INCLUDING IAQ COMPUTATION FEATURES IN MODELS FOR THERMAL SIMULATION OF RESIDENTIAL BUILDINGS

S. Costanzo[*], A. Giaccone[§], M. Pietrafesa[&], G. Rizzo[*]

[*] Dipartimento di Energetica ed Applicazioni di Fisica, Università di Palermo, Viale delle Scienze, Palermo, Italy
[§] CNR-IEREN, Via U. La Malfa, 153, Palermo, Italy
[&] Dipartimento di Elettronica e Matematica Applicata, Università di Reggio Calabria, Italy

Summary

Through this paper we describe the introduction of a comprehensive routine, able to take into account air changes needed for IAQ purposes, in a computer simulation code based on the explicit form of the finite difference method and devoted to the evaluation of the thermal behaviour of multizone buildings. Main characteristic of the routine is the capability of selecting and comparing different international technical standards, like those provided by the ASHRAE, the E.U. guidelines and so on. An application is then described aiming at analysing the influence of different standards on building energy demands, thermal comfort and indoor air quality conditions.

1. Introduction

Building thermal analysis is suitably performed by means of computer simulation models that, although at different levels of complexity, represent at the moment useful tools widely employed by technicians.

Recently, along with the increasing awareness about comfort and health requirements of confined environments, new calculation features, mainly referring to ventilation issues, are becoming of primary interest. In fact, new standards concerning the indoor air quality of commercial and residential buildings focus a great attention not only on the pollutant emissions from occupants, but also on the pollutant loads originated from furniture materials and HVAC system, while the presence of smoking people is particularly considered. Within this frame, the role of mechanical and natural ventilation should be carefully analysed.

Unfortunately, at present time, only a few computer models, essentially belonging to the more sophisticated ones, is characterised by the presence of such computing features.

Starting from these considerations, we will describe here a simple computer routine that contemplates among its features the most relevant international technical standards aimed at the evaluation of the air changes for both health and comfort purposes of confined environments. The routine can be employed at different levels of complexity (essentially referring to the chosen time-step for the simulation) and its main characteristic is represented by its exportability to other computer codes that perform the thermal balance of buildings. By means of some parametric analyses of an example building, the influence of new ventilation standards on the energy demand for building climatization is underlined and a novel method for ranking results in terms of thermal comfort and indoor air quality conditions achieved inside buildings is also presented.

2. Building models

2.1. Thermal simulation models

As it is well known, buildings act as shelters placed between men and the outdoor environment in order to regulate energy (heat, light, sound) and mass (air, moisture, pollutants) transfers between outdoors and indoors and so delimitate a comfortable thermohygrometric, visual, acoustic and respiratory-olfactive indoor environment for living.

The discipline known as "building physics" has since long time developed procedures devoted to analyse the aforementioned energy and mass processes occurring through buildings.

The larger availability of increasingly powerful computing machines has then spread the use of simulation models based on such procedures.

Thermal simulation models are now commonly used to dynamically analyse thermal energy flows through building and their thermal behaviour as a response to time-dependent outdoor climatic sollecitations (Clarke, 1986).

Such models are able to analyse the complex behaviour of a building, imagined as composed of several non-homogeneous zones and regarded as a network of thermal resistances and capacitances linking different regions of the building fabrics or indoor spaces, where nodes will represent portions of the fabric (insulation/capacity layers), air volumes (still as in ambient rooms or moving as in open gaps or ducts) or interface layers between the fabric and indoor or outdoor air volumes, while nodal connections will represent conductive, convective, radiative, advective heat transfer processes.

They generally use some input parameters, describing the building (its spaces and its material parts, its systems, its surrounding environment, etc.) and will obtain, through the analysis of the aforementioned heat transfer processes, results dealing with the energy demands and the environmental performances of buildings in terms of temperatures and thermal comfort levels attained in its interiors.

The differential equations governing heat transfer processes are solved by analytical (time-domain and frequency-domain response function methods) or by numerical means (finite difference and finite element methods).

Some of these models are only available for research purposes (generally the most complex and updated), but others (not necessarily the less sophisticated) are already used by architects to investigate alternative design choices, optimum configurations of particular building components or the impact of different operating strategies.

The model here employed is SMP, a computer simulation code developed since long time by some of the authors (Butera et al., 1984a) and validated against experimental data within a IEA international exercise (Butera et al., 1984b).

It is based on the explicit form of the finite difference method and devoted to the evaluation of the thermal behaviour of multizone buildings.

It encompasses all the energy flowpaths occurring in a building, dealing with:

- transient heat conduction through the walls with the associated storage and lag effects
- external and internal, forced or natural, surface convection
- inter-surface longwave radiation exchange between internal surfaces
- external surface longwave radiation exchange with the sky vault and the surroundings
- shortwave solar radiation impinging on exposed external surfaces and penetrating through glazings into the building
- casual gains from occupants, lights, equipments, etc.
- heating and cooling system interaction.

