BUILDING SIMPLIFIED MODEL DEFINITION

4.1. Building zone model

In his PHD thesis (ref. [19], chapter 8), L. Laret defined a zone simplified dynamic model, represented on fig. 4.1. Building walls are shared into three categories:

- Light external walls (windows and doors), are modeled through resistance R_1.
- Massive external walls are modeled through two resistances R_{21} and R_{22} and one capacity C_2.
- Massive internal walls are modeled with adiabatic boundary conditions, through the capacity C_4. The capacity C_4 also includes the mass of the air included in the zone, that mass being multiplied by a factor ranging from 5 to 6 to take into account the lack of homogeneity of the indoor temperature in the zone.

The indoor heat flow is directly introduced on the room indoor node. It involves heat flow through windows, occupancy heat gains and emission from the heating system.

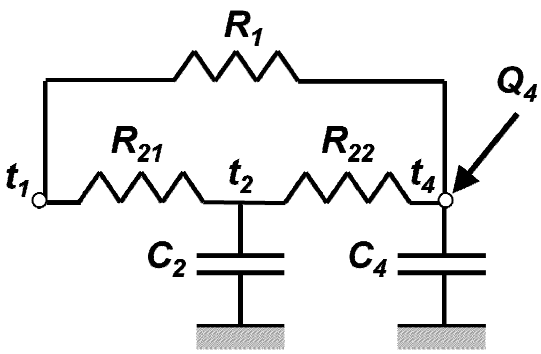

Fig.4.1: L. Laret zone simplified dynamic model.

t_1 : outdoor temperature ; t_4 : indoor temperature

Laret zone model parameters are obtained through indoor temperature responses analysis, either to step (or to sinusoidal) solicitations of indoor heat flow and outdoor temperature. Indoor temperature responses are computed through Laplace transforms. External wall boundary conditions are Fourier type conditions i.e. related to the wall environment including wall environment temperature as well as boundary layer convection and radiation heat transfer coefficient. Internal wall boundary conditions are Fourier type condition for the zone side of the wall and Neumann condition, i.e. imposed heat flow, for the null heat flow plane wall side.

The model used in this work is defined for the same boundary conditions as Laret model, regarding to walls. Wall responses are computed for sinusoidal solicitations (chapter 3) but they are gathered differently:

- External walls are first gathered as in Laret model (fig. 4.2.b), but a new category regarding roof appears when considering solar gains absorbed through opaque walls (chapter 5, §7.2 fig. 5.24).

- Massive internal walls are gathered in a new category represented by resistance R_3 and associated capacity C_3 (fig. 4.2.b).

4.1.1. External and internal massive walls

As soon as all walls are modeled by 2R1C networks, they can be gathered to build a whole model of a building zone (fig. 4.2.a). A first branch collects *external massive walls* surrounding the zone while another corresponds to *internal massive walls*.

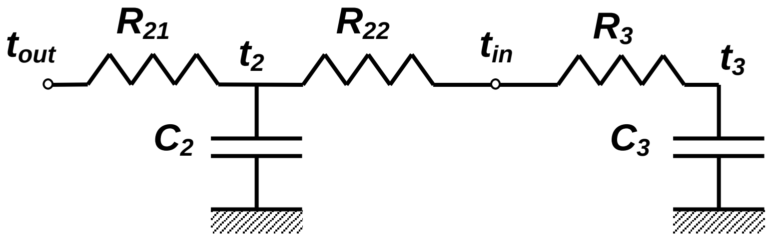

Fig.4.2.a: One zone building model including external walls and internal massive walls.

For each wall category (external and internal), the adjustment process requires a preliminary computation of the zone admittance matrix, through the sum of the wall network *admittance matrixes* **Y** (equations (2.17) and (2.6)) multiplied by their corresponding areas. Consequently, the admittances corresponding to the zone isothermal and adiabatic boundary conditions branches are expressed in *W/K*, while they were expressed in *W/K-m²* for the walls.

An adjustment is then performed in order to generate both external and internal branches for the whole building zone:

- for *external walls*, the adjustment process consists in equalizing the magnitudes of the zone isothermal admittance and transmittance, computed for a 24 hours time period; the adjustment yields two resistances R_{21} and R_{22} and one capacity C_2.

- for *internal walls*, the adjustment process consists in equalizing the magnitude and angle of the zone adiabatic admittance, computed for a 24 hours time period; the adjustment also yields two resistances but one of them can be erased as there is no heat flow. The remaining resistance is R_3 and the associated capacity is C_3.

