A TRNSYS Component to Calculate Natural Ventilation and Indoor Air Quality in Multizone Buildings

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ABSTRACT

The prediction of air infiltration is very important when simulating a building, due to the coupling aspects of the thermal and ventilation problem. So, the development of codes capable of performing simple yet precise calculations is of great usefulness. Their utility can even be enlarged if we add subroutines capable of air quality calculation and automation of some preliminary but necessary assessments, like local pressure coefficients over the building facades and wind speed profiles. Such code can be compiled to be run under a well-known simulation environment like IISiBat/TRNSYS, where the coupling of thermal and ventilation problems can be held. This paper describes a computer application that was developed using these concepts. It was developed in Delphi and was divided in two modules. The first one is a stand-alone application used to generate the description files necessary to the second module. The second module is a DLL file compiled as a TRNSYS component. Inside TRNSYS, the module reads the building description files saved by the “interface” application and then calculates air infiltration and air quality for every time step of the simulation. Firstly, the assumptions used to develop the TRNSYS component are described. Next, the program utilization is presented.

KEYWORDS

Natural Ventilation, Computer Calculation.

INTRODUCTION

During summer in moderate climates or through all the year for the hot climates, natural ventilation contributes to the improvement of thermal comfort of people. Also, even in winter natural ventilation plays an important role in indoor air renewal contributing to a better quality of the interior air. Moreover, the air flows which penetrate a building will intervene in an important way on the heat balance of the building. These flows depend on wind speed and orientation, on the facade characteristics, air temperature differences and on the size and the shape of the openings.

The prediction of air infiltration is thus a important problem and can be solved by numerically simulating the building. Although there are computer tools capable of carrying out this type of simulation, they are generally excessively complex if we want to consider simpler situations, like the absence of mechanical system of ventilation, for example.

Thus, the development of a better adapted and simpler code which is able to carry out such calculations is of a great utility. Its utility will be of as much better if we add to this code of the numerical routines able to calculate the quality of the interior air. Such a code can be compiled to be able to function both as standalone application as under a well-known environment of simulation like IISiBat/TRNSYS, where problems of coupling with the building and the systems can take place.

SCIENTIFIC BACKGROUNDS

Air Flow Calculation

The approach used for calculations of the internal flows resulting from the action of the wind on the building, followed the traditional scheme of dividing a building into zones, each of them associated with a node. According to this model, each node represents an interior zone of the building (interior node) or an external environmental condition corresponding to an opening on the facade (external node). An interior node is characterized by the air temperature and the pressure inside the corresponding zone. An external node is characterized not only by the air temperature and the pressure in the vicinity of the windows, but also by a local pressure coefficient, resulting from the distribution of the dynamic pressures over the building facades. As in practice, the building is generally not isolated in site, but inserted in an urban context of greater density, a correction of the local coefficients of pressure should be considered to reduce these pressure coefficients due to the presence of adjacent buildings. This reduction is here calculated by a relation presented by Rousseau and Mathews (1996). Finally, the connections between two interior nodes (passages of air between two adjacent zones) or between an external node and an interior node (openings of the facades) are considered as nonlinear conductances, characterized by the type of flow.

The model based on these principles considers the following assumptions:

1. The simulated building is considered as constituted of several zones of rectangular horizontal surface and prismatic volume;
2. The flows of air between the various zones (environments) and between a zone and the outside are considered in steady state within each step of time of the simulation;
3. The temperatures and the pressures are considered uniform within the zone;

For the calculation of the air flows of the network, the solution is given using an iterative process of the equation of the assessment of the mass flows of each zone:

$$\sum_{i=1}^{j} Q_{mi} = 0$$

where Q_{mi} is the mass flow of air through the i'th opening (in kg/s).

Interior Air Speed Calculation

The problem of interior air speed calculation due to the wind on the facades is of difficult solution. Normally, only CFD (computational fluid dynamics) techniques can precisely evaluate these speeds and even so, for very specific situations. Nevertheless, one can establish a more general relation between the speed of the external wind and the interior air speed (C_v, velocity coefficient). This can be done for several configurations of wind angles of incidence and the proportion between the size of the window and surface of the wall (porosity of the facade). In this work, we used the correlation found by Kindangen (1997) (see figure 1 below).

