CODYBA – V.6 : NEW VERSION OF SOFTWARE FOR BUILDING DYNAMICAL BEHAVIOUR SIMULATION

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Abstract. *In CODYBA software new version, a building model is based on its decomposition in elementary objects (air volumes, walls, windows, control systems, etc). The global building model is obtained by the connection of these different "objects/models", associated to excitations like the exterior climate and/or the internal loads. These excitations are also manipulated as "objects/models". To summarize, the CODYBA's graphical user interface introduces concepts that are identical to those manipulated in everyday practice by building professionals (walls, windows, materials, regulators, etc) and reproduced on screen by a classic "icono-graphical" representation in the "Windows" environment.*

Keywords. *Thermal system, Energetic conception, Design tool, Objects/models building decomposition*

1. INTRODUCTION

CODYBA software has existed at CETHIL since 1985 (CODYBA, 1992). It has shown the validity of scientific concepts that it utilises, as well as their efficiency in the development of industrial software. Taking into account the evolution of computer tools and methods of these last years, a complete change has been made on the practical and theoretical plans. This change was implemented to extend the building modelling.

A preliminary bibliographical study showed that the functioning of the " thermal system" represented by a building in its climatic environment, is the object of numerous developments for the energy conception design tools. One of our conclusions is that a major difficulty encountered even before the development phase of these tools, is the building decomposition in elementary objects permitting a sophisticated programming and giving to the professionals the possibility to find familiar entities in the graphical user interface. We present next our new modelling which, we hope, provides a solution. Once the modelling was adopted, it had to be programmed taking into account available tools on the market. As we have adopted an "object" type modelling, an "object" type programming language has been imposed. So, **CODYBA** was developed in the C++ programming language : we will present here formally the classes issued from our modelling.

2. METHODOLOGY

CODYBA aims to offer to the greatest number of users a prevision tool for the thermal behaviour of a building permitting to establish an energy balance or to analyse the influence of certain parameters (like, for example, the control, the windows, the solar protections, the

building inertia or orientation, etc.). This simulation tool should be simple, accessible, reliable, robust, and evolutionary. The calculation module must also authorise the most advanced calculations, which cover or could cover in the future all the domains of building physics applications, as well as the implementation and exploitation of new components.

This double objective brought us, among other reasons, to introduce two levels of modelling : one for the structuring of the building data and another one for the implementation of the calculation algorithms. The necessity to distinguish two levels is not a novelty in itself (Laret, 1989).

3.   MODELLING OF THE BUILDING ENTITIES

3.1   Schematisation

For example, the integration of the Fourier equation gives (when limited only to "mass" volumes with uniform properties) :

$$\rho.C.\text{Volume}.\frac{dT}{dt} = \sum \text{Surfaces Flux} + \sum \text{Voluminal Flux} \qquad (1)$$

The modelling we have adopted consists in representing the volumes by the nodes of a graph and the fluxes by its arcs (see "Fig. 1"). In reality, the voluminal fluxes are linked to only one volume. To generalise, we consider that the energy that they involve comes from a specific volume that we call "exterior" (see "Fig. 2"). In this way, we always dispose of two nodes for each arc.
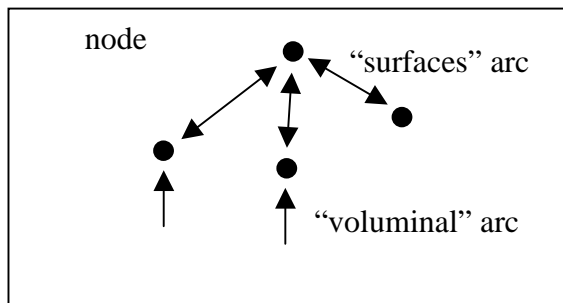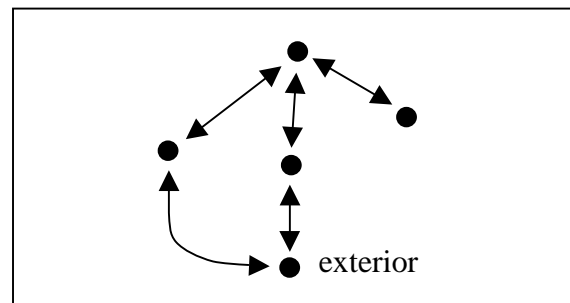

Figure 1 : Nodes and arcs modelling   Figure 2 : "Exterior" modelling

The adopted modelling consists in reducing it to a "valued" graph. This modelling is not new, it has already been used under the form of "capacity-conductance" in the domain of building physics. Our originality is that we simply "push" the logic to its limits, generalising this modelling to the whole of the building and to its climatic environment.

