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The influence of the user on the results of multizone air flow simulations with COMIS

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Abstract

The multizone airflow simulation program COMIS was evaluated within an International Energy Agency research program. One of the steps in the evaluation procedure is to test the user–code interface, consisting not only in the appearance of the computer screen, but also in the user guide or any other tutorial or help system. The user–code interface of COMIS was then tested through round robin tests. Two types of problems were submitted to several users: a simple and well-defined problem and a real world problem. This study first allowed great improvements of the user guide. While results for the well-defined case were very close to each other, large differences were observed for the 'real world' case. Results of simulation largely depend on the user options, and users easily make modelling errors when the studied case becomes complex. © 1999 Elsevier Science S.A. All rights reserved.

Keywords: COMIS; Multizone air flow simulations; User–code interface

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1. Introduction

The objectives of a user test performed on a computer program are:

1. to assess the difficulties experienced by users when applying the code,
2. to determine the errors made by users when entering input data, and
3. to use the results to improve the user guide and the input routines of the code.

Two tests, prepared by the LESO and AIVC were proposed. The first represents a simple benchmark analysis in which the network and input data are provided. No interpretation of building leakage and weather data is necessary. The second is an open test requiring interpretation of the raw data by the user. The user must devise the network from the general information provided.

In both cases, a short data set is provided which should be used to prepare an input file. The results of the simulations, that is input and output files, were returned along with replies to a questionnaire concerning the performance of the model.

The questionnaire asked the following questions:

1. Program and version used for the test
2. Purpose for which the program is mostly used
3. Data input processing:
   (a) Input processor
   (b) User friendliness (from −5, bad through 0, OK, to +5, good)
   (c) Problems encountered
   (d) Proposals for improvement.
   (e) Value of User Guide for input instructions (from −5, bad through 0, OK, to +5, good)
4. Data output processing:
   (a) Output processor
   (b) User friendliness (from −5, bad through 0, OK, to +5, good)
   (c) Problems encountered
   (d) Proposals for improvement.
   (e) Value of User Guide for output instructions (from −5, bad through 0, OK, to +5, good)
5. Other comments

2. User tests on case 1

2.1. Presentation of the case

The USERTEST1 building is presented in Fig. 1. It comprises a four-zone system of five external flow open-

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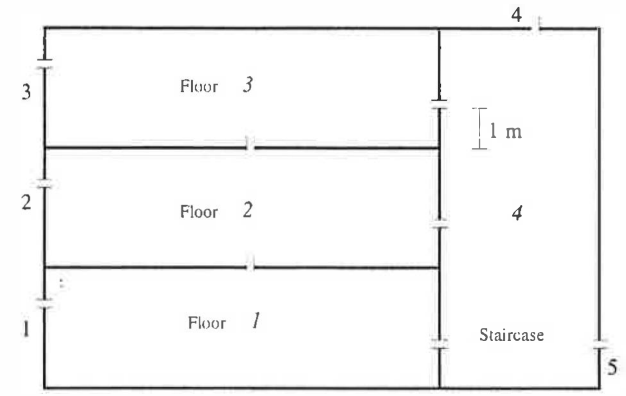


Fig. 1. The building USERTEST1. Number of zones are in italics, while envelope elements are numerated in normal numbers.

ings and five internal flow openings. This test network has been devised to test input and output routines for a very simple example and to test the performance of the model in simulating both horizontal and vertical flow, thermal gradients and flow through vastly different sizes of opening. The wind pressure coefficient is given for each of the external openings while the height, leakage coefficient, C and exponent, n, are given for all openings. The objective is to evaluate the ventilation rate in each zone and the air flow rate in each path for the following set of conditions.

The characteristics are presented in Table 1. All the outdoor–indoor conductances have the same air tightness. Between the zones and the stairwell, the conductances modelling the door are less tight especially in the first floor. The leakage through ceilings are small.

Outdoor temperature is 10°C and there is a wind speed of 2 m/s at roof height (9 m above ground). There is a uniform upward temperature gradient of 1.67 K/m in zone 4. Envelope element and internal leakage characteristics are presented in Tables 2 and 3, respectively.

Table 1
Characteristics of the zones of building USERTEST1

Zone	1	2	3	4
Volume [m^3]	150	150	150	135
Height [m]	3	3	3	9
Floor above ground [m]	0	3	6	0
Temperature [°C]	18	20	23	10–25

Table 2
Characteristics of the envelope elements of building USERTEST1

Envelope element	1	2	3	4	5
Height above ground [m]	2	5	8	9	1
Leakage coefficient [kg/s]	0.02	0.02	0.02	0.02	0.02
Exponent	0.66	0.66	0.66	0.66	0.66
Pressure coefficient	0.2	0.4	0.5	−0.4	−0.3

Table 3
Characteristics of internal leakages of building USERTEST1

Leakage path	1–2	2–3	1–4	2–4	3–4
Height above ground [m]	3	6	1	4	7
Leakage coefficient [kg/s]	0.004	0.004	2	0.04	0.05
Exponent	0.66	0.66	0.66	0.66	0.66

2.2. Sensitivity analysis

In order to evaluate the effect of the variation of input parameters on responses of the model a sensitivity analysis, using factorial design (Refs. [1,2] and paper in the same issue), has been performed for this case. The infiltration rate in a building depends a priori on the ratio between the forces induced by the wind and by the thermal buoyancy. For that reason the sensitivity analysis has been performed for different wind speeds from 0.5 [m/s] to 4 [m/s].

A two-level fractional factorial design has been used (see Refs. [1,2], and paper in the same issue for detailed information) to determine the sensitivity coefficients. This design allows, with 256 simulations, the determination of 136 coefficients among the 301 corresponding to a linear model of 24 parameters. It is a design in which the main effects α_i are neither merged with themselves, nor with first order interaction coefficients, while the first order