The resulting network is made of resistances expressed in *K/W* and of capacities expressed in *J/K*, while the wall 2R1C networks are made of resistances in *K-m²/W* and capacities in *J/K-m²*.

4.1.2. External light walls

Beside external and internal massive wall categories, a third wall category is defined for light external walls (windows and doors). Those walls are modeled by a resistance R_1. The resulting zone network is presented on fig. 4.2.b.

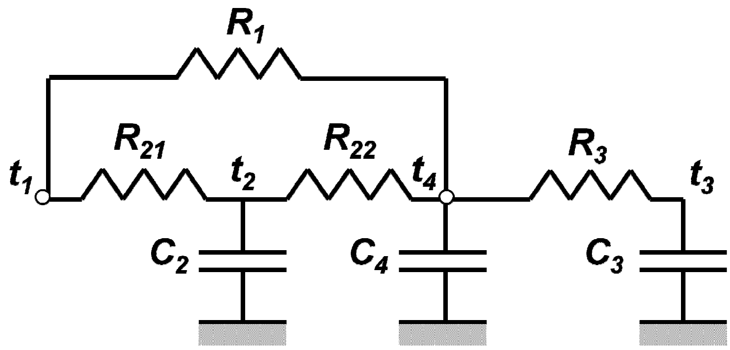

Fig.4.2.b: One zone building model including external walls (massive and no massive) and massive internal walls.

The capacity C_4 represents the mass of the air included in the zone, that mass being multiplied by a factor ranging from 5 to 6 to take into account the lack of homogeneity of the indoor temperature in the zone.

4.1.3. Examples of adjustments

The adjustment process has been performed for five two-level houses:

- the first house is a traditional concrete bloc structure with an insulated wooden sloped roof,
- the second house is a massive wooden structure with an external brick layer and covered by an insulated wooden sloped roof,
- the third house is similar to the first one but it is covered with a flat concrete roof with outdoor insulation, and one of its facades is an attached building party wall,
- the fourth house is similar to the first one, but its floor and several of its walls are in contact with ground,
- the last house is the same as the third one, with attached building party walls on both sides.

The houses are described in annex 2. Table 4.1 presents the resulting network parameters for the five houses modelled as one zone.

Table 4.1. Parameters related to the five houses models.

House 1	**AU = 1/R** [*W/K*]	**C** [*J/K*]	**θ** [-]	**ϕ** [-]
Windows and doors	52			
External massive walls	141	8.720E+07	0.10	0.57
Internal massive walls	2287	6.071E+07	0.81	0.84

House 2	**AU = 1/R** [*W/K*]	**C** [*J/K*]	**θ** [-]	**ϕ** [-]
Windows and doors	35			
External massive walls	113	6.099E+07	0.14	0.53
Internal massive walls	1113	1.988E+07	0.63	0.97

House 3	**AU = 1/R** [*W/K*]	**C** [*J/K*]	**θ** [-]	**ϕ** [-]
Windows and doors	42,24			
External massive walls	81,02	6.503E+07	0.09	0.75
Internal massive walls	1150	3.360E+07	0.75	0.85

House 4	**AU = 1/R** [*W/K*]	**C** [*J/K*]	**θ** [-]	**ϕ** [-]
Windows and doors	29,4			
External massive walls	109,3	8.176E+07	0.08	0.50
Internal massive walls	1822	4.739E+07	0.78	0.86

House 5	**AU = 1/R** [*W/K*]	**C** [*J/K*]	**θ** [-]	**ϕ** [-]
Windows and doors	42,24			
External massive walls	66,13	5.401E+07	0.09	0.79
Internal massive walls	1221	3.938E+07	0.70	0.86

The following curves (fig.4.3) represent the quality of the adjustment for houses 1 and 2.