3.2. Basic modelling : the network element

The building entities representation is based upon two basic conceptual classes : the nodes and the arcs. In fact, because of the duality arc-node, we use only one entity, which will be of a "node" or of an "arc" type according to the cases. This entity is called "**Element of Network**" (**ENET**). An ENET is a node if it is of a "mass" type and an arc if it is of "energy" type. An ENET of "energy" type (arc) has always an "upstream" and a "downstream" ENET.

3.3. Auxiliary modelling : the material and the function

Our modelling is completed by the addition of two complementary entities : the "**material**" and the "**table**". The "material is a constituent that has a unique list of thermo-physical properties. The "table" is an entity that permits to define the variation law of a variable. This law can be a piecewise constant or linear function for which the values are coded internally or stored in a file. For our modelling, each data of the building is potentially a variable. But practically, only certain ones are.

A material is uniquely associated to an ENET of a "mass" type, while a "table" can be, a priori, associated to any variable of our modelling.

3.4. Manipulation : the typical-object

This basic "brick" that is the ENET is difficult to access for the user. So, we have joined a work entity to the modelling: the "Typical-Object". This entity brings together a certain number of ENETs, though permitting their manipulation by blocks. Moreover, it contains a certain amount of information relative to all the ENETs that constitute it.

These "Typical-Objects" are classified in two categories : those which have a spatial existence (volume, walls and windows) and those that act by power injection (regulators and internal loads). From a conceptual point of view, this distinction has no reason to exist, but it permits to limit the input windows to a number of two (see "EXAMPLE").

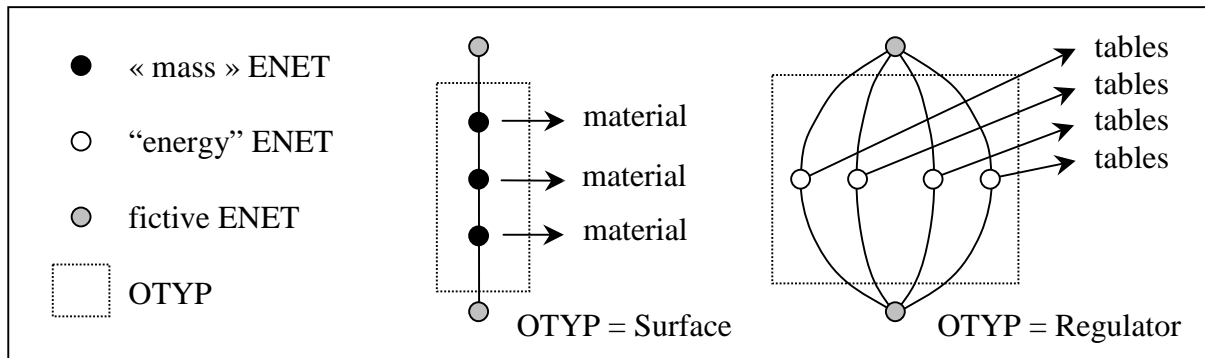We exemplify next a wall and an internal load (see "Fig. 3") :

Figure 3 : Examples of "Typical-Objects"

The final ENETs of a "Typical-Object" are called "fictive" and serve uniquely to link the "Typical-Objects" together.

Remark : actually, the ENETs of a "Typical-Object" are predefined. A possible future evolution will allow the user to create and to access the ENETs of a "Typical-Object" in order to make his own models based upon the polymorph entity, which is the ENET. This will be accessible only to **CODYBA**'s developers, which will be in charge of verifying that the introduction of any combination of these "atomic" models in the global network would not noticeably modify the calculation algorithms performances.