2.2. Natural and mechanical ventilation models

Since it is generally recognized that ventilation can constitute as much as up to about the 30% of the heating load of buildings, thermal simulation models have to generally include a model for the calculation of ventilation rates.
Furthermore, temperature acts as a driving force for air movement in buildings and conversely each air movement between regions of different temperature correspond to an advective (fluid-to-fluid) heat exchange and determine the amount of the convective heat exchange between the material parts of the building and its air volumes, so that a correct solution of the heat and air transfer processes in a building can be given only by coupling thermal and ventilation models.
As it is well known, air movement in buildings is generally produced by pressure differences between the indoor and the outdoor environment or between two adjacent indoor spaces, communicating through the intentional opening of windows, doors and vents or through fabric junctions and small cracks around windows and doors.
Such pressure differences are naturally caused by the action of the wind or by temperature differences between two adjacent spaces.
A mechanical ventilation system can also be present in the building to move air between and inside building spaces.
Since an air mass balance has to be maintained in the whole building and in each of its spaces, any air loss or gain in a space induces a corresponding air movement through all the paths connecting the different air volumes (rooms) as well as inside each volume itself.
Computational models for natural and artificial ventilation are ranging through three levels of increasing complexity (Clarke, 1986):
i) simplified predictive expressions correlating the air flow rates due to natural ventilation with temperature differences and/or external wind speed and sometimes direction;
ii) models applying air mass balance conditions to nodal networks (Feustel et al., 1989) in which nodes represent discrete volumes of air (rooms or portions of them, if movement inside a single room has to be analysed), characterised by their pressure and temperature, while nodal connections represent air flow paths occurring through internal and external apertures (doors, windows, vents) or cracks;
iii) very detailed models (Awbi, 1989) particularly dedicated to analyse the distribution of air velocities inside building spaces by numerically solving, often in steady-state conditions, the governing differential equations relative to the conservation of mass, energy, momentum and turbulence in two- or three-dimensional fluid flow fields.
These last ones generally require a considerable computing effort, so that the use of such models is usually restricted to the analysis of very large indoor spaces, like theatres, auditoriums, indoor sport arenas, etc. (Kent, 1994).
Moreover, the unpredictability of the actions of occupants, as it concerns with the opening and shutting of windows, doors and manual vents and with the operation of the mechanical ventilation system, has a major influence on air movement inside residential buildings and buildings where the mechanical ventilation is manually regulated by the single occupant (Clarke, 1986), so that very often a fixed value of the air volume exchanges is given as input to the simulation models.
Literature on this matter is very wide; nevertheless further information can be found in some useful surveys (Haghigat, 1898; Feustel et al., 1992; Cafaro et al., 1992).

3. The SMPVENT ventilation routine

In the SMP thermal simulation model, a routine called SMPVENT allows the calculation of ventilation rates for a building utilising natural or mechanical ventilation.

Since indoor air quality of buildings is largely dependent on ventilation, the authors have modified the routine in order to introduce some features allowing to make use of the SMP model to analyse IAQ conditions as well as thermal comfort conditions.
The routine is written in the QuickBASIC language and can be run under the DOS and Microsoft Windows operating systems.
It can now activate, on request of the SMP user, five different procedures which will be here described.
According to the first procedure, air flow rates Q_v (in m^3/h) due to infiltrations through window leakages are computed by means of the following equations:

$$Q_v = A\ (7 + 0.22\ P_v)$$

$$Q_v = A\ (3.7333 + 0.0813\ P_v)$$

$$Q_v = A\ (1.7333 + 0.0206\ P_v)$$

respectively taking into account windows of bad, medium or good airtightness (classes A1, A2 or A3 according to the Italian national rules UNI 7979), being A the window area in m^2 and P_v the wind pressure in Pa (UNI, 1979), calculated as a function of the wind speed v (in m/s) through the following equation:

$$P_v = 0.613\ v^2$$

According to the second procedure, air flow rates Q_v (in m^3/s) due to natural ventilation are calculated for cross-ventilated buildings by means of the following equation:

$$Q_v = A\ v \prod_{i=1}^{6} K_i$$

where the K_i (i = 1, 2, ...6) coefficients are respectively the “discharge coefficient”, the “wind pressure coefficient”, the “inlet-outlet area ratio coefficient”, the “inlet-outlet distance coefficient”, the “internal partition coefficient” and the “fly screen coefficient”.
The procedure is based on the most consolidated developments in the field and has been checked by means of experimental data provided by the Ispra Joint Research Centre (Butera et al., 1991).
Anyway, both the aforementioned procedures do not take into account the temperature difference between indoor and outdoor environments but only the pressure difference produced by the wind.
Through the third procedure, a constant value can be arranged by the SMP user for the air flow rate of a building, like those suggested, for example, by the Italian national rules UNI 10344 as conventional values of the air changes per hour for the case of natural ventilation (UNI, 1993).
A fourth procedure allows to assign the values suggested by the ANSI-ASHRAE 62 Standard, that is for example 7.5 l/s per person or 0.35 air changes per hour in the living rooms and bedrooms, 50 l/s in kitchens, 25 l/s in bathrooms for a ventilation effectiveness $\varepsilon_v = 1$ (ANSI-ASHRAE, 1989).
Finally the last procedure allows to take into account a quite recent methodology depeloped by Fanger et al. (Fanger, 1988; Fanger et al., 1988) and then proposed as European Union guidelines (CEC, 1992; CEN, 1994).
It requires as input data:
- the pollutant emission rate G, measured in olf, due to the occupants (smoking or not) and to the building itself;
- the desired indoor air quality level C_i and the actual outdoor air quality level C_o, measured in decipol

- the ventilation effectiveness ε_v of the indoor space.
According to the Fanger's theory, the air flow rate Q_v to be provided is then calculated through the following equation:

$$Q_v = 10\ G / ((C_i - C_o)\ \varepsilon_v)$$

4. Using the SMPVENT routine for IAQ building investigations

4.1. Ventilation requirements and energy demand

Since ventilation rates provided by recent standards are generally higher than those suggested by the previously employed technical documents, an extra-cost resulting from the application of IAQ related air changes is suspected, in terms of energy demand for climatisation purposes.
In order to check the energy impact of the new regulations and in the aim of showing the use of the described computer routine, we will report here a simulating application.
A typical working class Italian apartment (Figure 1) is selected and fourteen levels of ventilation rates are applied, belonging to three different standards.

