The Role of Ventilation
15th AIVC Conference, Buxton, Great Britain
27-30 September 1994

Applications of the Air Infiltration and Ventilation Centre's Numerical Database

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Synopsis

Building airtightness data are essential for design and model evaluation. An attempt has been made with the Numerical Database to compile data appropriate to infiltration and ventilation studies. These cover the air leakage characteristics of building components, the characteristics of buildings themselves and data on wind pressure distributions.

AIVC Technical Note 44 (*Orme, Liddament, and Wilson, 1994*), contains detailed summary tables and graphs of the information stored in the computer Database, together with a complete list of references. Technical Note 44 also discusses wind pressure distributions on buildings.

This paper outlines some potential applications of the Numerical Database and illustrates one of these with a worked example. It also briefly discusses how airtightness is represented in the Database.

1. Introduction

The Air Infiltration and Ventilation Centre's Numerical Database has been developed in order to establish a core of numerical data suitable for design purposes and model validation, and to provide a focus for data derived from related International Energy Agency projects. Source information is contained within a computerised database from which direct searching for specific material is possible. The purpose of this paper is to present some potential areas of application of the Database.

Data have been derived from as wide a range of sources as possible, including many organisations who have contributed both expertise and experimental results. By combining information from these sources, it has been possible to consider a far wider range of operating conditions than would have been possible if only a single set of measurement results had been used.

Users are cautioned that the data presented are based on measurements published in the literature or provided by various institutions for inclusion in the Numerical Database. Therefore, there is no guarantee that it is suitable for any specific design application. Wherever possible, applicable standards or airtightness recommendations should be applied to new and retrofit construction.

The nature of the representation of airtightness used by the Numerical Database is shown in Section 3. Determination of ventilation rate and its applications are briefly outlined in Section 5, whilst Section 6 discusses airtightness.

2. About the Numerical Database

The AIVC's Numerical Database is contained in Idealist for DOS software and, in order to ensure ease of operation, a User Guide (*Orme and Limb, 1994*) is supplied. AIVC Technical Note 44 (*Orme, Liddament, and Wilson, 1994*), contains detailed summary tables and graphs of the information stored in the computer Database, together with a complete list of references. This Technical Note also discusses wind pressure distributions on buildings.

The Numerical Database includes typical data (from both laboratory and field test experiments) for individual components and whole buildings, and wherever possible, relevant standards and recommendations for building or component airtightness performance have been incorporated. The appropriate standards and recommendations are described in detail in AIVC Technical Note 43 (*Limb, 1994*).

3. How Airtightness Characteristics are Described in the Numerical Database

3.1 Building Components

The Power Law equation is given by:

Volume flow rate ($dm^3.s^{-1}.m^{-1}$) *or* ($dm^3.s^{-1}.m^{-2}$) — *Flow exponent*

$$Q = C.\Delta P^n$$

Flow coefficient — *Pressure difference (Pa)*

The Power Law equation is essential for understanding the contents of the Numerical Database. This equation is empirically based and it relates the pressure drop across components to the volume flow rate of air passing through them. Building component characteristics collected in the Numerical Database are in the form of flow coefficients, C, together with their associated flow exponents, n. Every flow coefficient has been normalised by dividing, either by the length of crack, or where more appropriate, by the area of the permeable surface. This enables direct comparison between components of different physical dimensions and also more general application of the collected data.

The following types of component are covered in the Database:

- Windows
- Doors
- Interfaces of window and door frames with walls
- Wall construction, ceilings and floors
- Ceiling/wall/floor interfaces
- Wall to wall interfaces
- Penetrations
- Roofing
- Fireplaces and flues
- Trickle ventilators and vents

3.2 Whole Buildings

In the case of whole building records, airtightness values have been normalised by dividing the volume flow rate at 50 Pa pressure difference by the internal building volume to give air changes per hour at 50 Pa. Expressing airtightness in this way allows the leakage of buildings of different volumes to be compared. The basis of the artificially induced 50 Pa pressure difference, is that it is sufficiently large to prevent naturally occurring pressure differences from significantly influencing the result. On the other hand it is not so large that cracks and gaps are distorted by the applied pressure. The flow exponents, and in most cases the building volumes, have also been included so that conversion to other pressure differences is still possible, by using the Power Law. (See Section 3.1.)