3.5. The classes

In practice, the four predefined entities exist under the form of classes and they inherit from the same class, the "Graphical-Object" which must assure their visibility (see "Fig. 4") :
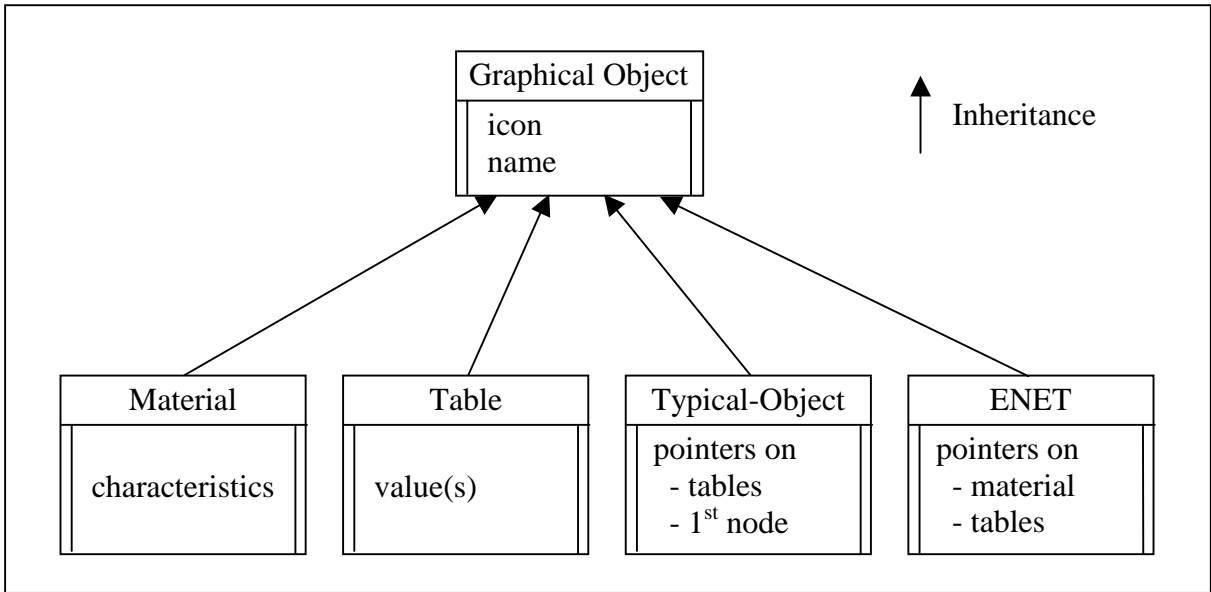
Figure 4 : Modelling classes

3.6. Overview

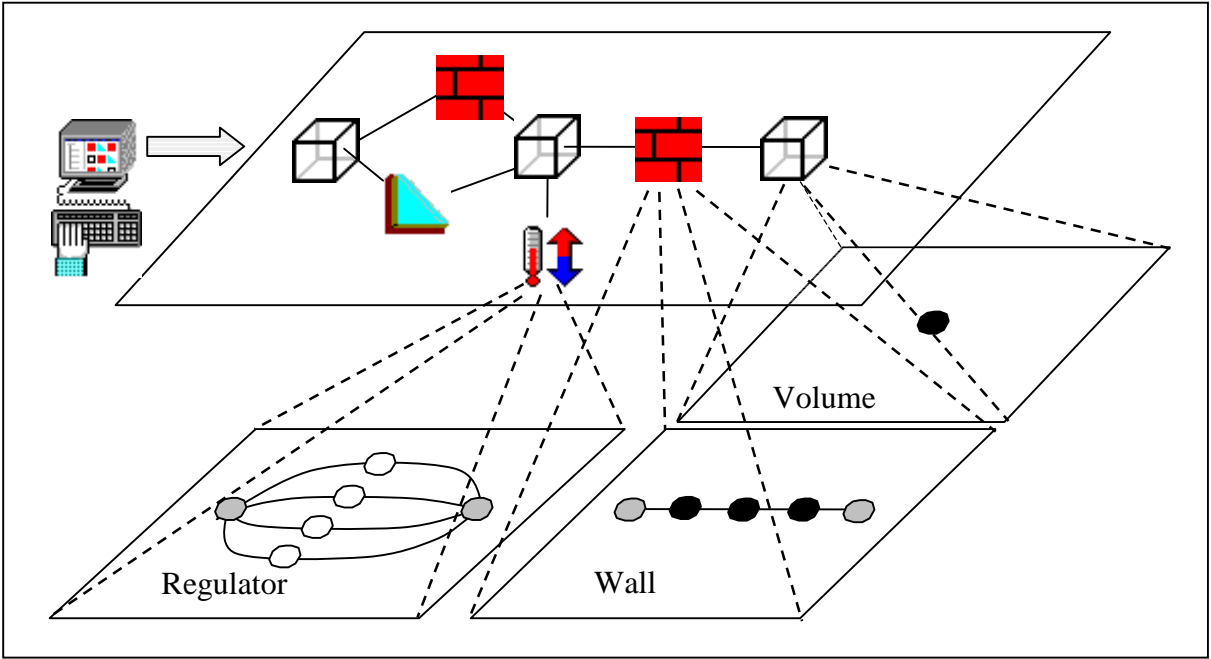We present here an overview of our modelling and its implementation :