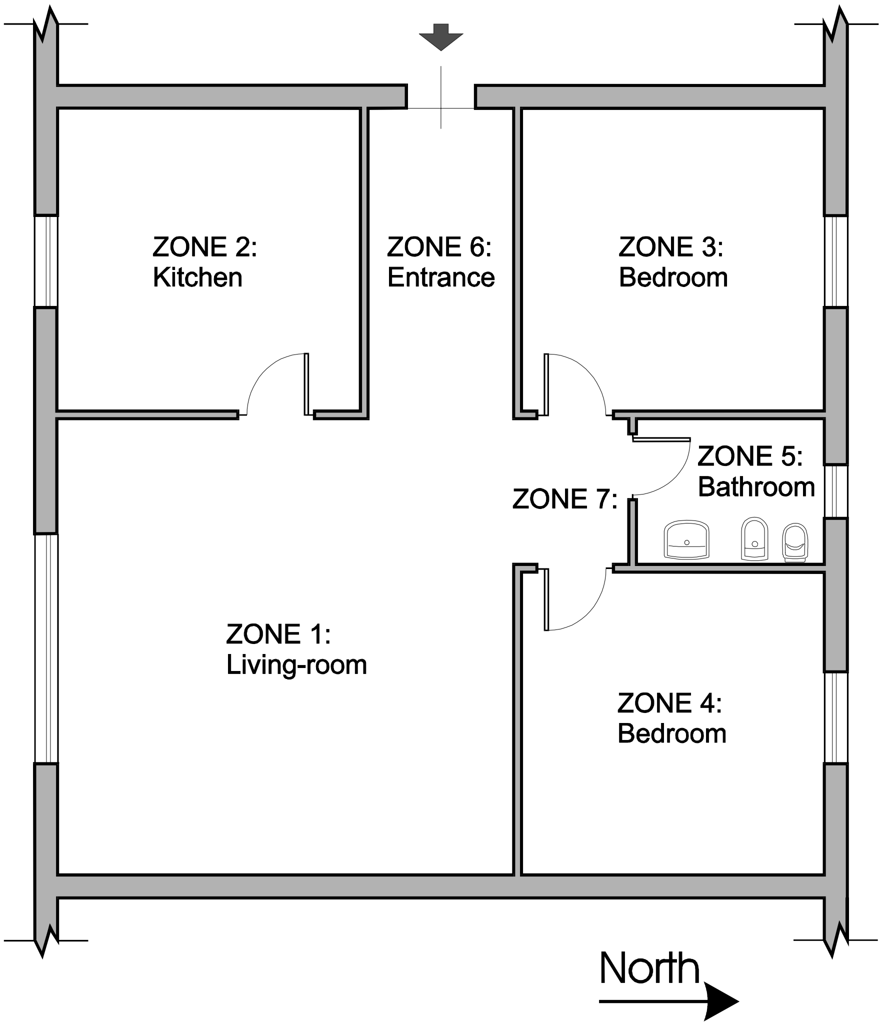

Figure 1. Layout of the selected apartment

The apartment shows an indoor floor surface of 100 m^2, with a corresponding volume to be climatised of 300 m^3.

The dwelling, where four people are supposed to live in, realising a given occupation schedule, is compounded by seven thermally separated spaces, as illustrated in Figure 1, that is a living room and a kitchen (both facing south), two bedrooms, a bathroom and two small service zones.
The materials characterising the envelope are typical of the recurrent building technologies, that is a thick wall of autoclaved concrete and double glazed windows.
Depending on the thickness of the walls, the obtained overall thermal transmittance, U, of the envelope ranges from 0.25 to 0.38 $W/m^3°C$.
Four values of the overall transmittance have been chosen for the simulations, falling within the limits imposed by a recently released Italian regulation for the energy saving in buildings, that is 0.25, 0.29, 0.34 and 0.38 $W/m^3°C$.
The dwelling is supposed to operate in four different Italian climates, that is a continental warm summer situation (Milan), a typical Mediterranean climate (Rome), a typical coastal Italian situation (Naples) and an island north Mediterranean climate (Messina).
Table 1 reports the main climatic parameters of the selected sites, along with the indication of the related heating periods permitted by law.

Location	North latitude	Degree days	Heating period defined by law	
			Duration	Hours per day
Messina	38° 12’	707	dec. 1 - march 31	8
Naples	40° 51’	1034	nov. 15 - march 31	10
Rome	41° 48’	1415	nov. 1 - apr. 15	12
Milan	45° 26’	2404	oct. 15 - apr. 15	14