Table 4
Tested parameters

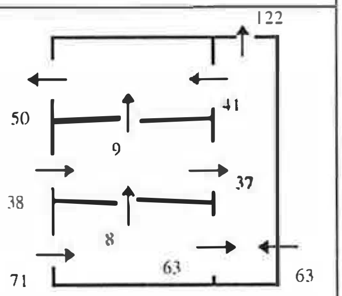
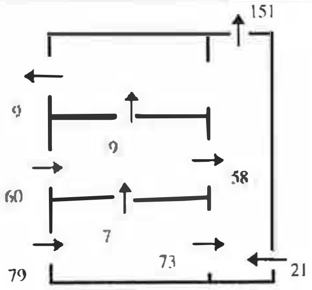
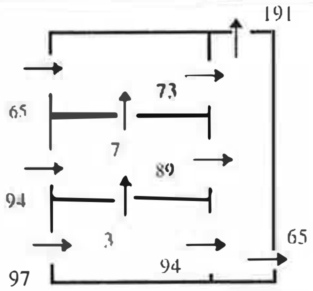
Description	COMVEN parameters
1. Elementary indoor–outdoor air tightness	$\mathrm{CR}_{\mathrm{OUT}}$
2. Indoor–outdoor exponent	n_{OUT}
3. Air tightness between the floors	$\mathrm{CR}_{\mathrm{FL}}$
4. Exponent between the floors	n_{FL}
5. Air tightness between zone 1 and stairwell	$\mathrm{CR}_{\mathrm{ST1}}$
6. Exponent between zone 1 and the stairwell	n_{ST1}
7. Air tightness between zone 2 or 3 and the stairwell	$\mathrm{CR}_{\mathrm{ST2}}$
8. Exponent between zone 2 or 3 and the stairwell	n_{ST2}
9. Temperature in the 1st floor	T_{fl1}
10. Temperature in the 2nd floor	T_{fl2}
11. Temperature in the 3rd floor	T_{fl3}
12. Temperature in the stairwell	T_{st}
13. Temperature gradient in the stairwell	$\mathrm{Grad}(T)$
14. Windward pressure coefficient, in front of zone 1	Cp(1)
15. Windward pressure coefficient, in front of zone 2	Cp(2)
16. Windward pressure coefficient, in front of zone 3	Cp(3)
17. Pressure coefficient on the roof	Cp(4)
18. Leeward pressure coefficient, at back of zone 4	Cp(5)
19. Wind profile coefficient	W_{profil}
20. Wind speed	W_{speed}
21. Outdoor temperature	T_{ex}
22. Outdoor humidity	Humidity
23. Atmospheric pressure	P_{atm}

interaction coefficients are aliased between themselves. The tested parameters are listed in Table 4.

2.2.1. Results from the sensitivity analysis

The meteorological conditions and geometry of the building are such that wind counteracts the stack effect in the building. Zone three is then in a critical situation when the wind pressure exactly compensates the stack pressure near 2.1 m/s. The fresh air cannot enter from the window and very little air enters from the stairwell. Since ventilation in then close to zero, such situations are critical under the steady state conditions assumed for calculations. In

Table 5 :
Flows matrices and flows for typical Archimedes number

Wind speed	**Ar**	**Flow matrix**	**Flow scheme**
1.3m/s	2.5	$\begin{array}{ccccc} l/s & 0 & 0 & 50 & 122 \\ 71 & 71 & 0 & 0 & 0 \\ 38 & -8 & 46 & 0 & 0 \\ 0 & 0 & -9 & 50 & -41 \\ 63 & -63 & -37 & 0 & 163 \end{array}$	
2.2m/s	0.7	$\begin{array}{ccccc} l/s & 0 & 0 & 9 & 151 \\ 79 & 79 & 0 & 0 & 0 \\ 60 & -7 & 67 & 0 & 0 \\ 0 & 0 & -9 & 9 & 0 \\ 21 & -73 & -58 & 0 & 151 \end{array}$	
3m/s	0.4	$\begin{array}{ccccc} l/s & 0 & 0 & 0 & 256 \\ 97 & 97 & 0 & 0 & 0 \\ 94 & -3 & 97 & 0 & 0 \\ 65 & 0 & -7 & 73 & 0 \\ 0 & -94 & -89 & -73 & 256 \end{array}$	

reality, wind speed and direction fluctuate, and thereby diminish this effect.

A similar phenomenon occurs for the stairwell when the wind speed is close to 2.2 m/s. The equilibrium between stack and wind pressure at the low opening of this zone results in less ventilation compared to what occurs when one cause dominates. When the stack effect dominates, fresh air enters in the stairwell. When the wind is dominant, polluted air from the dwellings leaves the building through the stairwell.

The two other zones have monotone behaviour, the mean age of air always decreasing when the wind increases.

The airflows with the corresponding flow matrices are shown in Table 5. The elements of the flow matrix are defined as follows [4]:

Q_{ij} = minus the air flow going from zone j to zone i, and

$$Q_{ii} = \sum_{j=0}^{N} Q_{ji}\left(1 - \delta_{ij}\right). \tag{1}$$

In the first line of the matrix are the algebraic sums of respective columns, that is the total infiltration rate of each zone. In the first column of the matrix are the algebraic sums of respective lines, that is the total exfiltration rate of each zone.

Assuming by convention, a pressure coefficient equal to 1, the Archimedes number Ar is defined as:

$$\mathrm{Ar} = \frac{\Delta T g h}{T_i v^2} \tag{2}$$

with ΔT = indoor–outdoor temperature difference, [K]; g = gravity acceleration, [m/s^2]; h = warm zone height, [m]; T_i = indoor temperature, [K]; v = wind speed, [m/s].

This number corresponds to the ratio between stack and wind induced forces. It is lower than one for a wind dominated situation, but larger than one for stack induced flows.

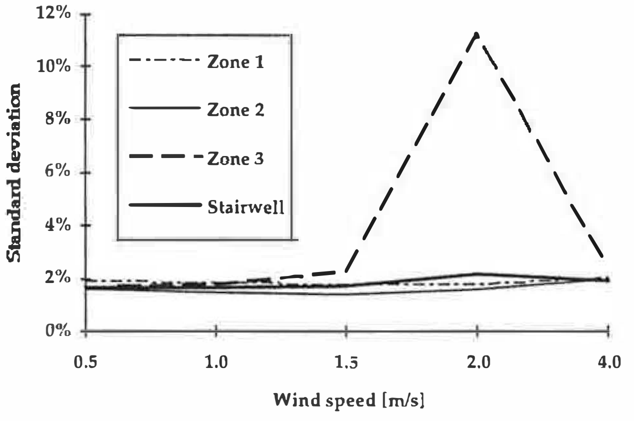


Fig. 2. Variation of the standard deviation σ for the mean age of air obtained with 256 simulations.