Figure 5 : Overview of building modelling and its implementation

4. MODELLING OF THE CALCULATION ENTITIES

4.1. The classes

The previous "valued" graph can not be exploited directly : so, we rebuild a new graph based on it which allows us to take into account equations as well as a form where a simple algorithm could be applied. For that, we it was necessary to define the next class hierarchy (see "Fig. 6") :
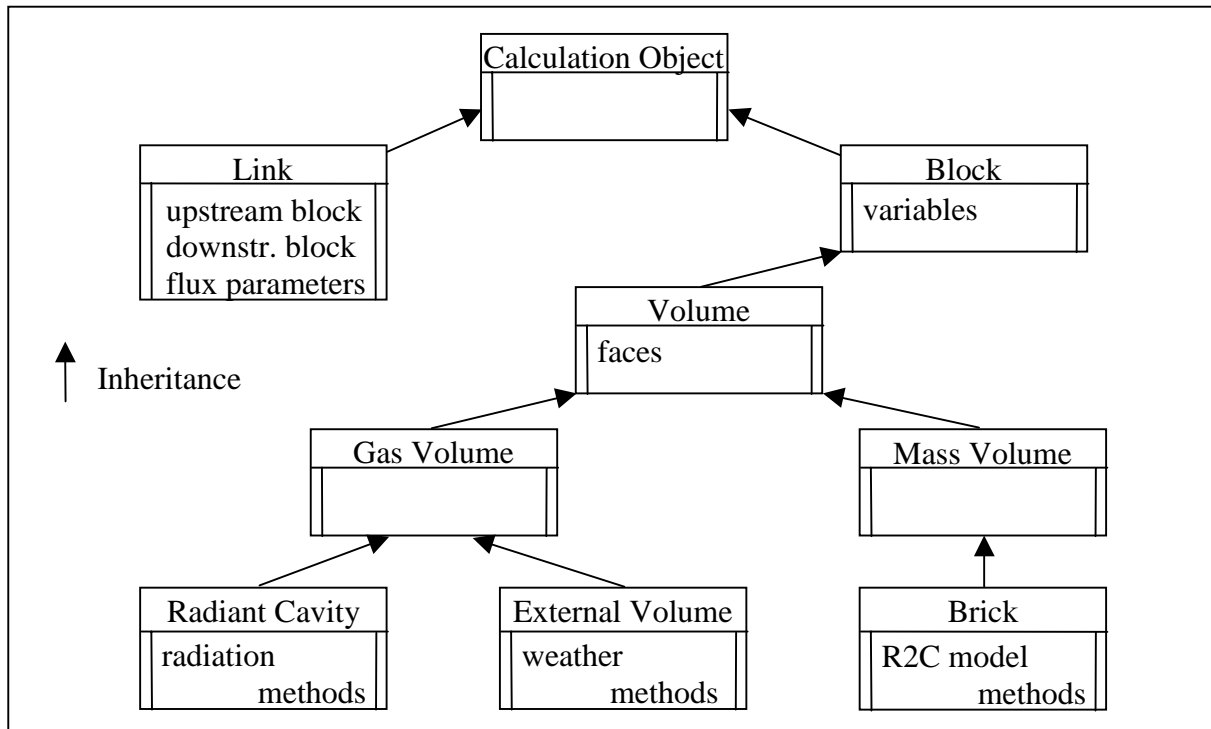
Figure 6 : Hierarchy of calculation classes

The derived classes contain the physical models, which are hidden to other classes ("data-hiding"). In the future, several other models could be introduced without changing the software : simplified models (Laret, 1989), reduced models (Roux, 1991), finite elements, etc). The models' common point is their linear aspect, which allows their integration in the utilised iterative solver.