Table 1. Relevant parameters for the selected sites

Although the locations belong to the Italian peninsula, its climatic spread can be assumed at least like representative of the European Mediterranean and continental warm summer zones, as the values of the pertinent degree-days show.
As regards ventilation rates adopted in the simulations, three different regulations have been examined (Costanzo et al., 1996).
The involved air changes are respectively the following.
Case a): air change rate of 0.6 volumes per hour, corresponding to a value generally used for heating calculations and suggested by the Italian standard UNI 10344 (UNI, 1993); this value conventionally refers to a medium permeability window with a partially shadowed glass.
Case b): ventilation rates as suggested by the ANSI-ASHRAE Standard 62 (ANSI-ASHRAE, 1989) and depending on the type of analysed room; that is 7.5 l/s per person or 0.35 volumes per hour in the living room and bedroom, 50 l/s in the kitchen and 0.25 l/s in the bathroom for a ventilation effectiveness εv = 1.
Cases c to p): ventilation rates as computed according to the procedure contemplated within the E.U. guidelines (CEC, 1992), for two different values of the ventilation effectiveness ε_v (0.5 and 1.0) and of the pollutant emissions from furniture, materials and equipment (0.05 and 0.1 olf/m^2 floor) and for three percentages of smoking people, that is 0%, 50% and 100% (people are however supposed not to smoke in the bedroom during sleeping time). The dwelling is supposed to face outdoor IAQ conditions of 0.2 decipol, corresponding to a medium quality air in urban areas; the quality level of the required indoor air is 1.4 decipol, corresponding to a predicted percentage of 20% dissatisfied people. In other words, in accordance with the E.U. guidelines, each room shows various pollutant levels, depending on the presence of smoking or not-smoking people and on the emissions of furniture, materials and equipment, while the effect of different ventilation effectiveness is also considered.

Referring to the ventilation effectiveness in residential buildings, that, particularly for the class of building here considered, are generally naturally operated, we have here adopted two values, that is 0.5 and 1.0.
As a matter of fact, there is presently a lack in the availability of such kind of data: one of the most complete analysis is reported by Sateri et al.(Sateri et al., 1991), where natural, mechanical exhaust and balanced ventilation systems are taken into account, for small houses and blocks of flats.
Table 2 summarises the simulation conditions for the twelve cases pertinent to the E.U. guidelines, while Figure 2a), 2b), 2c), 2d) report the energy demand for heating purposes for the above described dwelling: four values of the envelope thermal insulation are considered for each of the selected sites.
Cases a) and b) refer respectively to the Italian regulation and the ASHRAE Standard, while cases c) through p) refer to the E.U. guidelines and show different (and increasing) levels of indoor pollutant sources, as depicted in Table 2.

cases	ε_v	smokers %	pollution load (olf/m^2)	cases	ε_v	smokers %	pollution load (olf/m^2)
c)	1	0	0.05	i)	1	100	0.1
d)	1	50	0.05	l)	0.5	50	0.05
e)	1	100	0.05	m)	0.5	100	0.05
f)	1	0	0.1	n)	0.5	0	0.1
g)	0.5	0	0.05	o)	0.5	50	0.1
h)	1	50	0.1	p)	0.5	100	0.1

Table 2. Specifications of the cases analysed with regards to E.U. guidelines.

A first consideration to be drawn by Figures 2a) to 2d) is represented by the very close behaviour of the Italian standard UNI (case a) and the ASHRAE Standard 62 (case b), through all the sites and the transmittance values of the envelope.
On the contrary the adoption of the E.U. guidelines, that are affected by higher values of the ventilation rates for acceptable indoor air quality, leads to a remarkable increase in the energy consumption for building climatization.
This increase appears dramatically evident, as one moves toward more pollutant buildings: the differences of the energy demand between the most favourable case (case c), characterised by a specific pollution load of 0.05 olf/m^2, absence of smoking people and an efficiency of ventilation equal to 1.0, and the worst case (case p), characterised by a building pollutant emission of 0.1 olf/m^2, only presence of only smoking people and an efficiency of ventilation equal to 0.5, ranges from three to five times, through all the sites and the envelope insulation.
Of course, these results only constitute an example of the energy consumption for acceptable IAQ, but are definitely representative of the entity of the problem.
Avoiding sick building syndrome is obviously a must for architects, but it costs strongly in terms of energy for climatisation purposes.

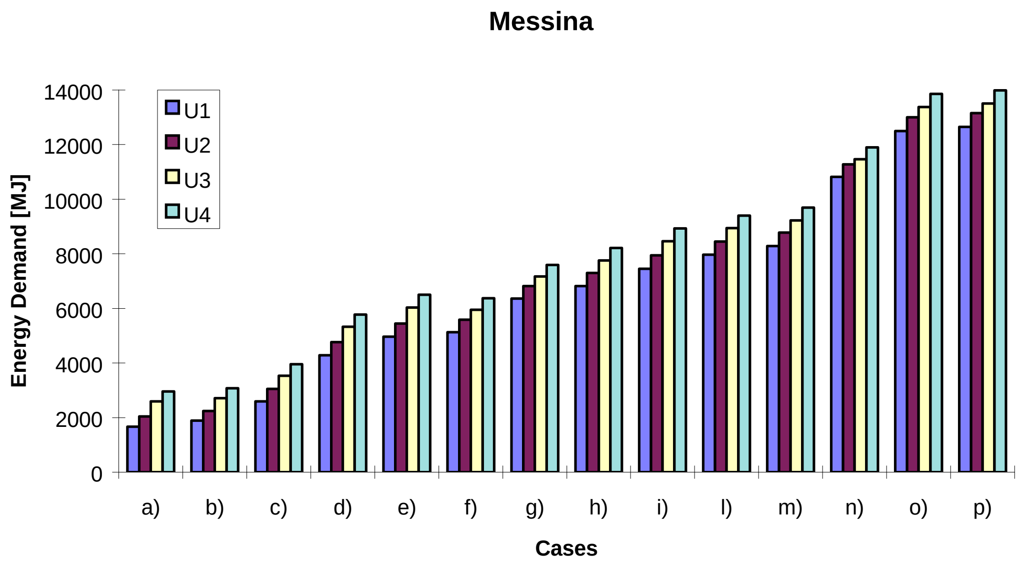

Figure 2a). Energy demand for heating purposes for an apartment situated in Messina and showing different levels of pollutant indoor sources and four different values of the overall transmittance (U1=0.25 W/m^3 °C, U2=0.29 W/m^3 °C, U3=0.34 W/m^3 °C, U4=0.38 W/m^3 °C)