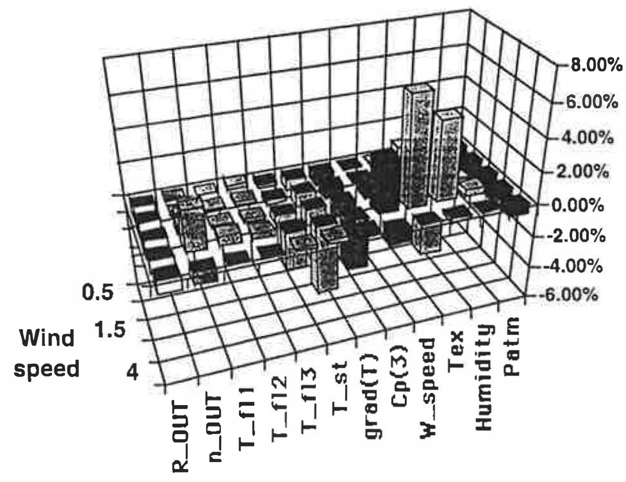


Fig. 3. Evolution of the largest main effects with the wind speed.

Except for the critical situation described above, close to Ar = 1, the standard deviation does not vary significantly with the wind speed variation. Fig. 2 shows the standard deviation for the mean age of air for the four zones. During a critical situation, when the flows are very weak, an extreme sensitivity is observed, as seen in other cases.

Fig. 3 presents the evolution of the largest main effects of the global mean age with increasing wind speed. The critical situation appears clearly here also, even hiding the monotone evolution of the effect of the wind speed and the temperatures.

We see that the test case, with a wind speed of 2 m/s, corresponds to the critical situation where small changes in temperatures and wind speed induce large changes in the results.

When comparing a stack dominated situation with a wind dominated one (Fig. 4); the following remarks can be made.

- The wind speed (W_{speed}) effect increases with the wind speed, but the relation is not linear as expected.
- The same thing can be observed for the pressure coefficients (Cp(i))
- The inverse is observed for the temperatures (T_{ex}, T_{f12}, T_{f13}, T_{st}) and the temperature gradient in the stairwell (grad(T)) whose effects decrease when the wind speed increases.
- The other dominant parameters are the outdoor indoor air tightness ($\mathrm{CR}_{\mathrm{OUT}}$) and the atmospheric pressure (1% variation in P_{atm} corresponds to about 300 m height or significant weather change). The compared effect is the mean age of air, which is related to volume flow rates. Since it is mass airflow rates that are calculated, any change in indoor air density will have an effect.
- The effect of the exponent (n_{out}) becomes important when the wind dominates stack effect, that is when wind pressure on facades reach 10 Pa or more. Slight change in the exponent has no effect at low-pressure differential.

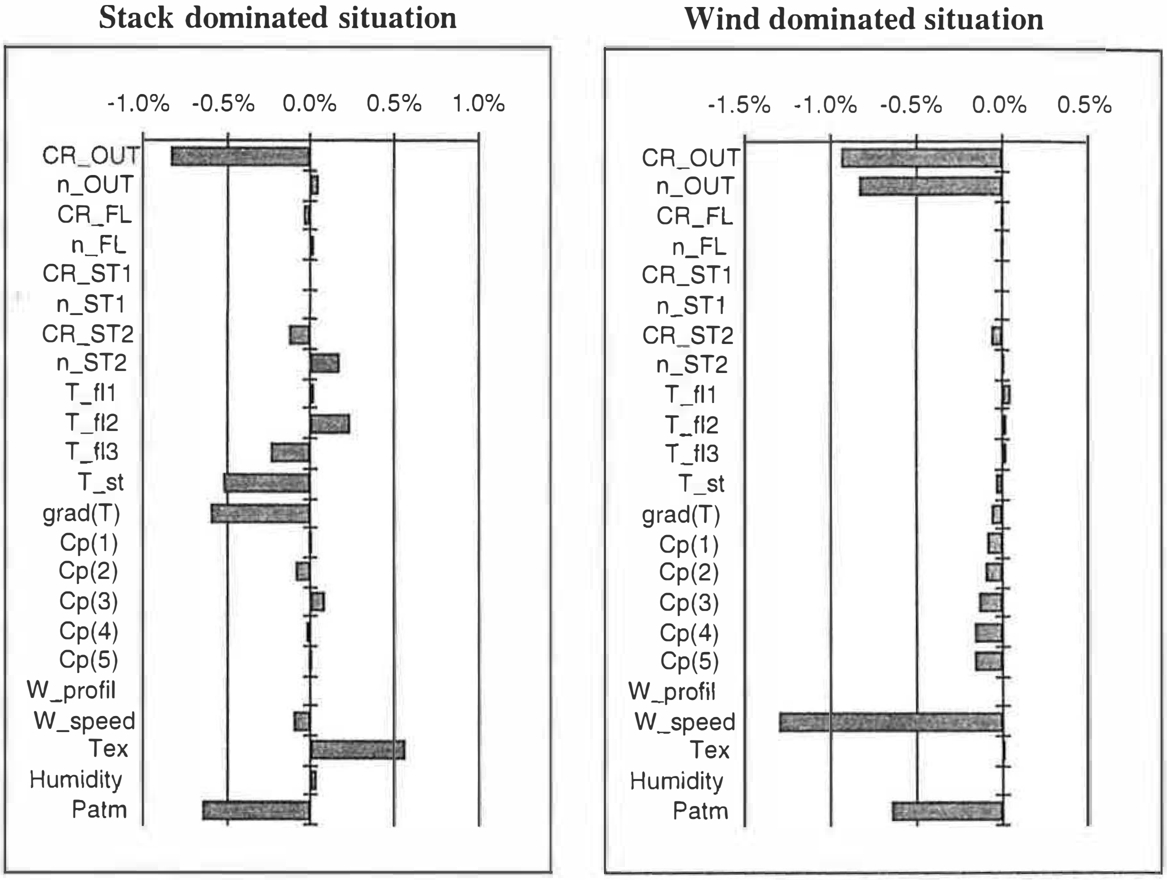


Fig. 4. Comparison of main effects in a stack dominated situation ($W_{speed} = 1$ m/s) and a wind dominated one ($W_{speed} = 4$ m/s).

2.2.2. Results from first run

Two runs were performed with this building. The first run was initiated in November 1992, and was performed by eight participants from various countries with COMIS 1.1 and the corresponding User Guide. A summary of results is given in Tables 5–7, and comments, which are the most interesting results from this first run, are replicated below.

Table 7 gives the total pressures in each zone and the total air flow rates going through the four zones. Already severe differences can be seen among the results. As expected, the largest differences in airflow rates occur in zone 3, which is the critical zone: very small pressure differences between zones 3 and 4 may result in large changes in airflow rates. Fig. 5, on the other hand, compares zonal air flows taken by different participants with the USERTEST1 first run.

