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A Wind Pressure Database from Hungary for Ventilation and Infiltration Calculations

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Introduction

Wind pressure coefficients (C_p values) are among the basic data required for ventilation and air infiltration calculations and modelling. More than two years of systematic wind tunnel testing in ETI of some of the most frequent building shapes has resulted in a database that has been provided with a handling program. This package is available from ETI, for IBM XT/AT and compatible PC's.

The CPBANK Concept

Sources of C_p values are almost exclusively, wind tunnel tests. These tests are, however, usually much too expensive to be incorporated into the budget of design of small or medium scale building projects, though some of these may require the knowledge of C_p values. Computer simulations of ventilation and air infiltration processes also use such data. There are three main approaches to provide C_p sets for these calculations:
(1) Wind tunnel testing is always workable but seldom economic.
(2) Use of existing databases - this requires quality and easy access to data.
(3) Generating parametric functions from measurement databases and using these to reproduce C_p's. Except for some rather simple cases this method is not generally workable. CPBANK follows the second approach.

CPBANK is a software package comprising a set of wind pressure coefficient (C_p) data files for a range of building shapes, fixed degrees of shielding and three types of upwind terrain. It also includes a handling program that supports easy selection of parameters, definition of distribution of points over the building envelope and a simple management of user files. CPBANK is built around a nested menu concept in which Main Menu items activate submenus.

The primary application of the produced C_p data is to supply input for air infiltration and ventilation calculations. Without any deeper knowledge of building aerodynamics

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CPBANK should only be used for building geometries included (see Figs 1,2). In most cases about 25% deviation from predefined geometric ratios may be accepted without causing substantial error. The same tolerance may be applied for the absolute dimensions of the buildings.

The C_p's in this package are all time-mean values and to calculate wind pressures the wind speed at the reference height, conventionally taken equal to the building height, has to be known.

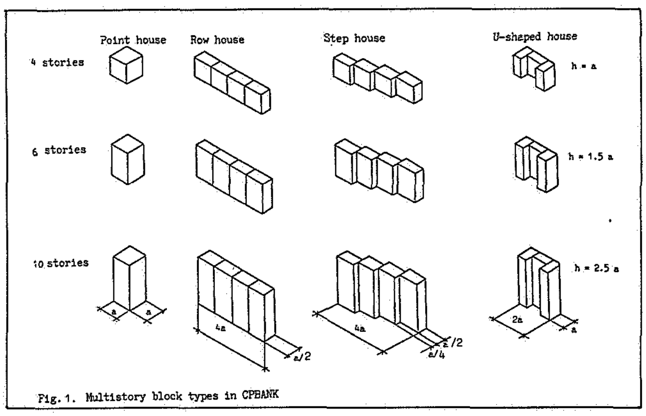

Fig. 1 Multi-story block types in CPBANK

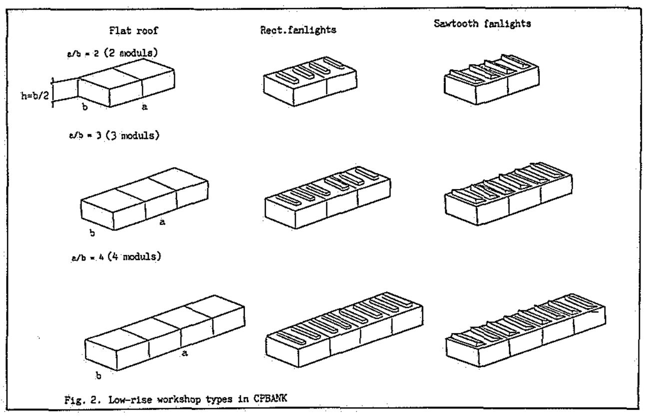

Fig. 2 Low-rise workshop types in CPBANK

Air Infiltration Review

Editor: Janet Blacknell

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Wind Tunnel Tests

The Wind Tunnel Laboratory of the ETI carried out hundreds of test runs to develop the C_p database. After multiple checking the measured pressure data were transformed into C_p values.