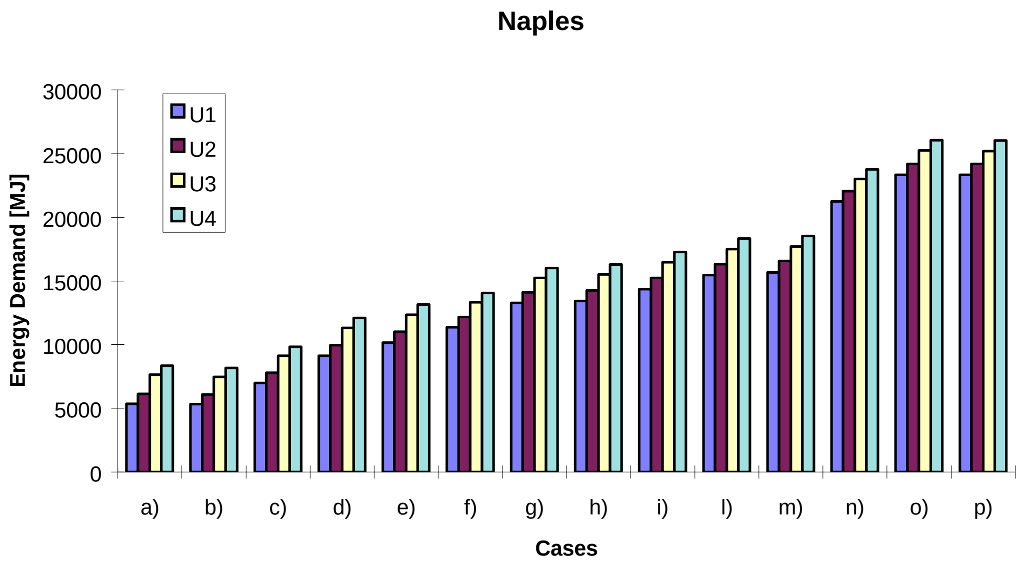

Figure 2b). Energy demand for heating purposes for an apartment situated in Naples and showing different levels of pollutant indoor sources and four different values of the overall transmittance (U1=0.25 W/m^3 °C, U2=0.29 W/m^3 °C, U3=0.34 W/m^3 °C, U4=0.38 W/m^3 °C)

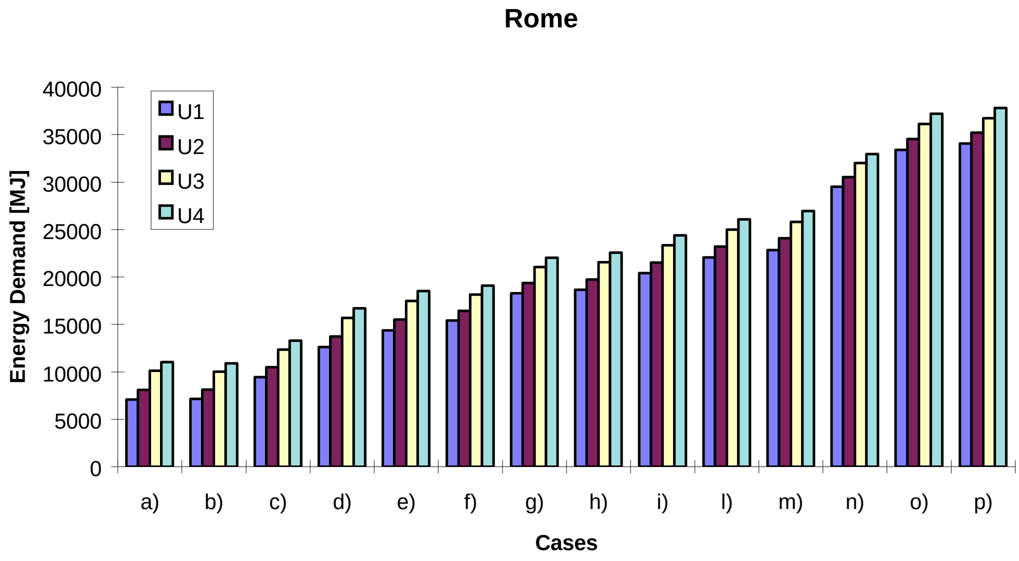

Figure 2c). Energy demand for heating purposes for an apartment situated in Rome and showing different levels of pollutant indoor sources and four different values of the overall transmittance (U1=0.25 W/m^3 °C, U2=0.29 W/m^3 °C, U3=0.34 W/m^3 °C, U4=0.38 W/m^3 °C)