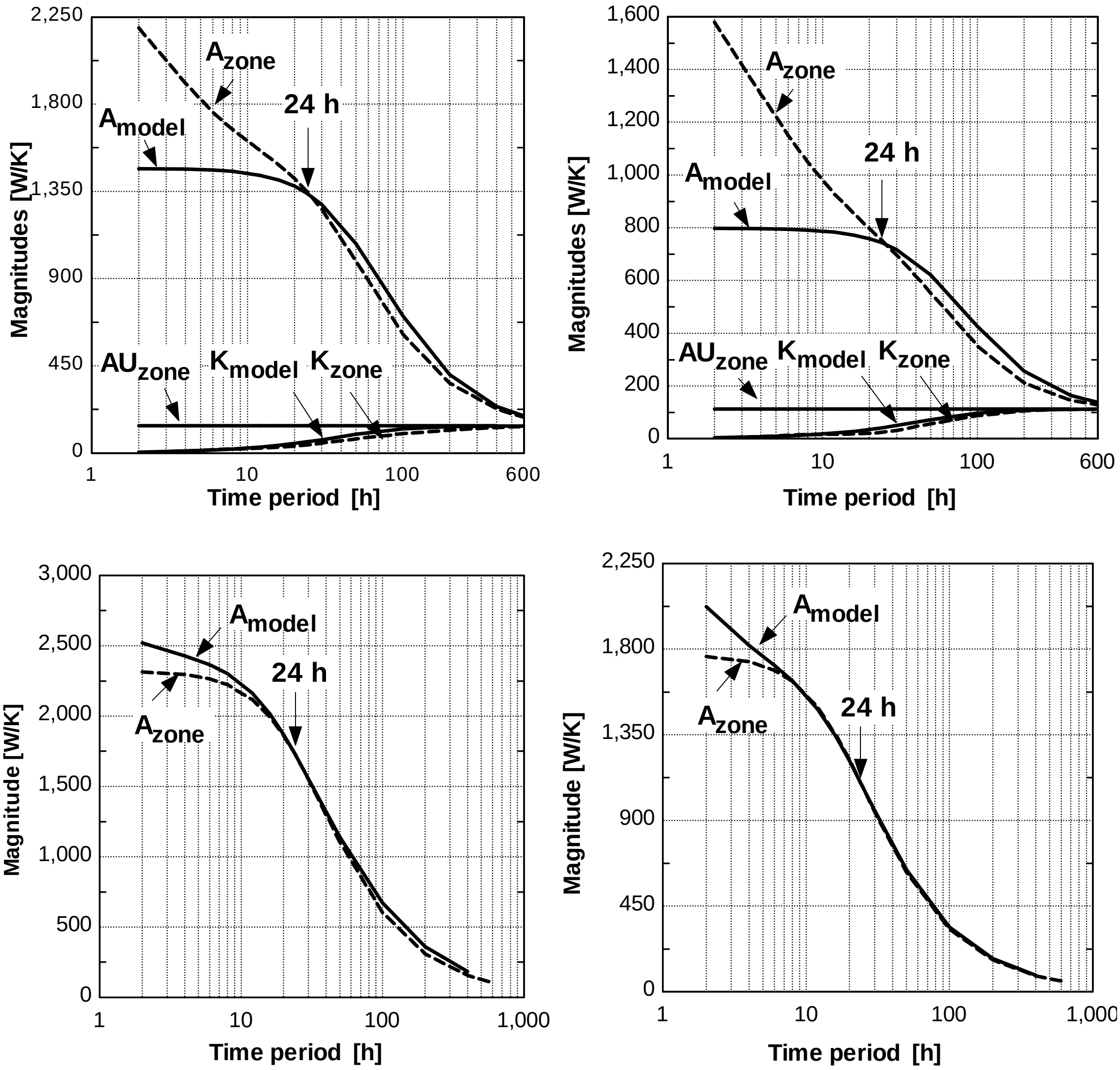

Fig 4.3: Bode Diagrams of global isothermal transmittance and admittance (up) and of global adiabatic admittance (down) for house 1 (left) and house 2 (right) one zone models.

The adjustment has also been performed for an office room proposed as a case study in the framework of IEA annex 27 program. This example differs from the preceding houses as the walls are mainly internal walls. The room is presented on fig. 4.4. It has been modeled with and without suspended ceiling. The associated parameters are given in table 4.2.