Fig. 3 shows shielding degrees used during wind tunnel testing. CPBANK offers three categories for the aerodynamic roughness of the upwind terrain. Rural terrain applies for flat, smooth, rural land with low vegetation, scattered trees, bushes or cultivated agricultural area. Suburb terrain means single family housing areas, villages and suburbs of low-rise housing. Urban terrain refers to densely built up urban area of multi-story housing.

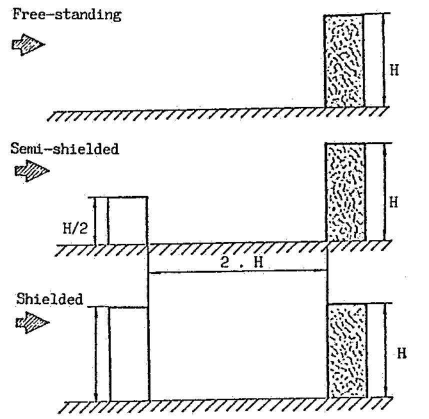


Fig.3. Shielding cases in CPBANK

Fig. 3 Shielding classes in CPBANK

The above exposure parameters may be, and usually are, dependent on the wind direction, which may be selected in 22.5 degrees increments. Zero degree wind direction coincides with the +y axis of the building coordinate system.

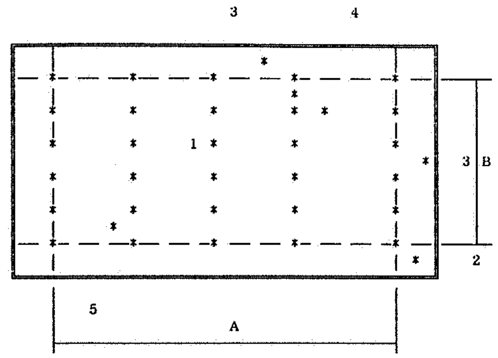
Data for Input

Two groups of data are required for input. The first comprises building data, and the second exposure data. The input of these data through the keyboard is supported by help screens, simple graphics and other tools that facilitate easy amendments and modifications. The simple file management tool and the fixed format of the user files makes it possible to create house data files by other means and pass them to CPBANK.

How CPBANK works

One group of the supplied CPBANK files contains the x,y,z coordinates of the surface points for which C_p values have been measured. These coordinates are stored in non-dimensional form, i.e., x/X_{max}, y/Y_{max}, z/Z_{max}, where the subscript '$_{max}$' refers to the total building dimension. In order to enable the location of the surface points of the given building, its coordinates must be scaled accordingly. Thus CPBANK starts with calculating scaled surface point coordinates of the defined building. Then it performs a search in the database for retrieving all data files necessary for the given task. C_p values are assigned to any defined surface point from the CPBANK files by interpolation (see Fig. 4).

Example of a building facade (roof) with the array of reference points included in CPBANK file



A,B - limits of the array of measured points

Position of the point:		CP value assigned to the point is equal to the
1 - coincidence with a measured point	:	value at the measured point
2 - offside the array in a corner of facade area:		value at the corner point
3 - offside the array	:	interpolated value between the nearest two measured points at the edge of the array
4 - inside the array in line with two points	:	interpolated value between the two points
5 - surrounded by four array points	:	value determined by triple linear interpolation

Fig. 4. How CPBANK assigns CP values to your surface points by their position relative to surface point arrays in CPBANK files.

Fig. 4 How CPBANK assigns Cp values to your surface points by their position relative to surface point arrays in CPBANK files

Structure of CPBANK Database Files

There are two types of CPBANK data files. These are: XYZ files - these contain the serial numbers and non-dimensional XYZ coordinates of the surface points where measurements were made, and C_p files - these contain 3x2 arrays of C_p data corresponding to the three roughness catagories of the upwind terrain. C_p values are tabulated according to the serial number of surface points (rows) and actually measured wind directions (columns). The second array of C_p averages are tabulated according to the serial number of surfaces (rows) and measured wind directions (columns).