4. Determination of Ventilation Rate Using the Numerical Database

Part of the information needed to estimate the ventilation rate of existing or planned buildings is located within the Numerical Database. Ventilation rate is expressed in terms of volume air changes per hour (ach) and is the fundamental quantity involved when considering aspects of occupant comfort, indoor air quality, contaminant dispersal and energy use. The airtightness value of a building can be approximately derived from the Database, either by dealing with the structure as a single item, or as a combination of components. The latter of these approaches forms the basis of Section 7. Theoretically these two approaches should coincide. The airtightness of previously investigated real buildings or components can then be used in order to predict the ventilation rate obtained under certain internal and external climatic conditions, for the test configuration. This can be achieved with, for example, an air flow mass balance model.

5. Ventilation Rate Applications

5.1 Design Studies and Ventilation Strategies

As a consequence of its application in determining ventilation rates, the Numerical Database can be used to provide some of the initial data which are necessary for the evaluation of different ventilation strategies. Design studies are needed to derive an indication of typical expected airtightness values for a building specification, as well as ensuring the building is adequately, but not excessively, ventilated. For these reasons it is anticipated that designers will find the Numerical Database a useful tool.

5.2 Model Evaluation

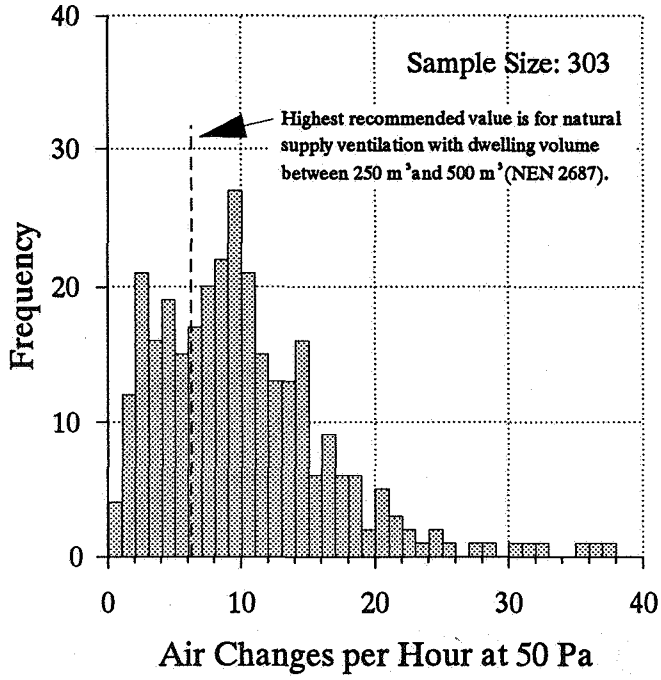
For the purpose of evaluating air flow models, it is desirable that the airtightness characteristics of buildings, either considered as combinations of components, or as single structures, are represented in a realistic manner. This includes making certain that the magnitudes of leakages are within the appropriate commonly measured ranges. The Numerical Database allows the identification of such data, so that models can be configured to accurately represent the real world.

6. Airtightness

6.1 Effectiveness of Standards

Another area in which the Numerical Database may be beneficial is the effectiveness of national standards. It can be used to judge the proportion of components or whole buildings in a particular country that conform to the relevant standard(s). For instance, Figure 1 shows such data from the Netherlands, which approximately indicates the proportion of dwellings complying with existing recommendations. A major assumption made here is that the airtightness distribution is representative of the building stock of the entire country.

Figure 1 Dwelling Airtightness (All Building Types) for The Netherlands



Data Source: TNO Air Leakage Database

6.2 Assessment of Airtightness

It is possible to search the computer Database for specific types of construction, and as such, an investigation of factors which influence airtightness can be made and different constructional techniques examined. This enables an assessment of the effect of retrofit or replacement on component or whole building leakage. It is also possible to explore the impact of climatic conditions by considering the measured range of airtightness encountered in different countries.