5. EXAMPLE

5.1. The general screens

The input screen as well as the detail of the building's entity, "*Interior*" are shown next :
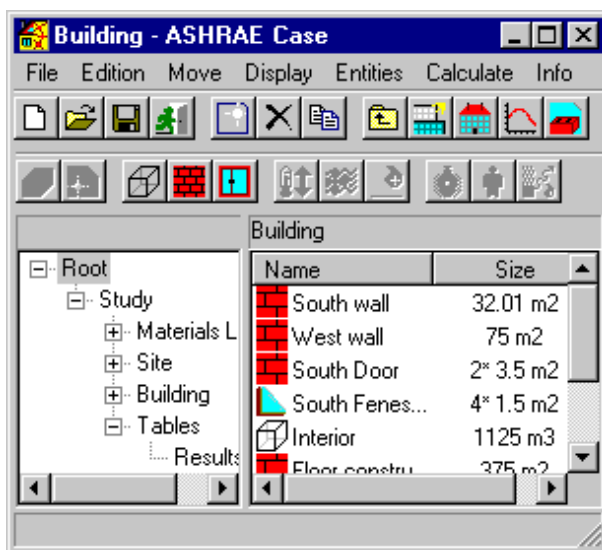

Figure 7 : "Icono-graphical" description of the project
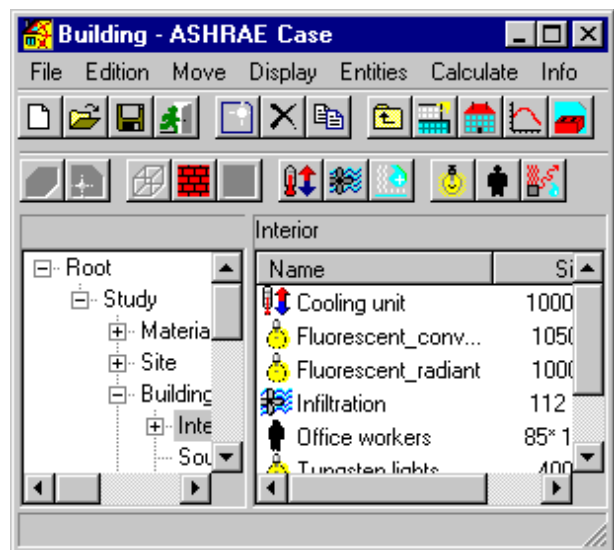

Figure 8 : Regulators and internal loads for the described building

We remark in "Fig. 7", that the building is presented under a hierarchical form according to usual ergonomics in modern exploring software. Each entity is accessible by its icon for the edition operations. The drag-and-drop technique facilitates the introduction of a component from the libraries.

5.2. The "Typical-Objects" screens

As an example of "Typical-Objects", we present below the screens for a wall in "Fig. 9" and for a temperature regulator in "Fig. 10".
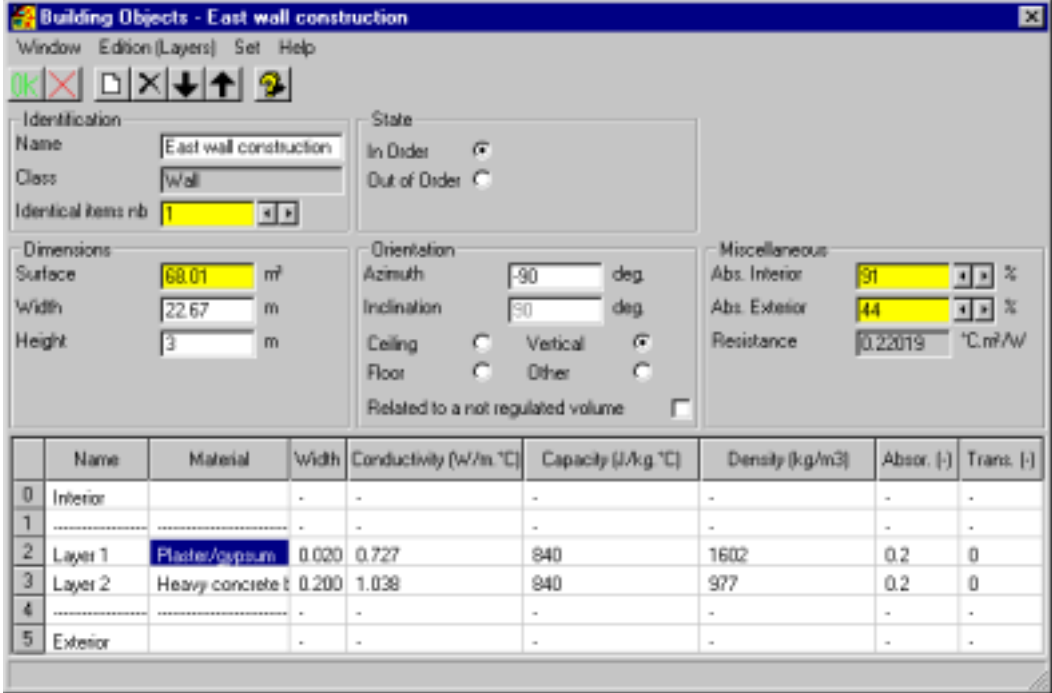