C_p values for wind directions other than those tabulated are derived from the measured values by making use of symmetry to one or two axis or the center point of the actual building type.

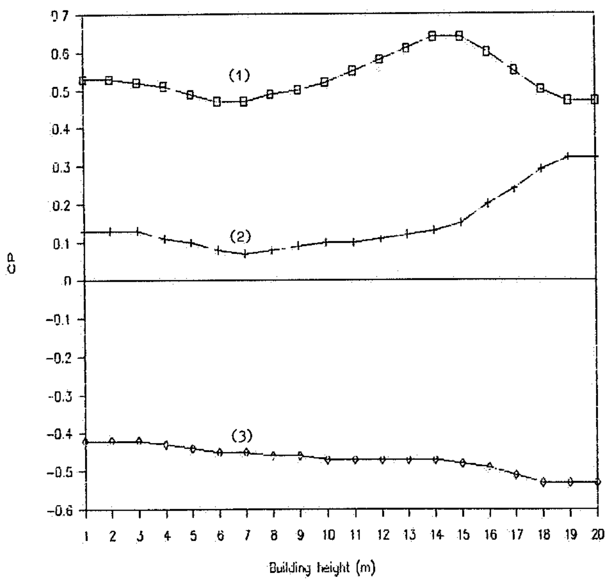


Fig.5. Vertical CP-profiles along the center line of the windward long facade (1) Free standing (2) Semi-shielded (3) shielded. Upwind terrain: Suburban. Wind direction perpendicular to facade.

Fig. 5 Vertical Cp profiles along the center oine of the windward long facade (1) Free standing (2) Semi-shielded (3). Upwind terrain: Suburban. Wind direction perpendicular to facade

Table 1 Example file of house data

Project
Example of looking up CP values for a rowhouse
1st December 1988
Building Wizard consultants Ltd, Fabuland County, Nowhereland
File nameL
a:\EXAMPLE2.hus

House data:
House type : 1 Rowhouse
Nominal size : 4
Length (m) L 40.2 Width (m) L20.0 Height (m) 12.0
Your choice of Averages/Distribution : 2
Surface distribution of CP values
Number of faces of the defined building : 5
Total number of defined points : 33
Serial number of the first and last points on building faces:

Face no.	First point	Last point
1	1	3
2	4	8
3	9	14
4	15	23
5	24	33

X Y Z coordinates of points selected on the building envelop:

Point number	X (m)	Y (m)	Z (m)
1	20.0	0.0	10.0
2	1.0	0.0	1.0
3	2.0	0.0	2.0
4	0.0	1.0	1.0
.	.	.	.
.	.	.	.
.	.	.	.
30	2.0	3.0	12.0
31	4.0	7.0	12.0
32	8.0	9.8	12.0
33	2.0	8.0	12.0

Table 2 Example file of exposure data

Project:
Example of looking up CP values for a rowhouse
1st December 1988
Building Wizard Consultants Ltd, Fabuland County, Nowhereland
File name:
a:\EXAMPLE2.env

Defined environmental data
Defined wind directions : 2

Number	Wind direction	Shielding	Terrain type
1	1 0.0	2 semi shielded	1 Flat rural
2	5 90.0	1 exposed	2 Suburbian

Table 3 Example of Cp values

Project:
Example of looking up CP values for a rowhouse
1st December 1988
Building Wizard Consultants Ltd, Fabuland County, Nowhereland
File name:
a:\EXAMPLE.cpv

Your choice of Averages/Distribution :12
No. of points : 33 Wind dirs : 2
Surface distribution of CP values

Point no.	Wind direction	
	00.0	90.00
1	00.13	00.08
2	- 0.21	- 0.46
3	- 0.20	- 0.42
4	- 0.52	00.66
.	.	.
.	.	.
.	.	.
30	- 0.44	- 0.04
31	- 0.43	- 0.23
32	- 0.41	- 0.60
33	- 0.44	- 0.04

Output and User Files

All data files created by the user are stored as text files which are easy to handle by means of common word processing and spread sheet programs.