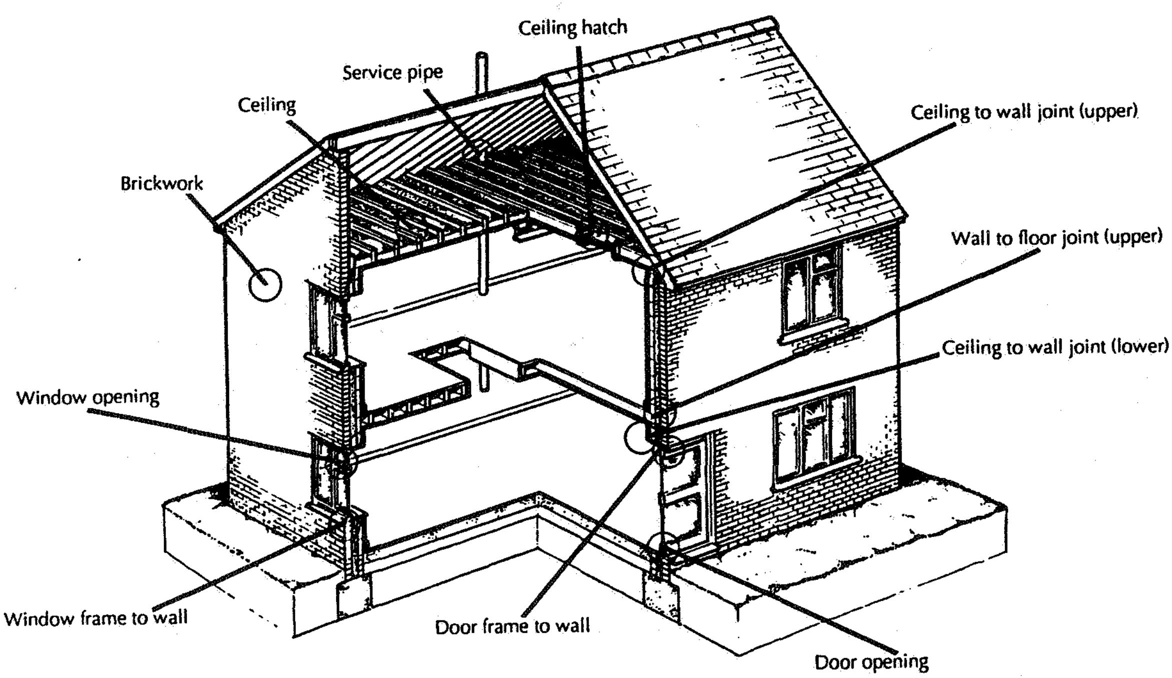
7. How to Derive the Airtightness of a Building from the Airtightness of its Individual Components - A Worked Example

The worked example illustrated in Figure 2 calculates the airtightness of a building from its component data. Estimations of the air change rate of this building, with an inside to outside pressure difference of 50 Pa, are given in Table 1. These are based on the building being of (i) high construction standard (lower quartiles), (ii) good construction (medians), or (iii) poor construction quality (upper quartiles).

Table 1 Worked Example - Estimation of Whole Building Airtightness

Component	Dimension /m^2	Lower quartile: C /$dm^3.s^{-1}.m^{-2}.Pa^{-n}$	Lower quartile: n	Lower quartile: Leakage at 50 Pa /$m^3.h^{-1}$	Lower quartile: Percentage	Median: C /$dm^3.s^{-1}.m^{-2}.Pa^{-n}$	Median: n	Median: Leakage at 50 Pa /$m^3.h^{-1}$	Median: Percentage	Upper quartile: C /$dm^3.s^{-1}.m^{-2}.Pa^{-n}$	Upper quartile: n	Upper quartile: Leakage at 50 Pa /$m^3.h^{-1}$	Upper quartile: Percentage
Ceiling	59	0.042	0.81	212	10.5	0.11	0.75	439	17.0	0.20	0.72	710	17.9
Brickwork	138.8	0.016	0.86	231	11.5	0.018	0.85	250	9.7	0.021	0.84	281	7.1
	Dimension /m	C /$dm^3.s^{-1}.m^{-1}.Pa^{-n}$	n	Leakage at 50 Pa /$m^3.h^{-1}$	Percentage	C /$dm^3.s^{-1}.m^{-1}.Pa^{-n}$	n	Leakage at 50 Pa /$m^3.h^{-1}$	Percentage	C /$dm^3.s^{-1}.m^{-1}.Pa^{-n}$	n	Leakage at 50 Pa /$m^3.h^{-1}$	Percentage
Service pipe	0.63	0.63	0.60	15.0	0.7	0.74	0.60	17.3	0.7	0.84	0.60	19.9	0.5
Ceiling hatch	4	0.64	0.60	96.5	4.8	0.68	0.60	102	4.0	0.75	0.60	113.0	2.9
Ceiling to wall joint (upper)	32	0.45	0.60	542	26.9	0.49	0.60	590	22.9	0.53	0.60	638	16.1
Ceiling to wall joint (lower)	16	0.45	0.60	271	13.4	0.49	0.60	295	11.4	0.53	0.60	319	8.1
Wall to floor joint (upper)	16	0.45	0.60	271	13.4	0.49	0.60	295	11.4	0.53	0.60	319	8.1
Window frame to wall	52	0.053	0.60	104	5.2	0.061	0.60	120	4.6	0.067	0.60	131	3.3
Door frame to wall	12	0.053	0.60	24.1	1.2	0.061	0.60	27.5	1.1	0.067	0.60	30.1	0.8
Window opening	66	0.086	0.60	214	10.6	0.13	0.60	324	12.5	0.41	0.60	1018	25.7
Door opening	12	0.082	0.60	36.7	1.8	0.27	0.60	122	4.7	0.84	0.60	379	9.6
Total				2018	100			2582	100			3958	100
Air changes per hour at 50 Pa				7.5				9.6				14.7	