Figure 9 : Wall screen

The screen for a window is similar to that of a wall, as the screens for ventilation, humidification regulators or internal loads are similar to that for temperature regulator.
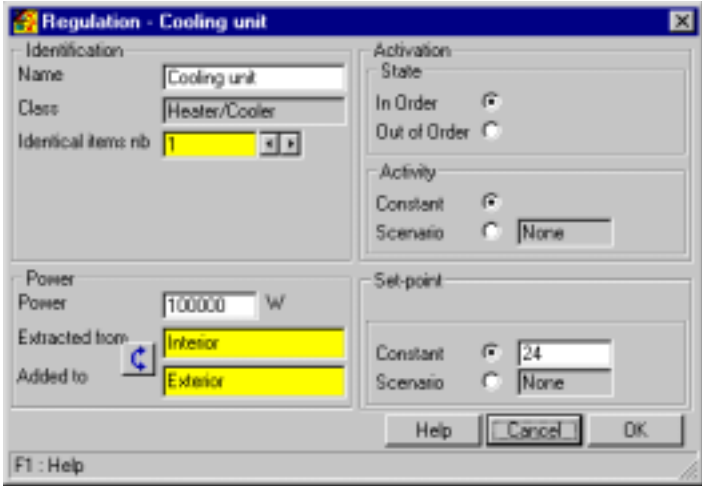

Figure 10 : Typical screen for a cooling device

The "activity" and "set-point" variables can have scenarios : in this case, the tables are associated to the cooling device (according to the tables definition).

5.3. The materials and tables screens

The materials can be opaque as in "Fig. 11 a)." or transparent like the glass. For transparent materials, the screen has two more fields concerning the transmissivity and absorptivity coefficients.

The profiles can be defined hour by hour for one day or for a week. They are presented in a graphical form as shown in "Fig. 11 b)." or as a table.
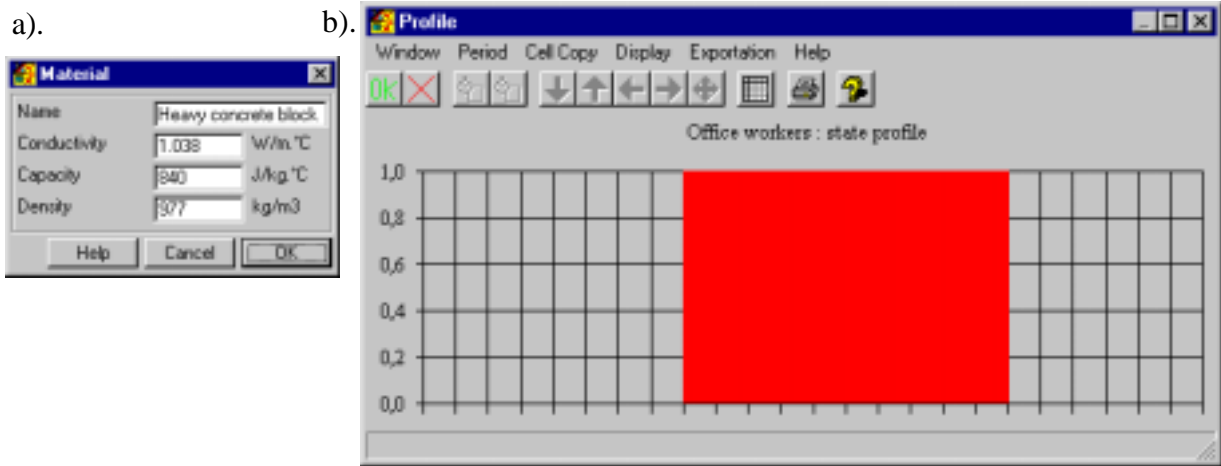
Figure 11 a., b. : Materials and profiles screens

5.4. Description

We must determine the daily evolution for the sensible cooling load necessary to assure a given temperature in a one-story commercial building (see "Fig. 12"), located in the eastern United States near 40°N latitude. Adjoining buildings on the North and West are not conditioned, and the air temperature within them is approximately equal to the outdoor temperature at any time of day.