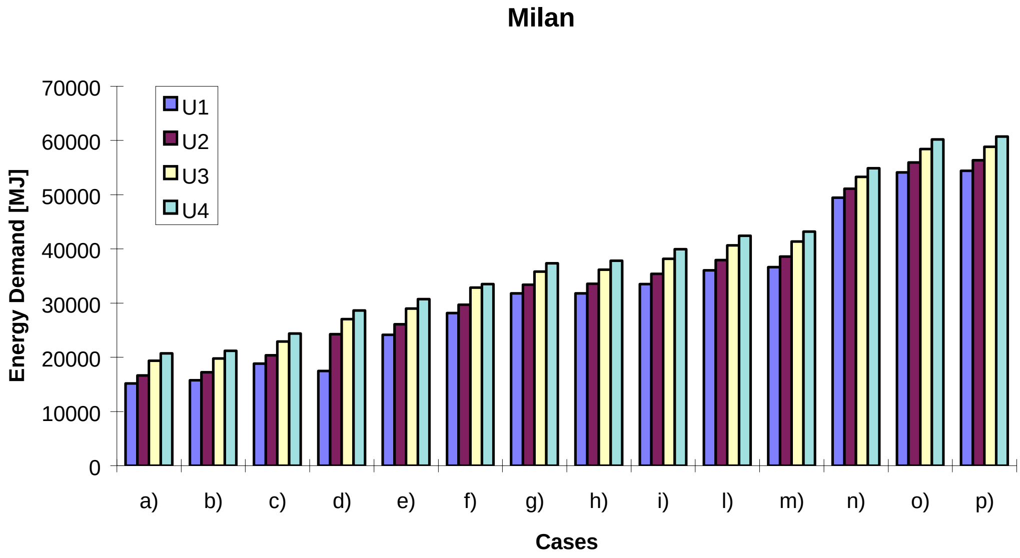

Figure 2d). Energy demand for heating purposes for an apartment situated in Milan and showing different levels of pollutant indoor sources and four different values of the overall transmittance (U1=0.25 W/m^3 °C, U2=0.29 W/m^3 °C, U3=0.34 W/m^3 °C, U4=0.38 W/m^3 °C)

4.2. Introducing I_p and $(ACH)_{av}$ indexes

A computing routine able to take into account the ventilation rates and the related energy demand for achieving acceptable indoor air quality, does represent a very useful tool in order of judging the effects of different policies aimed at limiting the pollutant emissions of buildings.
For example, starting from an assigned basic situation, one could investigate the influence of limiting the emissions from the building materials and equipment, or modifying the ventilation efficiency, or limiting the presence of smoking people.
Having in mind this analysis, we have further simulated a bedroom located in the southern Italian town of Messina.
The base-case was referred to a 16 m^2 room (48 m^3) with two not-smoking people during night-time.
The needed air changes per hour ACH for this situation was 1.75.
In order of judging the effects of the above cited modifications, we adopt here an indicator that takes into account both the pollutant and the ventilation features of a building, that is the ratio of the total pollution load, G, and the efficiency of the ventilation system, ε_v. We call this parameter "pollution index", that is:

$$I_p = G/\varepsilon_v$$

As it is clearly evident in Table 3, the influence of the presence of smoking people is by far the most relevant in making worse the indoor air quality, followed by the change in the ventilation efficiency; in this case, a doubling of the building material emissions, although producing an increase of the required ACH, is less affecting the IAQ level.

Base-case	Effect of the building emissions	Effect of the ventilation efficiency	Effect of the presence of smokers
0% smokers 0.05 olf/m^2 ε_v=1.0	0% smokers 0.1 olf/m^2 ε_v=1.0	0% smokers 0.05 olf/m^2 ε_v=0.5	100% smokers 0.05 olf/m^2 ε_v=1.0
I_p = 0.18 ACH = 1.75	I_p = 0.23 ACH = 2.25	I_p = 0.36 ACH = 3.50	I_p = 0.80 ACH = 8.00

Table 3. Effects of different pollutant causes added to a given base-case.

When using the routine, one must consider that during the simulation implicitly is assumed the availability of an equipment able to adapt ventilation rates to the number of persons entering or leaving a room.
In other words, the computed air changes (generally at a time step of one hour or even less) refer to an ideal case of instantaneous control of the ventilation rates.
In the practice, architects want to know a medium value of the air changes affecting a building, in order of properly sizing the ventilation equipment and the window apertures.
The described routine can be usefully employed for determining such typical air flow rates of a building.
In fact, using the hourly air changes calculated through the simulation, an average value, (ACH)av can be computed, as follows:

$$(ACH)_{av} = \sum_{m=1}^{M} \sum_{n=1}^{N} \sum_{H=1}^{24} \frac{(ACH)_{mnh}}{24 \cdot N \cdot M}$$

where M and N are respectively the number of months involved in the computation and the number of hours contained in each month.
The algorithm for the computation of the average air changes has been applied to the building and the sites selected for the previously presented simulations, in the case of an overall transmittance equal to 0.25 W/m^3 °C.
The calculated values of the average ACH are shown in Table 4.

cases	average ACH	cases	average ACH
a)	0.48	h)	1.46
b)	0.6	i)	1.71
c)	0.71	l)	1.92
d)	0.96	m)	2.4
e)	1.21	n)	2.41
f)	1.22	o)	2.92
g)	1.41	p)	3.42

Table 4. Calculated values of the average ACH.

An extensive comparison has been then performed between the energy demand resulting from the application of the average air changes and those obtained by means of the correct hour-by-hour simulation.
As it appears from Figures 3a), 3b), 3c) and 3d), results are encouraging, demonstrating that, in some cases, a reliable analysis can be conducted by means of an early draft simulation, employing a medium value of the ventilation rates.
Analyses like those here presented are of primary importance in the aim of checking the influence of various parameters on the energy consumption for climatisation of buildings.
In this sense, the availability of a simple computer routine to be implemented in the existing computer codes, results of great utility.

4.3. Thermal environment and indoor air quality

Ventilation rates for acceptable indoor air quality, although important, represent only one of the several issues that contribute to the complete acceptability of a given confined environment: thermal, visual, acoustic, tactile, along with all the ergonomic issues converge to make pleasant or unpleasant an indoor space.
Within the frame of control of the equipment and technological tools, thermal comfort constitutes a design field that can be approached by means of computer simulation codes.
The problem obviously arises about the compatibility of the relative requirements for IAQ and thermal conditions purposes: in fact a building meeting the IAQ requirements could or not fulfil the requirements for thermal comfort.
Computer models can be employed for analysing in a joined way both the environmental conditions.