Tables 1- 3 show printouts of user files from an example run. Fig. 5 shows vertical C_p profiles along the center line of one long facade of a rowhouse type building for three cases of shielding. The upwind terrain is suburban type and the wind direction is perpendicular to the facade. C_p values in the figure were retrieved from CPBANK.

The CPBANK package is available at $1,000 U.S. from:

ETI, the Hungarian Institute for Building Science, H-1113, Budapest, David F.u.6.

Telex: 22-4285 eti h. Fax: 36-1-663-766.

For further information or inquiries please contact the author.

ASHRAE Annual Meeting

Vancouver, Canada, 24-28 June 1989

Report by Martin Liddament, AIVC

The Annual Meeting of the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) takes the form of technical sessions, symposia, seminars and forums. In addition, afternoons and evenings are reserved for ASHRAE Technical Committee sessions which all participants are invited to attend.

Technical Sessions

Infiltration and ventilation topics were well represented at several of the Technical Sessions and Symposia as well as being covered by a number of technical committee sessions and a forum. Technical papers included a contribution by Damin Zhang from China and Katsuhiko Tsuji from Japan which covered the solution of the Navier Stokes flow equations for two dimensional, isothermal laminar and/or turbulent flow. Turbulence was solved using a one equation model. Shinsuke Kato from the University of Tokyo, Japan introduced a 3-dimensional finite difference approach to solving turbulent air flow in and around buildings. An approach using curvilinear coordinates was introduced in which the boundary of a space could be better represented than when using a classical Cartesian coordinate system. Simulated results compared favorably with measurement. Shuzo Murakami also from the University of Tokyo described how computational fluid dynamics modelling could be used to study the effect on air distribution of supply and exhaust opening configurations in clean rooms. Air distribution in offices resulting from the use of supply plenums located under raised floors was covered in a technical paper by Robert Genter, USA. He considered the design aspect and provided examples based on variable air volume systems.

Symposia

Infiltration related symposia included:

- Residential duct leakage and infiltration
- Calculation of interzonal heat and mass transfer in buildings.
- Calculating air flow around buildings
- Scandinavian symposium on displacement ventilation

The symposium on residential duct leakage followed concern in the United States over air leakage from warm air heating ducts located in the roof space or in other unheated zones. Five papers were presented, the first paper by D Parker of the Florida Solar Energy Center and the second by Les Lambert of Lambert Engineering reported on comparisons between the energy consumption and airtightness of dwellings with ducted and unducted heating systems. It was noted that 13-40% more heating energy was found to be required in the ducted homes. The third and fourth papers by David Robison of Lambert Engineering and James Cummings of the Florida Solar Energy Center reported on more detailed testing while the final paper by Mark Modera of the Lawrence Berkeley Laboratory analysed the impact of the problem from a national perspective. His paper also covered methods to reduce duct losses.

Interzonal air flow can play an important role in determining the energy performance, air quality and comfort in buildings. The objective of the interzonal heat and mass transfer symposium was to review calculation methods to predict such flow. J van der Maas from the École Polytechnique Fédérale de Lausanne, Switzerland reviewed gravity driven flow through large openings, while the combined effect of door opening and gravity driven flow was discussed in a paper by Darwin Kiel and David Wilson from the University of Alberta, Canada. The effect of turbulent natural convection in driving interzonal flow was described by F Haghighat of Concordia University, Canada. George Walton of the National Institute for Science and Technology in the United States described recent developments in multizone flow modelling and James Axley of the Massachusetts Institute of Technology described the coupled solution of air flow and thermal analysis.

