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A NEW MODEL TO COMPUTE AIR DISTRIBUTION

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ABSTRACT

In thermal simulation codes for buildings, aeraulic transfers are computed either with very simplified models (fixed air distribution) or with sophisticated models (based on the computation of the pressure fields). The simplified models are not accurate enough and the sophisticated models are too complicated for only thermal computations.

An intermediate model has been developed. This new model is based on the computation of the temperature fields and on the knowledge of an average air distribution due to air leakage and specific ventilation. So, as this model needs no computation of the pressure fields, it is well adapted to thermal simulation codes. The new model has been validated on a real scale experiment. Details are given on the validation aspects.

1 . INTRODUCTION

The final aim of this research is to evaluate the influence of taking into account the internal partition of buildings on the computation of thermal performances either of envelops components or of heating systems components.

Until these last years, performances were computed by using buildings unizone models. A building was described as an isothermal single volume ; the free gains (solar gains, heat losses of systems, ...) were assumed to be uniformly delivered.

To take into account the real internal partition of buildings leads to take into account non-uniform temperature fields. For instance, overheatings are in places more important than with an unizone hypothesis. Then, for example, the computed rate of recovery of the free gains is lower when taking into account the internal partition [1 to 4].

To compute with some accuracy the thermal performances of envelops or heating systems components in a multizone environment, the heat transfers between rooms have to be computed as accurately as possible. The main difficulty concerns the modelization of the heat transfers due to aeraulic transfers. To compute with accuracy the aeraulic heat transfers, it seems a priori logical to use a model based on the computation of the pressure fields. In fact, for thermal computations (single goal of the aeraulic model : to provide thermal conductances due to air movements) an aeraulic model based on the computation of pressure fields is too much complicated. To use such a model leads to too long running times if annual simulations are needed. Moreover, sometimes problems of non-convergence occur [5 and 6].

A new model, adapted to thermal computation codes, has been developed. The application field of this new model has been defined in the framework of a global classification method for the various kind of aeraulic models (cf. §.2.1). At paragraph 2.2, the architecture of the new model is described. To validate this new model, an experiment has been designed ; the main characteristics of this experiment are given in section 3.

The first validated results and the limits of validity of this model are discussed in paragraph 4.

2 . ARCHITECTURE OF THE NEW AERAULIC MODEL

2.1.CLASSIFICATION OF AERAULIC MODELS

A classification of the various aeraulic models has been designed. The models are classified depending upon their main application field. Then the different classes are :

- C1 Class - models with fixed scenarios for air movements between zones.
- C2 Class - models taking into account at each time step the evolution of the temperatures in the different rooms but without computing the pressure fields.
- C3 Class - sophisticated models based on the computation of the pressure fields.

C1 class models are the simplest models and then the more common used for thermal computations. Their application field is strictly restricted to thermal computation codes. In a C1 class model, the air flow rate distribution between rooms (including with the outside of the building) is defined before to begin transient simulations. The air flow rate distribution can be defined by the software user or can be computed using a C3 class model. In any case, the air flow rate distribution does not change all along the simulation. At the very most, it is possible to define periodical time dependent scenarios.

C2 class models are designed to be used mainly for thermal computations. Nevertheless, with some restrictive conditions, they can be use to compute air flow rates. The new model we have developed is a C2 class model. At each time step, this model allows an accurate enough computation of the heat conductances due to air movements between rooms.

C3 class models are designed to compute with accuracy the air flow rates. They take into account the wind effects, the air leakage, the buyancy effects, the ventilation systems ... C3 class models are used in thermal computation codes (CSTBât(1), ESP(2) ...) to compute in fact only heat transfers coefficients between rooms.

As a conclusion of this presentation of the various kind of aeraulic models, what is to remain is that a complete aeraulic **module** would involve the different classes of aeraulic models. Because each one is adapted to a specific problem.

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(1) CSTBât : Code de Simulation de la Thermique du Bâtiment CSTB Sophia Antipolis - France

(2) ESP: Environmental Systems Performance University of Strathclyde - Departement of Architecture

2.2.ARCHITECTURE OF A C2 CLASS MODEL

To compute thermal performances for a whole heating period, it is more important to take into account the variations of the internal air movements than the variations of the air leakage and of the ventilation. For thermal computations, average values for the exchanges of air between the outside and the inside of a building can be used. Eventually, different average values will be used on one hand for winter and on the other hand for autumn and spring (only if a climatic analyse would shown that their are big differences upon the average values of air leakage because of very different average wind speed and wind direction and because of a bad airtightness of the building). In addition, mechanical ventilation can be defined as a periodical time dependent function.

Then, the aeraulic model involves a preprocessor to compute average distributions of air flow rates due to air leakage and ventilation. These calculations must be done for all the possible configurations, i.e. depending upon the possible status of the doors (open or close). The computations can be easily performed with a C3 class model assuming that all the temperature rooms are equal (because with this last hypothesis, the present C3 models run very well taking few time for calculation).