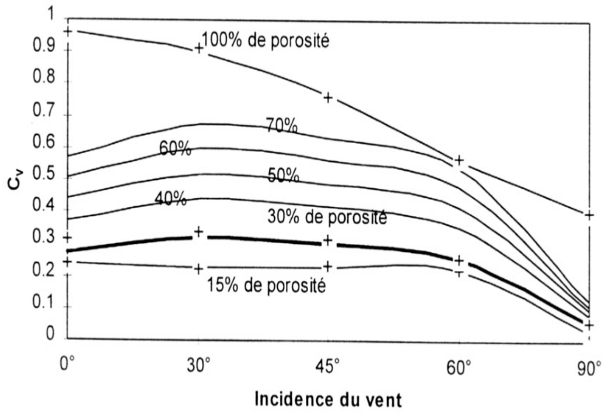

Figure 1 : C_v values

Interior Air Quality Calculation

The quality of air inside non-industrial buildings can be obtained by considering the number of people in the buildings, the type of activity, the number of air renewals per hour and the type of environment. By knowing these parameters, one can determine the air quality by using a index, like the one proposed by Fanger (1972). In this model, the problem of the identification of the chemical species and their concentrations is substituted by an olfactive characterization of the air. The unit which quantifies the intensity of a source of olfactive pollution is the *olf*, which represents the pollution produced by an adult, with a metabolic rate of 1.2 met, in a non-industrial environment, performing a sedentary activity and under certain conditions of hygiene and comfort. Other individual emissions of pollutants can be considered according to the activity of the person. To these values, one adds an emission of some olfs/m^2 due to the room itself. If there would be flows of air coming from other zones, one adds a load of pollution corresponding to this flow of air which penetrates in the room. The unit which represents the perception of the odor by a user of the building it is the *decipol*, which represents the air quality perceived by an individual in a confined environment receiving a fresh air flow of 10 liters/second and a polluting load of 1 *olf*. The quality of the air related to the pollution perceived in the environment can then be obtained by considering the quantity of air which penetrates in the environment. The quality of air perceived can be also expressed by the percentage of dissatisfied people (PPD), which is calculated by the expression:

$$PPD = EXP(5.98-(112/Q_{air})^{0.25})$$

where Q_{air} is given in *decipols*.

THE STANDALONE VERSION

To carry out the natural ventilation calculations, we developed a computer code called "AeolusMZ". The software was developed based on the approach described in detail in the preceding section. The main objective was to create a program with a rather user-friendly interface, in order to avoid the complicated input scheme so usual in other similar codes. In AeolusMZ, three screens allow the entry of the parameters for simulation.

The first screen allows the user to enter/modify the building external dimensions, the wind direction, the wind speed and the urban density of the site. With the second screen, one can enter the parameters of each building zone, i.e., the volume, floor surface, altitude (on the level of the stage), the internal air temperature, the number of people, the percentage of smokers, the type of room and the type of activity carried out at the zone interior. One last screen allows the entering of the parameters related to the openings: positioning, dimensions, and the state of the opening: natural opened (ventilation) or closed (infiltration). A special routine within the code allows the calculation of the local pressure coefficients of the external openings. After the entry of all the data, two types of simulations can be carried out:

i) instantaneous;

ii) long period, where time profiles of zone occupation and wind data are considered (and accessed from specific files in the computer hard disk).

After the calculation, the results are shown in the computer screen and saved in a textfile in the hard disk.