Figure 2 Worked Example - Building Layout



7.1 Construction Information

A two storey building of insulated cavity brick construction has internal floor dimensions of 8 m x 6 m and a ceiling height of 2.8 m on each storey. The ground floor is of solid concrete construction, which is perfectly sealed to the interior brick leaf. The ceilings are of plaster board construction and the interior walls are plastered and painted. The ceiling to wall joints are uncaulked. The floor of the upper storey is of suspended timber construction which only penetrates the inner leaf of each 8 m wall.

Door and window frame to wall joints are uncaulked. The net (internal) building volume approximately equals 269 m^3.

The upper storey ceiling is penetrated by:

(i) a non-weatherstripped roof hatch of dimension 1.0 m x 1.0 m, and

(ii) a service pipe of 200 mm diameter.

Each of the 8 m walls is penetrated by:

(i) a door of dimension 2 m x 1 m on the lower storey,

(ii) a window frame of dimension 1.0 m x 1.5 m on each storey, and

(iii) a window frame of dimension 1.0 m x 1.0 m on each storey.

Each of the 6 m walls is penetrated by a window frame of dimension 1.0 m x 1.0 m on each storey.

All windows and doors are of timber construction with weatherstripped opening sections.

The large window frames each have:

(i) 2 x side hung openers of dimension 1.0 m x 0.5 m, and

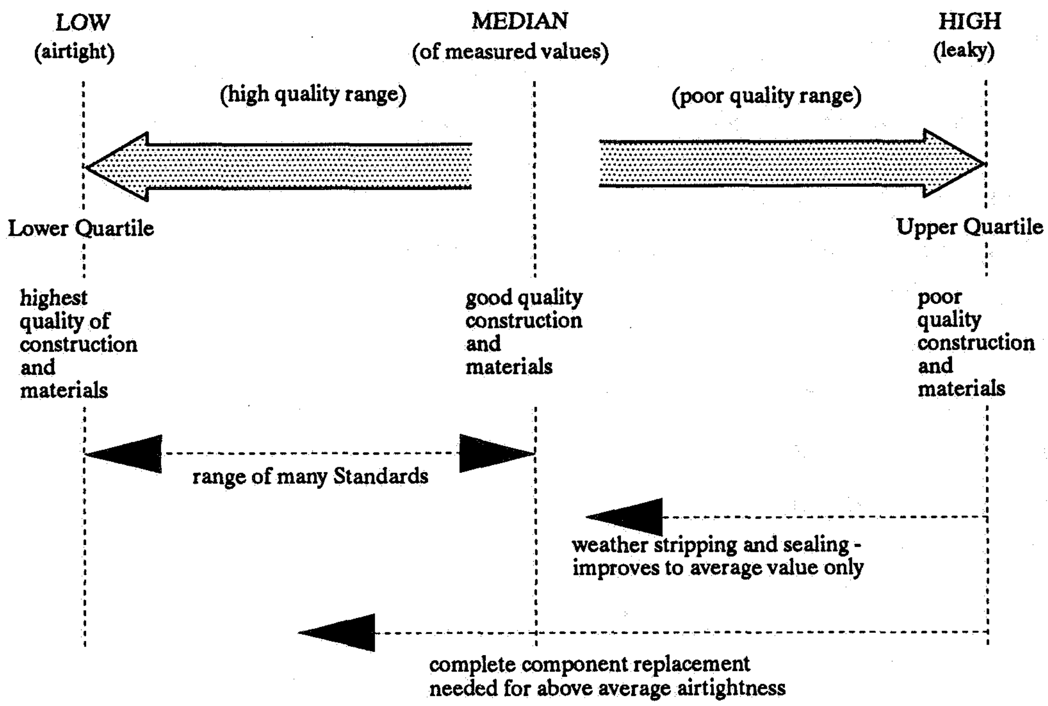
(ii) 1 x top hung opener of dimension 0.25 m x 0.5 m.