At the end, the results are translated in terms of thermal conductances (named Ke_{lm}) between rooms. The values of Ke_{lm} are stored in a matrix. This matrix is named **D**(i, j, k, l, m).

- Index i — is for the different period of the heating season (in general i = 1 or 2).
- Index j — is used if daily scenario for the mechanical ventilation are defined.
- Index k — is to differentiate the various configurations (possibilities to have open or close doors). The maximum value of index k depend upon the number of rooms and the hypothesis concerning the doors between rooms (behaviour of inhabitants).
- Index l and m — are to point out the rooms between which the conductance Ke (i, j, k, l, m) occurs.

When this initialized phasis is ended (i.e. when the D matrix is full), the transient computations can run. The air movements between rooms are due on one hand to air leakage and ventilation and on the other hand to buyancy effect. The thermal conductances due to air leakage and ventilation are extracted from D matrix. The thermal conductances due to **buyancy effect** are computed through a simplified model ; this simplified model can be a relationship as Nu=f(Gr, Pr) (Nu : Nusselt's number, Gr : Grashof's number, Pr : Prandlt's number) ; such a model leads to define temperature dependent conductances between two nodes representing two adjacent rooms.

The global thermal conductance is computed by using a **coupling model**. The coupling model consists of a simplified relationship to calculate the global thermal conductance between two rooms knowing the thermal conductance due to air leakage and ventilation and the thermal conductance due to buyancy effect..

The architecture of a C2 model is summarized on illustration 1.

Important points.

The aeraulic model of C2 class involves in fact several submodels. They are :

- a model to compute discharge coefficients as a function of opening characteristics;
- a model to compute the D matrix (i.e. the thermal conductances due to air leakage and specific ventilation) ;
- a model to compute the thermal conductances due to buyancy effect ;
- a coupling model to compute the global conductances.

These different models are described in details in [7].

To identify the parameters of these models, an experiment, which takes into account the results of the previous one [8, 9], has been designed. This experiment is described further (cf. § 3).

3 . EXPERIMENT

This experiment takes place in the DESYS test cell which is built within the area of the CSTB in Sophia-Antipolis [5 and 10]. Some important informations concerning this experiment are given below.

The aims of this experiment are :

- to provide some elements of reflection about the physical aspects of convection through an large opening ;
- to identify the parameters of reduce order models (as for example, a Nu=f(Gr, Pr) relationship) ;
- to provide experimental data to validate the whode C2 model.

The experiments aim to measure the heat transfer between two rooms when various conditions are applied. The heat transfer can be computed either by using the measured speed and temperature fields in the aperture (the air speeds in the opening are measured with nine anemometric probes - marque DANTEC, type 54R10. These probes are attached to a movable cane) or with a method of thermal balance.

The various conditions which can be applied are :

- fixed values for the heat fluxes in the two rooms (these fluxes can be positive - case of a heated room -, negative - case of a air-cooled room - or equal to zero - no heating or cooling system in the room -) ;
- different heating or cooling systems (convection - which depends on the system - inside one room can influence the air flow between the two rooms) ;
- air flow rate due to mechanical ventilation (there is an air-inlet in the room 2 and an air-outlet connected to a fan in the room 1, the rotation speed of the fan is adjustable) ;
- the dimensions of the opening (the surface area of the opening can be changed from some cm^2 to about 2 m^2).

4 . MAIN RESULTS

A model to compute the heat transfer due to buyancy effect has been validated. This model (relationship Nu = f(Gr, Pr)) uses as characteristical temperature difference **the difference between the average temperature of the rooms**. At the moment, the range of validity is :

$1.8\ 10^9 < Gr_D < 2.5\ 10^9$ and $D/H \geq 0.84$ (D is the width of the opening and H is its height) ; moreover, this model is not very well adapted if heating or cooling system by pulsed air are used. The model is :

$$Nu_D = 0.4\ Gr_D^{0.5}\ Pr$$

By comparison with the previous similar models, the main advantage of this model is that the characteristical difference of temperature is really the difference between the average temperature of the rooms. This is an advantage because in the aeraulic or thermal computation codes the only available temperatures are the average temperatures of the rooms (for experimental reasons, most of the previous similar models used the difference between the average temperature of the opposite walls).

In addition of evaluating heat transfer between rooms, the relationship Nu=f(Gr, Pr) can be used to evaluate very easily the air flow rate between two rooms with the only knowledge of the average temperatures of the rooms. But this calculation will give an enough accurate result only if the temperature profiles in the two rooms are almost linear (nevertheless, without leading to a phenomena of multiple neutral plan).

5 . CONCLUSION

The air flows in large openings, due to buyancy effect, can reached high values in compar with the values of the air flows due to air leakage and ventilation. For example, through a "standard" opening (about 0.9 m x 2 m), a difference of temperature of 0.1° creates a circulation of air of about 120 m^3/h ; 1° as difference of temperatures creates an air circulation of about 390 m^3/h.