The differences may be caused by errors in introducing input data and in differences between various versions of COMIS. The causes were not analysed in detail, as it was clear that some differences originated from severe bugs in COMIS 1.1, and that the User Guide clearly needed to be improved. There was also a doubt that the same code running on various computers provided different results. A second run for the user test was therefore decided.

Table 6
Summary of replies to questionnaires

Program	Canada	INSA	Italy	LESO	Anonymous
COMIS Version	1.1A	1.0	1.1	1.1	1.0
Input processor	COMIN and DOS editor	Text editor	COMIN	COMIN and text editor	COMIN and PE2
User friendliness	−1	−3	−5	−2	1
User Guide	−3	−1	0	−1	0
Output processing		Text editor		EXCEL	TABOUT
User friendliness		−2		5	3
User Guide		0		5	2

Table 7
Total airflow rates and pressures in zones as calculated by participants

Zone	Total air flow in zones [kg/h]				Pressures in zones [Pa]			
	1	2	3	4	1	2	3	4
BBRI	73.0	59.9	23.3	150.5	−1.28	−37.29	−73.19	−0.98
Canada	16.6	24.6	48.4	95.2	−0.22	−36.40	−72.24	0.08
EMPA	78.4	64.3	18.3	156.4	−1.37	−37.20	−72.96	−1.07
INSA	74.8	64.5	9.9	144.1	−1.23	−37.21	−73.09	−0.93
Japan	74.8	64.5	9.9	144.1	−1.23	−37.22	−73.11	−0.93
LBL	74.8	64.5	9.9	144.1	−1.23	−37.22	−73.11	−0.93
LESO	109.5	36.3	45.5	162.3	−2.01	−37.09	−72.83	−0.71
TNO	74.8	64.5	9.9	144.1	−1.23	−37.22	−73.11	−0.93
Average	72.1	55.4	21.9	142.6	−1.23	−37.11	−72.95	−0.80
Standard deviation	23.8	14.8	15.2	19.0	0.45	0.27	0.29	0.35
Min	16.6	24.6	9.9	95.2	−2.01	−37.29	−73.19	−1.07
Max	109.5	64.5	48.4	162.3	−0.22	−36.40	−72.24	0.08

This first run helped nevertheless to greatly improve the User Guide, as shown below from the received comments.

2.2.2.1. Comments on input processing. Several comments were made about the User Guide. Users not familiar with this Guide had difficulties understanding some parts. In some cases the User Guide did not correspond to the code. For example, zones were named with letters according to the User Guide, but COMIS 1.1 accepted only numbers.

Bugs in COMIS 1.1 were also revealed by this test. For example, some keywords could not be used, parts of the input file generated by COMIN were lost when saving, optional input parts are in fact mandatory, etc.

2.2.2.2. Comments on output processing. Routines for calculating total air change rate, fresh air change rate, inter-zonal and supply airflow for each zone should be provided.

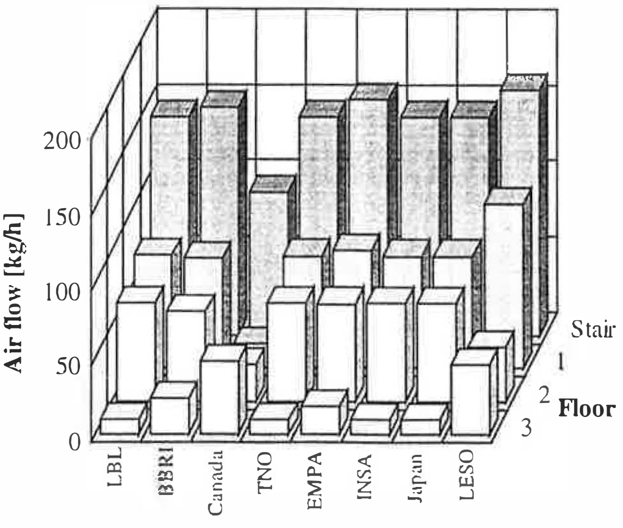


Fig. 5. Comparison between the zonal airflows obtained by various participants to first run of USERTEST1.

All these comments were forwarded to LBL, who improved both the code and the User Guide, allowing for an easier second run of the user test.

2.2.3. Results from second run

In order to clearly separate the effects of COMIS versions and users, the second run was performed exclusively with COMIS 1.2, which was version 1.1 corrected for bugs detected by the first run, and which took account of some comments. Eleven institutions participated in this test.

2.2.3.1. Comparisons between results. The main results are presented in Fig. 6, Tables 8 and 9. The results of one participant, who made an obvious networking error (see below), are not shown in the tables.

2.2.3.2. Reasons for differences. Apart from two exceptions, the results are obviously closer to each other than in the first run. In order to find the cause of the differences, input files were carefully analysed. The main reason for these differences are input errors and options taken by participants. These options are summarised in Table 10.

The tables and diagrams show one clear outsider, C. The cause is very likely the error in reference height. The

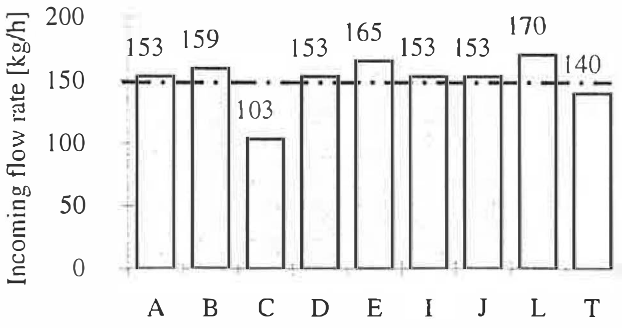


Fig. 6. Comparison of total airflow rates into the building. Second run on USERTEST1.

Table 8
Comparison of pressures in zones [Pa]

Zones	A	B	C	D	E	I	J	L	T	Mean	*s*
1	−1.23	−1.28	−0.22	−1.23	−1.37	−1.23	−1.23	−2.01	−1.02	−1	0.12
2	−37.22	−37.29	−36.40	−37.22	−37.20	−37.21	−37.22	−37.09	−37.30	−37	0.04
3	−73.11	−73.19	−72.24	−73.11	−72.96	−73.09	−73.11	−72.83	−73.36	−73	0.12
4	−0.93	−0.98	0.08	−0.93	−1.07	−0.93	−0.93	−0.71	−0.72	−1	0.12

next one is L, who took a strange option for moisture (dry inside and wet outside) and 10 m for overall reference height. T is next, probably also because of moisture: he is the only one to have adopted the default values, which are 0 inside and 10 g/kg outside. When comparing his results with the so-called reference file, E, he tried to get the same results, and in fact succeeded after changing moisture, wind coefficient and wind reference altitude, and finally atmospheric pressure.