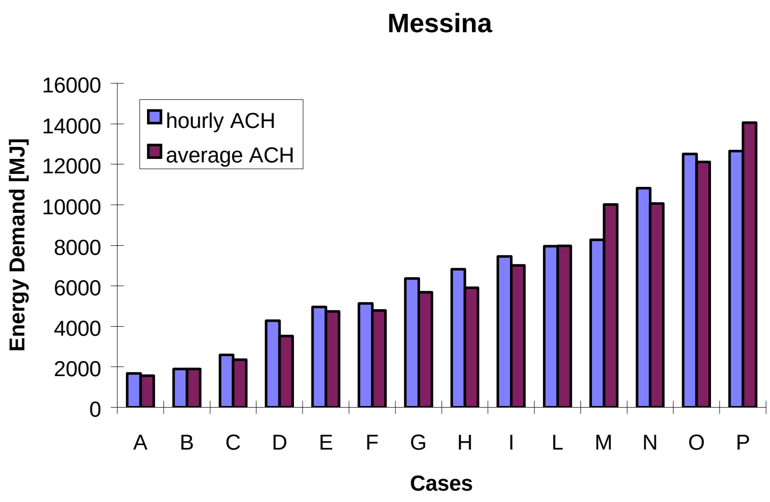

Figure 3a). Comparison of energy demand obtained for the city of Messina by means of average and actual values of the air changes for acceptable indoor air quality in buildings characterized by U = 0.25 W/m^3°C (E.U. guidelines)

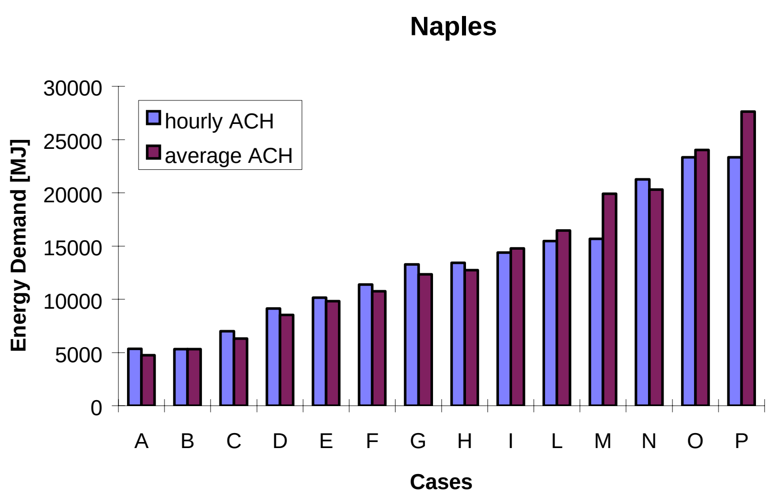

Figure 3b). Comparison of energy demand obtained for the city of Naples by means of average and actual values of the air changes for acceptable indoor air quality in buildings characterized by U = 0.25 W/m^3°C (E.U. guidelines)

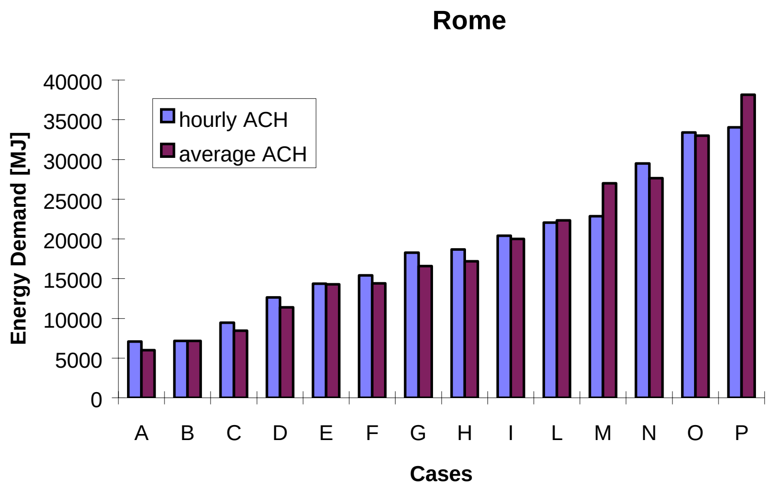

Figure 3c). Comparison of energy demand obtained for the city of Rome by means of average and actual values of the air changes for acceptable indoor air quality in buildings characterized by U = 0.25 W/m^3°C (E.U. guidelines)

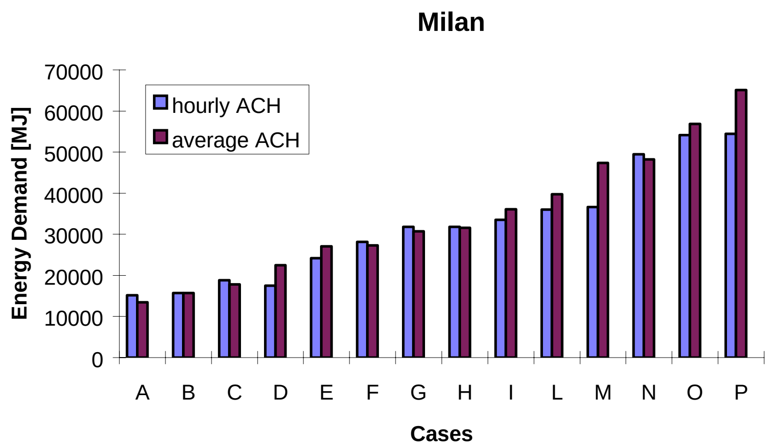

Figure 3d). Comparison of energy demand obtained for the city of Milan by means of average and actual values of the air changes for acceptable indoor air quality in buildings characterized by U = 0.25 W/m^3°C (E.U. guidelines)