THE TRNSYS COMPONENT VERSION

Coupling thermal behavior and ventilation

The simulation of the natural ventilation carried out by the AeolusMZ software provides good results for the air flows and the direction of the flows inside the building. Nevertheless, these results are obtained by considering fixed internal temperatures. In reality, the internal temperatures also depend on the air flows which enter and leave the zones. This makes the calculation of ventilation a problem coupled with the calculation of the thermal behavior of the building. One way of carrying out the coupling of the model of ventilation to the thermal model is to use an approach which one can call "onion coupling". In such approach the temperatures and the air flows are calculated several times in the same timestep of simulation, the results being used as "input" and "output" alternatively within the process until a convergence is reached.

Code Adaptation to TRNSYS

The use of the ventilation code inside TRNSYS was possible because the standalone version was adapted in the form of a component which could be recognized by that environment of simulation. TRNSYS Version 15 offers some possibilities for the implementation of an external module to its work environment. We used the option of compiling the developed module as a Windows DLL file, calling it "extdll.dll" and carrying it out from inside TRNSYS through Type61. By following the "onion" principle for the ventilation and thermal coupling problem, at each simulation timestep the airflows are calculated by Type61-AeolusMZ and are used as inputs of Type56 to calculate the internal temperatures inside the zones. These temperatures are then used as inputs of Type61 and are used for calculating new airflows, and so on, in a loop which is stopped only when convergence is reached for both the temperatures calculated by Type56 and the airflows calculated by Type61-AeolusMZ. After which TRNSYS advances for the next simulation timestep. The building description necessary to the simulation (dimensions, site data, the zones and the openings), is obtained by the component through the reading of a file named "trnsys.aif", which must be edited and saved in the disk by the standalone version (with interface) of AeolusMZ. That way, this version is used as an input module for Type61, in the same way that the software PREBID is used to produce the building description for the TRNSYS Type56. The reading of the "trnsys.aif" file is carried out automatically by the component at each simulation timestep. The developed component presents 15 inputs and 61 outputs, as follows:

- Inputs from 1 to 10 - Temperatures of the air inside each zone (maximum of 10 zones), calculated by Type56.
- Input 11 - Temperature of the outside air, value read from a weather file.
- Input 12 – Occupation profile of the building, given as a percentage of the total number of users in each zone.
- Input 13 – Wind speed (m/s) at a height of 10m.
- Input 14 – Wind direction (referred to the main facade of the building, clockwise).
- Input 15 – Facade porosity (relation between the surface of the windows and the surface of the facade)
- Outputs 1 to 10 - Infiltration of outside air in each zone, calculated by the component as the number of air changes per hour (Volumes/h)
- Outputs 11 to 50 - Air flows calculated for each internal opening (maximum of 20) linking two zones A and B (kg/h). Odd Outputs (11, 13,…, 49) means air flows in the ZoneA-ZoneB direction and Even Outputs (12, 14,…, 50) the air flows in the ZoneB-ZoneA direction. Each internal opening is thus represented by a pair of outputs (11-12,…, 49-50).
- Outputs 51 to 60 - Index of air quality perceived inside each zone (PPD).
- Output 61 - Air speed inside the building.

CODE VALIDATION

To check the precision of the developed code we carried out various simulations of natural ventilation for a standard case by using the software AeolusMZ and then we compared the results obtained with software AIOLOS 1.0. The standard case was represented by a small multi-story office building. For simulation, we considered the eighth of the fifteen stages. Each building floor was divided into seven zones, each one having only one opening towards outside (window) and some internal doors. The wind speed was considered equal to 2.5 m/s at the building top. The C_P of the facades were calculated by the AeolusMZ software and then used as simulation parameters in the AIOLOS software to ensure that the same conditions were used by the two codes. A comparison between the results found by AeolusMZ and AIOLOS for the air flows has shown an excellent agreement.

CONCLUSION

This article describes a computer application that was developed by using well established concepts of natural ventilation in buildings. By the way the software was developed, with a standalone version and another constituting a TRNSYS component, a very great number of simulations and exploitations can be carried out for obtaining good strategies of natural ventilation, mainly in the initial stages of building design. Moreover, because of the aspects of ventilation and thermal coupling, and the possibility of working jointly with TRNSYS Type56, this component brings out the possibility to obtain precise and reliable results of building simulation.

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