A, D, I and J have identical results. They all have zero air moisture inside and outside, but have various wind exponents. This exponent does not seem to be so important, at least for this case, in which reference heights are the same for the building and the meteorological station. Differences in wind profile exponent or reference height did not change the results very much. On the contrary, as seen from sensitivity analysis, air moisture has an influence on density, and hence on the stack effect.

Other specific comments resulting from the examination of the input files are listed below.

Input errors. Z made wrong links, all rooms being linked to the same Cp = 0.5. Link heights are also wrong. This was warned in the output file, but the user did not notice. These results are not taken into account in the comparisons.

T made a typing error, changing a 4 into −4 in the links section. Therefore, the second floor was not linked through a door to the staircase but to the facade element. When receiving the reference file, the user noticed the difference and corrected it. The corrected output file is used for comparisons.

C did not refer to his reference height in one zone to define the links levels, and this significantly modified several air flow rates.

Crack definitions. Four participants defined each crack individually, that is the envelope crack five times, the floor crack twice, etc. This is not necessary. The user guide was therefore improved to better describe the way to define facade elements, cracks, links, pressure coefficients, etc.

Air moisture. Humidity inside and outside was not defined in the provided input data. The participants have used all possible methods: default values, or defined moisture content both inside and outside, or defined it either inside or outside only. Table 10 provides the details. COMIS 1.2 had 10 g/kg: default value for outdoor air moisture content, while this default value is zero inside. This ugly defaulting was improved in version 1.3.

Wind profile. The wind profile exponent at &-ENV-WINd given for the meteorological station is added to COMVEN 1.2. In the case that 2 m/s should be fixed at roof

Table 9
Comparison of airflow rates [kg/h]

	A	B	C	D	E	I	J	L	T	Mean	*s*
Total in building	153	159	103	153	165	153	153	170	140	150	0.13
Ext. 1 to 1	75	73	17	75	78	75	75	101	59	70	0.32
Ext. 2 to 2	58	53	15	58	57	58	58	36	42	48	0.30
Ext. 3 to 3	−10	−23	−48	−10	−18	−10	−10	−45	−29	−23	−0.68
Ext. 4 to 4	−143	−136	71	−143	−147	−143	−143	−125	−110	−113	−0.62
Ext. 5 to 4	21	34	−55	21	30	21	21	34	38	18	1.57
1 to 2	7	7	9	7	7	7	7	−9	8	6	0.99
2 to 3	9	9	8	9	9	9	9	8	8	9	0.04
4 to 1	−68	−66	−7	−68	−72	−68	−68	−110	−51	−64	−0.41
4 to 2	−56	−51	−17	−56	−55	−56	−56	−19	−42	−45	−0.36
4 to 3	1	14	40	1	9	1	1	37	21	14	1.12
Flow in zone											
Floor 1	75	73	17	75	78	75	75	110	59	71	0.34
Floor 2	65	60	25	65	64	65	65	36	50	55	0.27
Floor 3	10	23	48	10	18	10	10	45	29	23	0.68
Staircase 4	144	151	95	144	156	144	144	162	131	141	0.14

Except for one participant, C, the results are much closer to each other than for the first run.

Table 10
Options used by various participants

	Air moisture [g/kg]		Wind profile exponent		Reference height [m]	
	In	Out	Meteorological	Wind	Wind	Cp
A	0	0	0.32	0.32	9	9
B	0	0		–	–	9
C	(0)	1		–	–	–
D	(0)	0	0.18	0.18	9	9
E	8	4		0.17	9	9
I	0	0	–	0.5	9	9
J	0	0		0.32	9	9
L	4	8		0.32	10	10
T	(0)	10		0.32	9	9
Z	4	(10)		–	–	10

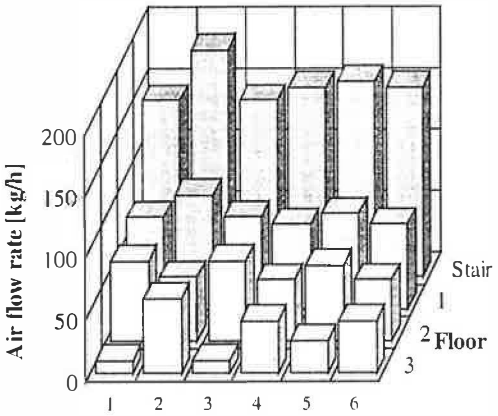


Fig. 7. Comparison of mass airflow rates from Japanese user tests.

level, the same exponent should be given for the building, and the height of the wind speed reference must be made equal to the roof height of the building.

Since nearly nobody was aware of that, only participant A and D did so. The others either put the default values (no input in this optional data section) or put in wind profile exponents in part 2 only. This exponent ranged from 0.17 to 0.32. Table 10 provides the details.

Reference height for wind speed and Cp was put at 9 m in most cases, but some did not provide it for wind speed and one put 10 m for both.

Other comments. Most participants used the modified Newton Raphson solver, but participants C and I used the standard Newton solver.

L is the only one to have defined an own height of 2 m for doors between rooms and staircase.

I provided a huge, complete input file, containing all the optional sections. Of course, only the necessary sections were filled up with data. This way of inputting data has two major disadvantages: it uses disk space and makes the debugging more difficult.

2.3. Comparison between versions and computers

2.3.1. Japanese study

Four Japanese groups have performed the USERTEST1 with three different input data, four versions of COMIS and five different computers including a workstation [5]. Com-

Table 11
Comparison of USERTEST1 with six simulations (from [5])

Group	1	2	3	4	5	6
Hardware	EPSON NEC compatible 80386/7SX,	NEC PC9801 not compatible with IBMPC 80486			IBM PS55-T04 80386DX, 80387	KUBOTA TITAN 3000 R3000
Operating system	Japanese MS-DOS by EPSON	MS-DOS Japanese version by NEC			DOS/V PC-DOS in Japanese	UNIX
COMIS Version	1.1	1.1	1.1A	1.2	1.2	1.3[a]
Input file	self made	self made	from user 1	from user 1	reference test1 file	from user 1
Results						
Total mass flow [kg / h]						
Floor 1	75	93	75	69	77	69
Floor 2	65	52	65	49	61	49
Floor 3	10	60	10	42	26	42
Staircase 4	144	185	144	155	159	155
Total pressure [Pa]						
Floor 1	1.23	1.64	1.23	1.35	1.39	1.35
Floor 2	37.22	37.67	37.22	37.43	37.25	37.43
Floor 3	73.11	74.01	73.11	73.34	73.00	73.34
Staircase 4	0.93	1.34	0.93	1.05	1.39	1.05

[a] Source Code at LBL in 1994.1

puting conditions and results are shown in Table 11 and Fig. 7.

