, Lyon, November.
3. Limam K, Allard F (1995). Ventilation-Thermal Mass Subtask, Final Report. Pascool EC Project Jou2-CT92-0013, DGXII, Brussels.

Table 1. Ventilation efficiencies for different window-opening patterns in the apartment at La Rochelle

			Efficiency (%)
S 1 opened		Case 1	68,3
S 2&3 opened		Case 2	71,7
S 1&4 opened		Case 3	87,5

4. AIOLOS Handbook (1997). Altener Program, Final Report, DGXVII, Brussels. The Handbook is obtainable from GBES, University of Athens, Greece.
5. BS 5925 (1980). Code of practice for design of buildings: Ventilation principles and designing for natural ventilation. British Standards Institution, London.
6. ASHRAE Fundamental Handbook (1985). Chapter 22: Natural ventilation and infiltration. American Society of Heating, Refrigeration and Air-Conditioning Engineers, Atlanta, GA.
7. Aynsley RM, Melbourn W, Vickery BJ (1977). Architectural Aerodynamics. Applied Science Publishers, London.
8. De Gidds W, Phaff H (1982). Ventilation rates and energy consumption due to open windows. Air Infiltration Review, 4(1), 4–5.
9. Givonni B (1978). L'Homme, l'Architecture et le Climat. Eyrolles, Paris.
10. Melaragno M (1982). Wind in Architectural and Environmental Design. Van Nostrand Reinhold, New York.
11. CSTB (1992). Guide sur la climatisation naturelle de l'habitat en climat tropical humide – Methodologie de prise en compte des parametres climatiques dans l'habitat et conseils pratiques. Tome 1. CSTB, 4 Avenue du Recteur Poincaré, 75782 Paris Cedex 16, France.
12. Ernest DR (1991). Predicting Wind-Induced Air Motion, Occupant Comfort and Cooling Loads in Naturally Ventilated Buildings. PhD Thesis, University of California at Berkeley.

K. LIMAM, F. ALLARD and M. ABADIE are at LEPTAB, University of La Rochelle, F-17042 La Rochelle, France and E. DASCALAKI is at GBES, University of Athens, Physics Department, G-157 84 Panepistimioupolis, Athens, Greece