To modelize this very important phenomena, we have developed and validated a new aeraulic model especially designed for thermal computations codes. This model needs only the knowledge of the average temperatures of the rooms and the knowledge of a predefined air distribution due to air leakage and specific ventilation. The accuracy of the results (in terms of average thermal performances of components) obtained with the use of this model is very good in compar with the use of a C3 class model (i.e. a model based on the computation of the pressure fields).

On the other hand, the problems of numerical convergence are widely reduced and the running times are reduced too.

In addition, the ongoing experimental study would provide some data to validate a model to compute the discharge coefficient of the large openings. Further, some elements of reflection could be provide about the "physical" mean of the discharge coefficient and its relevant use.

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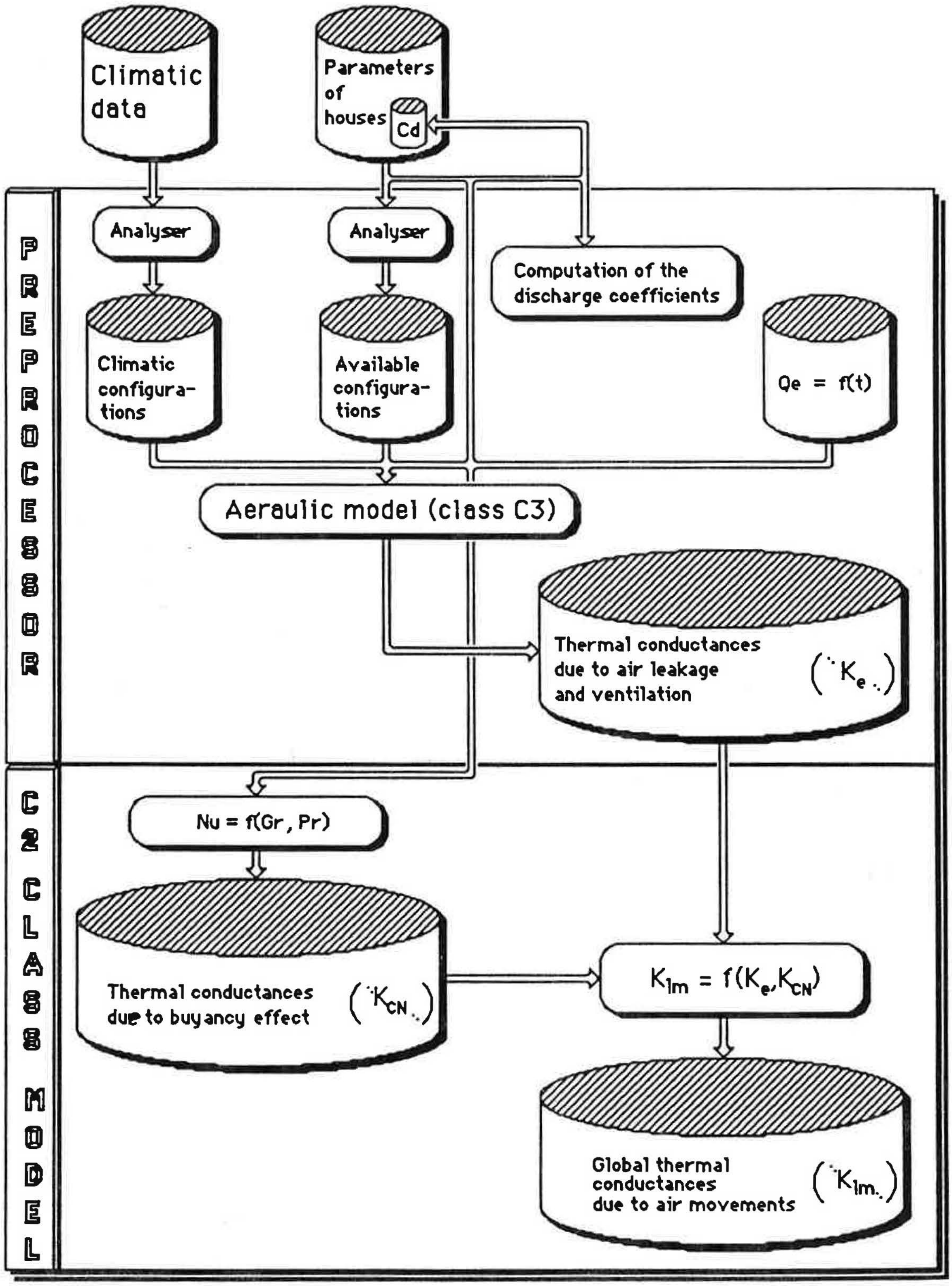

<u>Fig.1</u> - Architecture of a C2 class aeraulic model.