The small window frames each have:

(i) 1 x side hung opener of dimension 1.0 m x 0.5 m, and

(ii) 1 x top hung opener of dimension 0.25 m x 0.5 m.

Figure 3 Guidance on Interpreting Component Airtightness Distributions



7.2 Selecting Suitable Default Component Leakage Data

Data tables presented in Technical Note 44 (*Orme, Liddament, and Wilson, 1994*) summarise the building component records of the Numerical Database. These tables provided suitable values to describe the construction in the worked example. Figure 3 gives guidance on interpreting the quartile values of the distribution of component flow coefficients, as default leakage data.

7.3 Calculations and Assumptions

The flow coefficient, *C*, and the flow exponent, *n*, together with the dimensions of the components have been used to give volume flow rates at 50 Pa pressure difference (noting that the quantities have now been expressed in terms of units $m^3.h^{-1}$). The sum of these flow rates was then divided by the internal building volume to give the airtightness for each of the three standards of construction. A simplification was made by assuming that the inside of the roof space was at the same absolute pressure as the outdoor air.

In practice, a uniform pressure difference throughout is achieved by fully opening all internal doors during pressurisation tests. A discrepancy can occur between the airtightness value measured when a building is pressurised compared to when it is depressurised by the same amount. Pressurisation airtightness and depressurisation airtightness were assumed to be identical for the purposes of this example.

It should be emphasised that the component data contained within the summary tables in Technical Note 44 (*Orme, Liddament, and Wilson, 1994*) have originated from many different countries, where construction techniques sometimes differ. On the other hand, it was considered that the sample sizes were too low to distinguish between items from these countries.

8. Conclusions

Data are essential for design and model evaluation. An attempt has been made with the Numerical Database to compile data appropriate to infiltration and ventilation studies. These cover the air leakage characteristics of building components, the characteristics of buildings themselves and data on wind pressure distributions.

Component leakage data have been summarised in Technical Note 44 (*Orme, Liddament, and Wilson, 1994*), in terms of median values with upper and lower quartiles and their appropriate usage. Additionally, this Technical Note also presents whole building data in the form of graphs and as a series of data sheets for generic types of building construction.

It is essential that measurement data collected during individual tests should be compiled since, collectively, they may be used to identify trends in the performance of construction techniques. Much more can be accomplished in producing information about the leakage performance of the existing building stock by analysing the key structural components and the corresponding air leakage performance of measured buildings.

Further information on wind pressure coefficients are needed to accommodate a wider range of building shapes. These would enable basic design calculations to be accomplished without the need for excessive modelling or expensive wind tunnel exercises.

9. Acknowledgements

Valuable assistance and data were given to the AIVC by numerous individuals and research organisations during the preparation of the Numerical Database. Contributors are listed in the analytical review of the Database (*Orme, Liddament, and Wilson, 1994*).

10. References

1) LIMB, M.J.
"Ventilation and Building Airtightness: an International Comparison of Standards, Codes of Practice and Regulations"
Air Infiltration and Ventilation Centre Technical Note 43, February 1994.

2) ORME, M.S., LIDDAMENT, M.W. and WILSON, A.J.
"An Analysis and Data Summary of the AIVC's Numerical Database"
Air Infiltration and Ventilation Centre Technical Note 44, March 1994.

3) ORME, M.S. and LIMB, M.J.
"Numerical Database User Guide *Idealist for DOS format*"
Air Infiltration and Ventilation Centre, 1994.