These results show that:

1. Different input data, such as reference height, etc., give different results (users 1, 2 and 5).

2. Different versions of COMIS give different results with the same input file, but the differences are not significant. Differences are larger between versions 1.1 and 1.2 than between 1.2 and 1.3. The various COMVEN solvers and bugs in 1.1 provide reasons for these differences (users 1, 3, 4, and 6).

3. The same input data and different version of COMIS give identical output in two cases, (users 1 and 3 with versions 1.1 and 1.1A, users 4 and 6 with versions 1.2 and 1.3).

4. The same input data and the same version of COMVEN give identical output regardless of the different compiler and the hardware. Consistent results can therefore be expected under the same computing environment with the same *.CIF file.

2.3.2. Reference test

In order to ensure that the COMIS version 1.2 code does not provide different results on different computers, five laboratories in different countries used a reference input file. The results were all identical, except for one laboratory where slight differences were observed. For this laboratory, it appeared that the 1.2 version they had picked-up directly from the Annex 23 server was slightly different from the 'official' one.

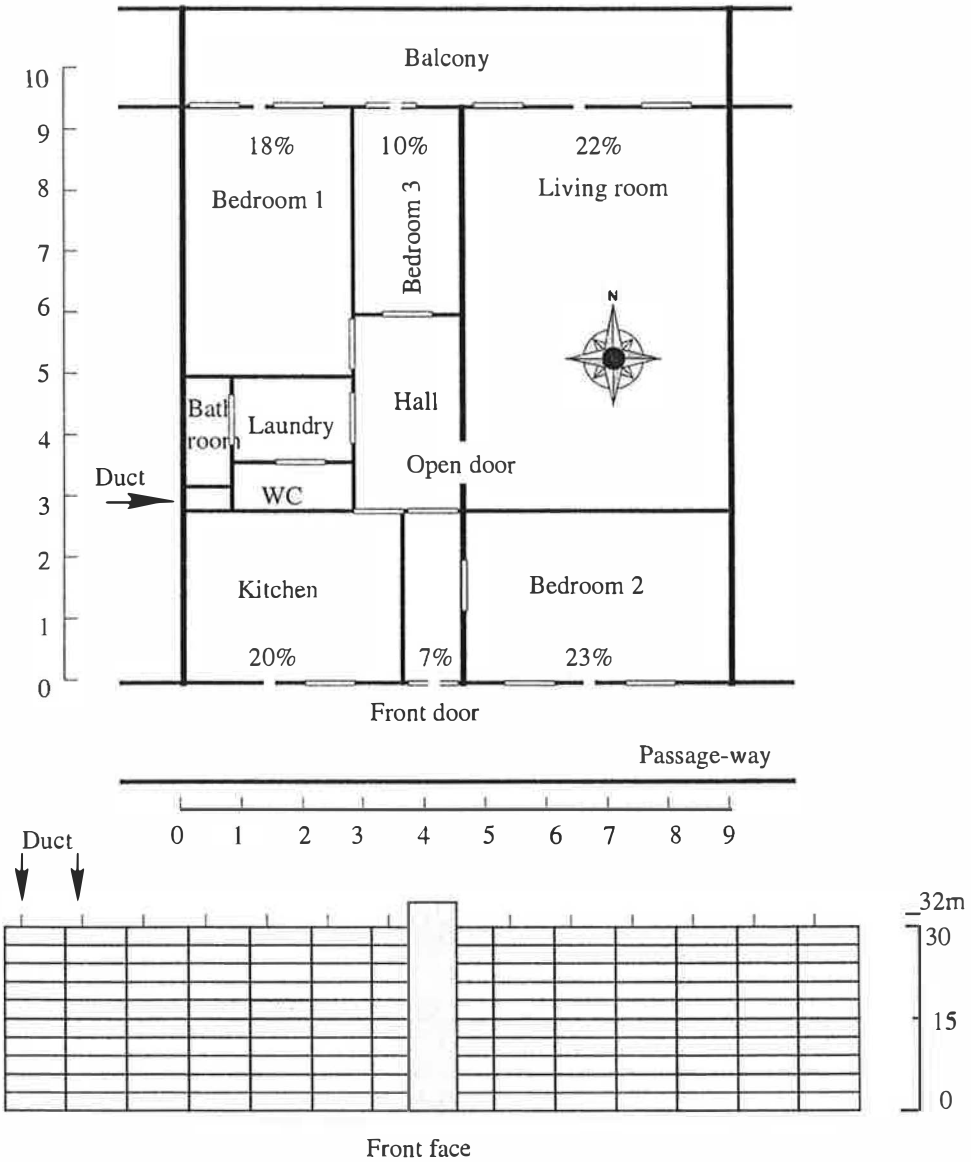


Fig. 8. User test 2 building.

3. User tests on case 2

3.1. Presentation of the case

Test case 2 is presented in Fig. 8. It is based on a building located in mainland Europe comprising a 5th floor apartment situated in the centre of a nine floor apartment block. Ventilation is by natural stack and make up air is provided by natural porosity. Provided data are given in Table 12.

3.2. Results

The first results are given in Table 13 and Fig. 9. First of all, large differences in modelling the network for the same flat can be seen: from 10 to 12 nodes, from 17 to 25 links and from 2 to 13 Cp's. Large differences can also be seen in the results.

3.3. Sensitivity study of input files

In order to eliminate any possible difference resulting from different versions of COMIS, all input files received were run with the same version, COMIS 1.3. A so-called reference input file was also built on the basis of the EMPA file. This file was carefully inspected and some minor changes were made. It should be noted that the so-called reference file does not pretend to be the absolute truth.