The symposium on air flow around buildings introduced Chapter 14 of the new ASHRAE 1989 Handbook of Fundamentals. This has been extensively revised in order to provide assistance for the designer in the calculation of wind induced pressures and exhaust gas dilution. This symposium focused on these areas to show how design methods from Chapter 14 can be applied in practical situations. Specific numerical examples were used to illustrate the ASHRAE methods for wind pressure and ventilation rates. For exhaust gas dilution, the ASHRAE design procedures were compared with the results of independent wind tunnel studies on real building configurations. Presentations included the estimation of wind pressures at ventilation inlets and outlets by Richard Aynsley of the Georgia Institute of Technology, USA, wind induced ventilation by Francis Allard of the Institute of Applied Sciences, France, analytical versus wind tunnel determined concentrations due to laboratory exhaust by R Petersen of Cernak, Peterka Petersen Inc, USA and Comparisons of wind tunnel test results with empirical exhaust dilution factors by F Schuyler of Turner, Rowan Williams Davies & Irwin Inc, Canada.

The final symposium on displacement ventilation was well attended, reflecting the considerable interest in this approach. In recent years many displacement ventilation systems have been installed in Scandinavia. Speakers from Denmark, Finland, Norway and Sweden reported their experience with these systems. The theory behind the displacement principle was presented and results of new laboratory research were given. Practical experience was presented by numerous case studies on systems in operation. Ventilation efficiency, the risk of draft as well as the energy economy of displacement systems compared to traditional ventilation was discussed.

The papers presented included:

- "Nordic experiences of displacement ventilation systems" by Anders Svensson of Stifab AB, Sweden,
- "Case studies of displacement ventilation in public halls" by Hans Martin Mathisen of the Norwegian Institute of Technology, Norway,
- "A comparison of conventional mixing and displacement air conditioning and ventilation systems in US commercial buildings" by Olli Seppanen of the Helsinki University of Technology Finland and Bill Fisk (presenter) of the University of California,
- "Displacement ventilation systems in office rooms" by Mats Sandberg of the National Swedish Institute of Building Research, Sweden
- "Local thermal discomfort due to draft and vertical temperature difference in room with displacement ventilation systems" by Arsen K Melikov of the Technical University of Denmark.

Much of the discussion in this symposium was concerned with comfort aspects which were claimed not always to be a success due to the need for relatively high air flow rates. It was stated by the first speaker that the predominance of displacement systems (50%) was in industrial installations or similar applications where comfort was not the main priority.

Forum

ASHRAE forums are intended to provide a focal point for discussion. One such forum was entitled "Should ASHRAE prepare a manual of standard practice for ventilation?" This meeting arose from the impending approval of ASHRAE Standard 62 on ventilation for acceptable indoor air quality. Once introduced, this standard will impose more rigorous ventilation requirements on building operators, especially in relation to smoking areas. It is argued that if these new requirements are met, experience and research results predict generally acceptable indoor air quality. However, throughout the review period of this standard concern was expressed on how contaminant levels, ventilation effectiveness and other system factors should be measured. The purpose of this forum was to explore the need for guidance in complying with the standard. It was concluded that there was a need for such a manual specifically aimed at designers, standards or coding authorities, building operators and independent testers.

Technical Committees

Two related Technical Committees are TC 2.5 on air flow around buildings and TC 4.3 on infiltration and ventilation requirements. Both of these groups met with the view of promoting new programmes of research. Proposed future work within TC 2.5 included an analysis of the shielding conditions surrounding buildings and the translation of wind data from remote sites to conditions at the locations of buildings. Under the auspices of TC 4.3 a standards Project Committee has been established to develop a standard technique of measuring the adequacy of ventilation rates in dwellings which rely on infiltration to satisfy ventilation needs. A draft standard has now been prepared and is aimed at specifying the effective air change rate for given climatic conditions and leakage area. Allowance is made for mechanically supplied air.

Ordering Papers

Preprints of papers presented at ASHRAE meetings are available at $4.00 each from:

ASHRAE Publications Sales,
1791 Tullie Circle, NE,
Atlanta, GA 30329,
USA.

In addition the transactions of this meeting will be published by ASHRAE in January 1990 price $170.00 ($115.00 members).

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