Referring to the percentage of dissatisfied people (PPD), the limit for thermal comfort are represented by PPD=10% (ISO, 1984), that correspond to a Predicted Mean Vote (PMV) of -0.5 and 0.5, respectively for slightly cold and slightly warm environments; the limits for IAQ requirements can be assumed equal to 10% of dissatisfied people, corresponding to 0.6 decipol for the quality of indoor air.
Of course, other limits can be adopted, considering, for example both 20% of dissatisfied, as suggested by the ASHRAE standard.
In any case, further assumptions must be taken about thermal conditions, that is the metabolic rate and the clothing ensemble of people supposed to live or work inside the building, along with four thermal and physics parameters, that is the indoor air temperature, the mean radiant temperature, the mean velocity of indoor air and vapour partial pressure.
Clearly, these parameters can be easily obtained by means of a computer simulation code that analyses the thermal behaviour of a building.
After these assumptions are made, a simple graph, like that reported in Figure 4, can be utilised in order of establishing the thermal and IAQ acceptability of a given environment.

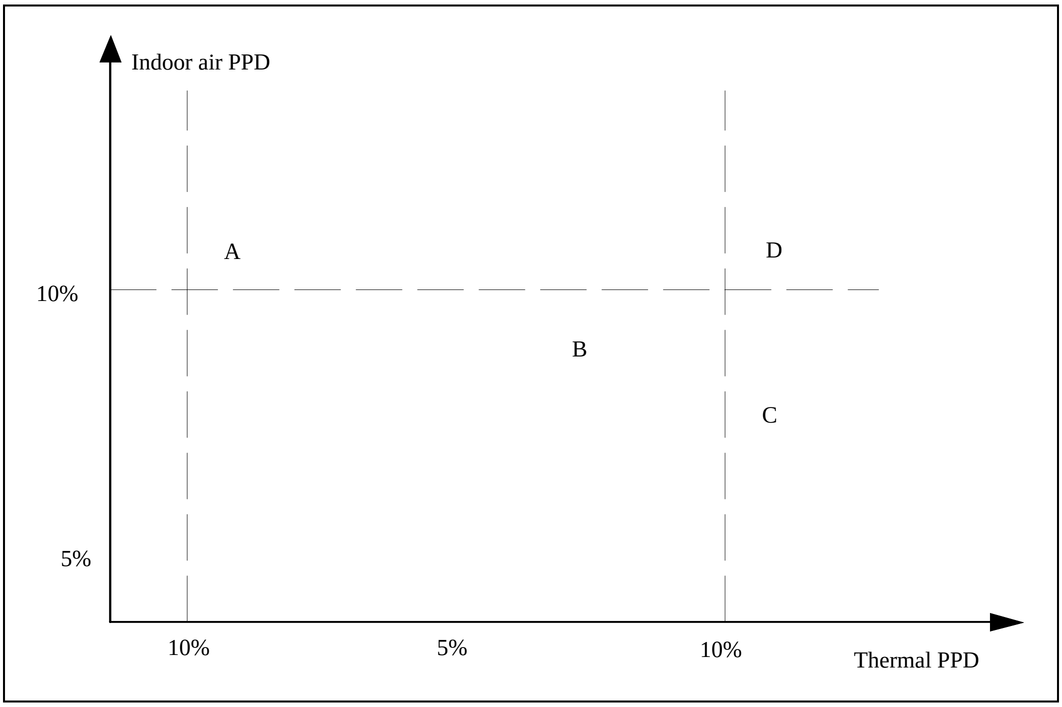

Figure 4. Joined calculation of thermal and indoor air percentage of dissatisfied.

The situations that can occur are generically denoted in Figure 4 by means of symbols A (only thermal comfort conditions achieved), B (thermal comfort and IAQ conditions achieved), C (only IAQ conditions achieved) and D (neither thermal comfort nor IAQ conditions achieved).
It is evident that these situations indicate comfort (or discomfort) conditions that can vary with an hourly step (the usual minimum time step for simulations), while a judgement about the acceptability of a given building should be assigned over a longer time-lag, and eventually on a seasonal base. This means that thermal comfort and IAQ conditions resulting from the hourly simulations need to be furthermore processed, in search of suitable comfort indexes that could be employed for long-term judgements.

5. Conclusions

The described computer routine demonstrates to be an useful tool for evaluating the ventilation rates of a dwelling, with respect to the most diffuse international standards.

It has been employed for checking the energy costs resulting from the application of the new indoor air quality related standards. Particularly, the recently released European guidelines show to be very energy expensive, as they are directly related to the pollution loads of a building. The application here presented implicitly assumes that a ventilation system instantaneously adapt to the air changes required for each changed situation, depending, for example, to (smoking or not) people entering or leaving a room. Clearly this is not the case for the actual ventilation tools. In other words, the simulations have been only conducted with the aim of investigating the structure of the standards and what does it mean in terms of energy demand for climatisation of buildings.

Through the paper an “average air changes per hour” and a “pollution index” have been introduced, in order of providing architects of a simplified calculation tool for draft analyses. Their usefulness has been verified through an example.

Finally, a tentative method has been proposed for a comprehensive evaluation of thermal comfort and indoor air quality features of a building, although some problem does remain concerning the proper time-lag within which the evaluations must be performed.

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