The main options taken for this reference file are as follows:

- Building reference level and reference level for external elements: 0 m
- Reference level for the internal zones: +15 m
- 11 internal zones. Open door between hall and living room.
- Level of links between internal zones 1 to 10: 1 m. Exhaust grilles at 2.6 m. Length of main ventilation duct: 14.4 m.
- Leakage exponents of cracks = 0.6. For open door and ducts, $n = 0.5$
- Wind from North (0°) and West (270°). Reference height for wind at building and meteorological station is 30 m. Wind exponent is 0.32 at both places.
- Plan area density = 0.144
- Pressure coefficients taken out of the AIVC 'Air Infiltration Calculation Technique' handbook. [3]
- Location of building > : 50°N Latitude; 2°E longitude, 0 m altitude (as for meteorological data), orientation of x half axis: 90°.

An elementary sensitivity study was performed with a star plan, changing only the parameters that were not identical in the various users input files. The result selected for this study is the extract airflow rate, which changes are shown in Table 14.

Large changes come from the meteorological station reference height and building orientation. Any change in pressure coefficient also has a large influence. Such change

Table 12

Building	9 storeys + 3 m high ground floor area	
Apartment	230 m^3 volume, dimensions 9.5 × 9.0 × 2.7 m^3	
Surroundings	similar buildings, 40 m spacing, urban	
Air tightness	Three air change per hour at 50 Pa, distributed according to Fig. 8	
Flow exponent	0.6	
Ventilation	natural duct system	
Ventilation ducts	Main duct	0.23 × 0.18 m^2
	WC duct	0.10 × 0.10 m^2, joining main duct. Inlet at 2.6 m height
	Bathroom duct	0.10 × 0.10 m^2, joining main duct. Inlet at 2.6 m height
	Kitchen duct	0.23 × 0.10 m^2, joining main duct. Inlet at 2.6 m height
	Air leakage of main duct	6.9 l/s at 1 Pa
	Flow exponent of main duct	0.5
Other components	Windows and doors are part of background leakage	
	Internal doors 1 × 2 m^2, perimeter gap 1 mm	
	Flow exponent of internal doors	0.5

The objective is to calculate the total air change rate of each zone, the airflow in each flow path and the proportion of fresh air into each zone for the following sets of conditions:

Configuration for Simulations	External windows and doors closed						
	Internal doors closed except hall to living room						
	Ventilation ducts open						
	Internal temperature	20°C					
	Wind direction	North	West				
	Wind speed	0	1	2	5	10	[m/s]
	External temperature	0	10	20			[°C]

Table 13
Some options taken by participants and total infiltration airflow rate under three conditions

	COMIS version	Number of network elements			Air flow rate [kg/h] with climate		
		Zones	Links	Cp	Cold, no wind	Cold and windy	Warm, no wind
Athens	1.2	11	25	13	154	347	41
Concordia	1.2	12	19	3	26	123	6
EMPA	1.2	11	19	3	113	263	17
INSA	1.2	11	19	3	80	288	11
Italy	1.01	10	17	2	0	39	0
Japan	1.2	10	18	7	125	261	187
LESO	1.2	11	19	3	128	275	7
WTCB	1.2	11	25	13	154	347	82

may come from reference heights, and from Cp values themselves.

Whenever one door between extraction and the facades is closed, the other internal leaks do not have a large influence on global air change. If there is a short circuit between extraction and the facades, no solution can be found.

3.4. Comparative study of user's files

Differences between each user's file and the so-called reference file are given below. Differences resulting in large discrepancy between the results are in italics.

3.4.1. EMPA

- $z = 1.2$ for ducts
- Air water content = 4 g/kg inside and 8 g/kg outside
- *Default wind exponent (0.14) at meteorological station*
- *Default values for building wind height, location and orientation*
- Plan area density = 0.25

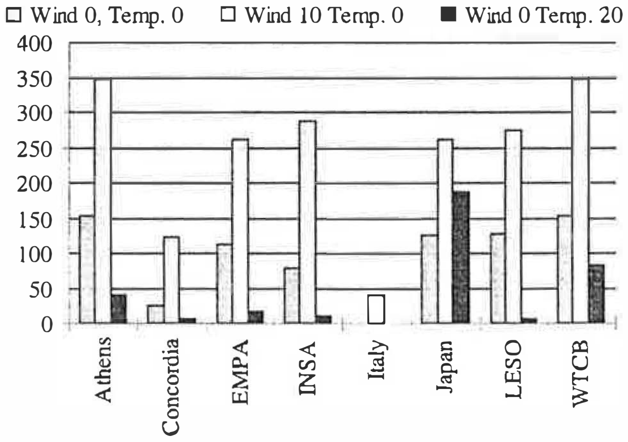


Fig. 9. Total outdoor airflow rate as calculated by participants for three different conditions.

3.4.2. LESO

- $z = 1.2$ for ducts
- Air water content = 4 g/kg inside and 8 g/kg outside
- *Default wind exponent (0.14) at meteorological station,* reference height 10 m
- *Default values for building wind height and location*
- Plan area density = 0.25
- *Wind direction 90° for West*

3.4.3. Japan

- Different control parameters
- $z = 1.5$ for ducts. Cylindrical main duct with Cs > 0. Duct end type 4 (circular)
- *Dry air inside and outside.* Infiltration temperature 20°C
- Link height 1.5 m, and 2.7 m for exhaust grid, *17 m for exhaust duct.*
- *Pressure coefficients from CPCALC, which are different than those from AIVC.*
- Wind exponent = 0.28 at meteorological station and building, reference height 32 m
- Other latitude, longitude and altitude.
- Plan area density = 0.25
- *Building turned 180° (North facade towards South)*

3.4.4. Athens

University of Athens provided two identical files with different names.

- Internal doors simulated by closed windows with low Cs and exponent $n = 0.5$.
- $z = 1.5$ for very smooth ducts. Cylindrical main duct with Cs > 0. Default duct end.
- *Dry air inside and outside.* Reynolds numbers given for transition zones between ducts.
- Two link height (0 and 2.7 m) in facades, each with half the permeability. Internal links at 0 m, *14.4 m for exhaust duct.*
- *Reference height of building + 15 m.*

Table 14
Effects of some changes on the extract airflow rate for test case 2

Temperature	0	20	0	20	0	20
Wind direction	N/W	N/W	N	N	W	W
Wind speed	0 m/s	0 m/s	10 m/s	10 m/s	10 m/s	10 m/s
Hall and living in one zone	No effect					
Closed door between hall and living	< 1%					
All internal doors open	No convergence					
Short-circuit between N facade and extract	No convergence					
Short-circuit between N and S facades	No effect	5%	5%	5%	5%	
Change in plan area density	No effect					
Changes in internal volume	No effect					
10% change on the roof Cp	No effect	5%	20%	10%	5%	
10% change on the N facade Cp	No effect	< 1%	10%	< 1%	5%	
10% change on the S facade Cp	No effect	1%	10%	1%	5%	
10% change on the internal doors Cs	2%					
10% change on the infiltration Cs	2%					
10% change on the Cs of main duct	2%					
10% change on the wind exponent	2%					
100 m on altitude of building	1%					
100 m on altitude of meteorological station	1%					
Meteorological station reference height at 10 m instead of 30	No effect	20%	40%	35%	45%	
10° change in building orientation	No effect	9%	17%	3%	4%	
2 m change in wind reference height	No effect	1%	2%	1%	2%	

These effects are related to the values obtained with the so-called reference file.