Figure 12 : Example of application

The summer outdoor and indoor conditions are : dry bulb 35°C, daily range 11°C, wet bulb 25°C, specific humidity 0.0159 kg (vapour)/kg (dry air), respectively dry bulb 24°C, wet

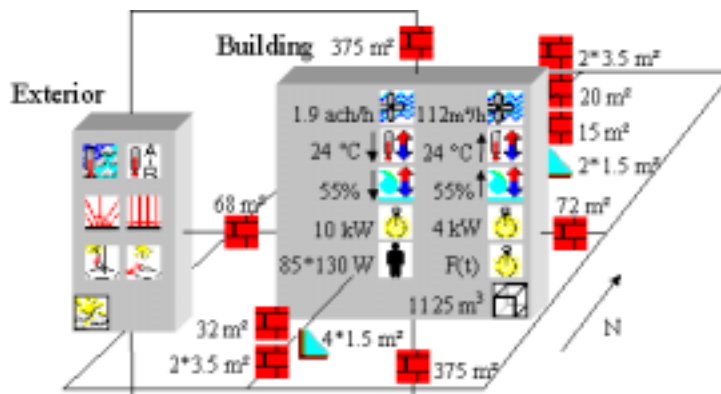bulb 18°C, specific humidity 0.0104 kg(vapour)/kg(dry air). The site ground reflectance is 0.2.

The control parameters are : simulation for the 21st of July with a step number of 60 minutes, 5 days for the initialisation and a relative precision of 0.001.

The example's data are listed in a report generated automatically by the software. We present it next, including only those data that are not shown in "Fig. 12" like building elements ("Table 1"), materials ("Table 2"), convective exchange coefficients ("Table 3"), regulators and internal loads ("Table 4") :

Table 1 : Building elements utilised in the example

Entity Name	Surface (m²)* Number	Azimuth (deg)	Inclination (deg)	U-value (W/m²K)	Layer (mm) / material	Int. / Ext. absorption (%)
North Fenestration	1.5 *2	180	90	4.6	3 Plate glass 3 Plate glass	-
North Interior Door	3.5*2	180	90	--	13 Finish 25 Wood	44/44
East Door	3.5*2	-90	90	--	13 Finish 25 Wood	44/44
West wall	75	90	90	--	200 Common brick 100 Face brick	88/88
North adjoining wall	20	180	90	--	200 Common brick 100 Face brick	88/88
South Door	3.5*2		90	--	13 Finish	44/44
South Fenestration	4*1.5	0	90	4.6	3 Plate glass 3 Plate glass	
Floor	375	--	180	--	100 Heavy concrete block	88/88
Roof	375	--	0	--	100 Low density concrete 2 Steel siding 51 Rigid insulation 10 Felt & membrane 12 Slag or stone	90/88
North Outside wall	15	180	90	--	20 Plaster/gypsum 200 Heavy concrete block	91/44
East wall	68	-90	90	--	20 Plaster/gypsum 200 Heavy concrete block	91/44
South wall	32	0	90	--	6-mm plywood panel 20 Plaster/gypsum 200 Common brick 100 Face brick	91/44

The position for the layers is from the interior to the exterior. The windows have no masks and are placed at 0 meters from the exterior wall.

Table 2 : Materials used in the example

Material	λ (W/m.K)	ρ (kg/m³)	Cp (J/kg.K)	τ (-)	α (-)
Slag or stone	1.436	1670	881		
Steel siding	45	7689	0.42		
Low density concrete	0.173	641	840		
Finish	0.415	1249	1090		
Wood	0.121	593	2510		
Plate glass	1.15	840	1000	0.85	0.08
Felt & membrane	0.19	1121	1670		
Rigid insulation	0.043	32	840		
Heavy concrete block	1.038	977	840		
6-mm plywood panel	0.115	540	1210		
Common brick	0.727	1922	840		
Plaster/gypsum	0.727	1602	840		
Face brick	1.333	2002	920		

Table 3 : Convective exchange coefficients utilised in the example

Convective Exchange Coefficients (W/m².K)	Floor	Wall	Ceiling
Interior	1	4.09	6.1
Exterior	11.7	11.7	15

The utilised radiative exchange coefficient is equal to 5 W/m²K.