- *Different pressure coefficients for facades, but identical roof Cp's.*
- *Default values for building wind height and location.*

3.4.5. Comut2.cif

File very similar to Japan file.

- Different control parameters
- Internal doors with lower Cs.
- $z = 1.5$ for ducts. Cylindrical main duct with $Cs > 0$. Duct end type 4 (circular)
- *Dry air inside and outside.* Infiltration temperature 20°C
- One zone for living room and hall. Link height 1.5 m, and 2.7 m for exhaust grid, *17 m for exhaust duct.*
- *Pressure coefficients from CPCALC, which are different than those from AIVC.*
- Wind exponent = 0.28 at meteorological station and building, reference height 32 m
- Other latitude, longitude and altitude.
- *Building turned 180° (North facade towards South)*

3.4.6. Concordia

- Internal doors with lower Cs. Open door treated as a link with $Cs = 2.2$, $n = 0.5$
- $z = 1.5$ for ducts. Cylindrical main duct with $Cs > 0$. Duct end type 4 (circular)
- *Dry air inside and outside.*
- *Kitchen, front door and bedroom 2 connected to a supplementary zone 'promenade', which is not connected to external node.*
- Wind exponent = 0.22 at meteorological station.
- Plan area density = 0.25
- *Default values for building height, orientation and location.*
- *Wind direction 90° for West*

3.4.7. INSA

- Different control parameters
- Internal open doors with exponent $n = 0.7$.
- $z = 0$ for ducts. Cylindrical smooth main duct 17 m long. Default duct end
- *Dry air inside and outside.* Infiltration temperature 20°C
- Reynolds numbers given for transition zones between ducts.
- Link height 1.35 m in rooms, 17.6 m for exhaust duct.
- *Pressure coefficients defined for 90° but not for 270°. Different Cp for 0°.*
- *Pressure coefficients from CPCALC, which are different than those from AIVC.*
- *Building height, orientation and location variables all at 0.*
- *Default wind exponent = 0.14 at meteorological station, and 0.5 at building.*
- *Wind direction 90° for West*

3.4.8. Italy

- Different control parameters
- Internal open doors with lower Cs and exponent $n = 0.53$
- $z = 2.5$ for main duct, and 0.5 for other ducts. Default duct end.

Table 15
Relative difference in extract airflow rate between users results and reference

Temperature	0	20	0	20	0	20	Main reason for difference (apart reference heights and building orientation)
Wind direction	N/W	N/W	N	N	W	W	
Wind speed	0 m/s	0 m/s	10 m/s	10 m/s	10 m/s	10 m/s	
EMPA	−5%	−7%	−2%	−8%	−1%	−2%	Relative humidity
LESO	−5%	−7%	−2%	−8%	−1%	−2%	Relative humidity
Japan	−1%	−100%	+55%	+181%	+40%	−35%	Cp, dry air
Athens	< +1%	−100%	+50%	+90%	< −1%	< +1%	Cp, dry air
Comut2.cif	−15%	−100%	+50%	+95%	+30%	+40%	Cp, dry air
Concordia	−50%	−100%	−10%	+30%	−70%	−75%	Geometry, dry air
INSA	−20%	−100%	−20%	−20%	+50%	−45%	Cp, dry air
Italy	< −1%	+35%	10%	−7%	−65%	−70%	Cp, geometry, humidity

Calculation made with corrected input files (see text).

- HVAC system defined (code 17) for connection of secondary ducts to main duct. This is not accepted in COMVEN 1.3. Reynolds numbers given for transition zones between ducts.
- *Dry air inside, 10 g water per kg dry air outside.*
- *Kitchen, front door and bedroom 2 connected to a supplementary zone 'promenade', which is not connected to external node.*
- WC, bathroom and kitchen connected to external node directly through main duct.
- *Link height not defined (default values).*
- *Different pressure coefficients*
- *Default values for building height, orientation and location.*
- *Default wind exponent = 0.14 at meteorological station*, which altitude is put at 50 m.
- *Plan area density = 0.49*

3.5. Comparisons

Since comparisons of files presenting strong differences because of unclear definitions are not easy, input files were corrected and made similar to the reference file for the following variables: reference heights, building orientation, wind direction and wind exponent.

Relative difference in extract airflow rates is the difference between extract flow rate and reference extract flow rate, related to the reference extract flow rate (Table 15).

When there is no density gradient and no wind, COMVEN gives a zero air flow rate, which is correct. Large relative differences in the fifth column result from slight differences in air density caused by differences in air humidity.

4. Conclusions

As far as COMIS is concerned, the conclusions below were found from this user test.

1. Identical input files give identical results on different computers or with codes issued by different compilers, if the same source version of COMIS is used. The code is not very sensitive to numerical noise.

2. Large differences between results come from modelling errors or input typing errors. Some misunderstandings of the User Guide resulted in large changes in wind velocity at the facade level. The most common misunderstandings occur when defining reference heights of buildings, zones, and the meteorological station; and when defining the building orientation.

3. Only slight differences result from different options chosen by the user.

The test also provided substantial and useful information, which was used, for the improvement of both the code and the User Guide.

More general conclusions can also be drawn from the experience gained in this test. First, it should be acknowledged that the user could be, by far, the largest source of errors. In order to minimise the risk of user errors; the interface between the user and the code should present the best possible quality. A basic part of the interface is the User Guide, but a well-designed graphical interface may also be of great help in avoiding user mistakes and misunderstanding. Such an interface should help the user to model his building, and perform check for erroneous inputs. It should provide a feedback to the users, showing them what they are modelling.

A sensitivity analysis, included in the code and performed automatically when the solver is run will make the user aware of the most sensitive input variables. They can then check these in particular and, when necessary, try to assess them more accurately (see 'Put a SAM in your Model' by J.-M. Fürbringer, in the same issue).

References

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