Table 4 : Regulators and internal loads utilized in the example

Entity Name	Nb	Activity	Nominal	Set point	Remarks
Humidification	1	steady	100 kW	55 %	
Dehumidification	1	steady	100 kW	55 %	
Fluorescent_radiative	1	steady	10 kW	--	lwr/swr : 50/50 %
Tungsten lights	1	steady	4 kW	--	conv/lwr/swr : 20/40/40 %
Fluorescent_convective	1	profile	10.5kW	--	conv : 100 %, from 8h to 17h
Cooling unit	1	steady	100 kW	24 °C	
Infiltration	1	profile	112 m3/h	--	2.8m³/h/person/passage for 10 persons/h from 8h to 17h
Ventilation	1	steady	1.9 ach/h	--	
Office workers	85	profile	75 W sensible 55 W latent	--	conv/lwr/swr : 67/33/0 % from 8h to 17h

lwr-long wave radiation, swr-short wave radiation, conv-convective

6. RESULTS

The results that we obtained, "*CODYBA_24°*", are represented in "Fig. 13". We compare our results with those presented in the "ASHRAE HANDBOOK FUNDAMENTALS" (1993) for the same example. The methods utilised in ASHRAE are the transfer functions method, "*ASHRAE_24°*", and the response factors method, "*ASHRAE_24°(2)*".
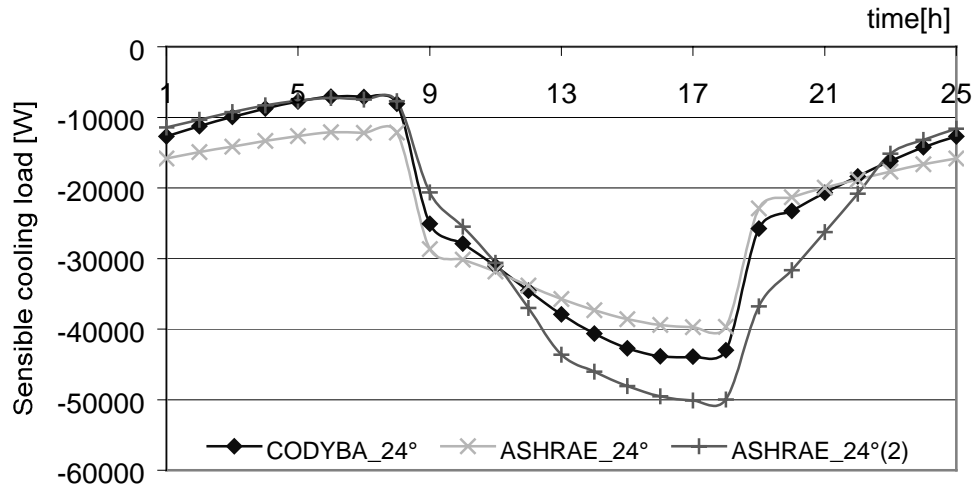
Figure 13 : Sensible loads given by CODYBA and ASHRAE

As we can remark, our results are always situated between those given by the two ASHRAE methods. Moreover, all the peaks for the sensible cooling loads are obtained at the same hour. The peak values obtained using the ASHRAE methods have *20%* of difference between them. We give below the maximum sensible cooling loads for our method, as well as for the ASHRAE methods :

Table 5 : Maximum sensible cooling loads

	CODYBA	ASHRAE (transfert functions)	ASHRAE (response factors)
Maximum sensible cooling load (W)	43911	39712	50096

7. CONCLUSION

In the present version, CODYBA is essentially a cooling/heating loads calculation tool for which the interface is well adapted to the treatment of buildings represented by a few zones. Concerning the treatment of more complex buildings (more than a dozen zones), our development is oriented in two directions. Firstly, a command language permitting to constitute rapidly a CODYBA file based upon macro-instructions (for example, the automatic generation of 6 walls for a volume). Secondly, a 3D representation for the created geometry based upon this command language. These two orientations demand a restructuring of the software to achieve the best utilisation of the commercial products.

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