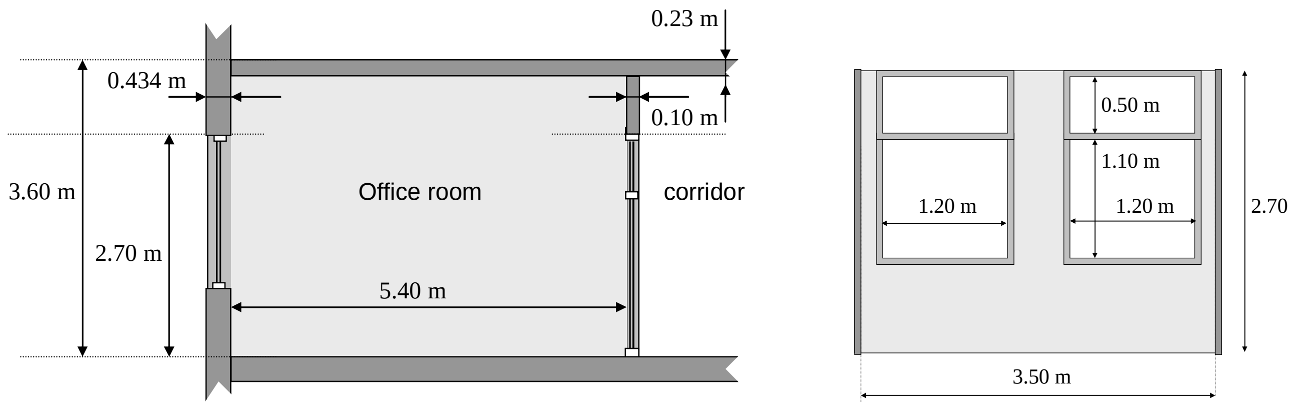

Fig. 4.4. Office room (IEA 27): section (left) and facade (right).

Table 4.2. Parameters related to the office room (IEA 27).

Office room – no ceiling	**AU = 1/R** [*W/K*]	**C** [*J/K*]	θ [-]	ϕ [-]
Windows and doors	9.59			
External massive walls	2.89	3.982E+06	0.07	1.00
Internal massive walls	274.8	1.043E+07	0.77	0.90

Office room with ceiling	**AU = 1/R** [*W/K*]	**C** [*J/K*]	θ [-]	ϕ [-]
Windows and doors	9.59			
External massive walls	2.89	3.982E+06	0.07	1.00
Internal massive walls	274.8	1.043E+07	0.84	0.64

4.2. Ventilation exchanges and internal heat gains

The ventilation heat losses are modeled by a resistance variable as function of time R_v .

The capacity C_4 represents the mass of the air included in the zone, that mass being multiplied by a factor ranging from 5 to 6 to take into account the lack of homogeneity of the indoor temperature in the zone.

The resulting network, represented on fig. 4.5, is a simplified dynamic model for the whole zone.

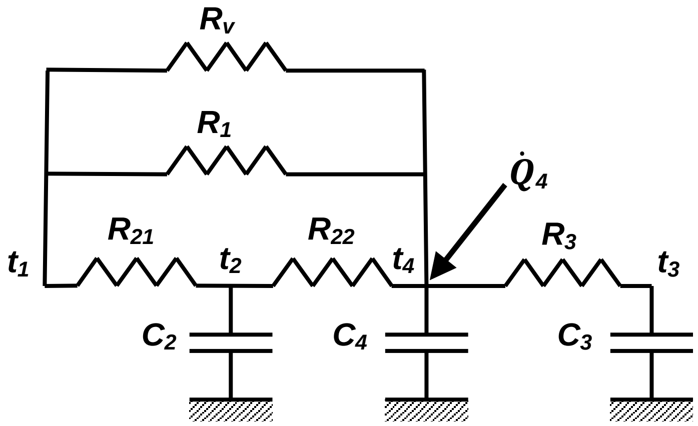

Fig. 4.5. Dynamic simplified model for a whole building zone.

t_1 : outdoor temperature *°C*
t_4 : indoor temperature *°C*

Building walls are shared into three categories:

- Light external walls (windows and doors), modeled through resistance R_1.

- Massive external walls modeled through two resistances R_{21} et R_{22} and one capacity C_2. The R_{21}-R_{22} branch also includes walls in contact with unheated rooms, such as a car-park. It also includes ground contact walls and walls in contact with cellars or crawl spaces. In those cases, the wall resistance is multiplied by a factor ranging from 3/2 à 3, depending on the ground contact type.

- Massive internal walls are modeled through a resistance R_3 and a capacity C_3. The R_3 branch also includes walls in contact with another zone whose temperature profile is similar to the zone under study, those walls incurring no heat losses.

The heat flow $\dot{Q}_4$ is directly introduced on the room indoor node. It involves the heat flow through windows, the occupancy heat gains and the emission from the heating system.

Solar gains involve direct heat gains, as well as diffuse and reflected solar heat gains. The calculation of direct solar gains is accelerated by a preliminary computation of solar ratios corresponding to different orientations for a whole year, those ratios being stored in tables.

The solar gains absorbed by opaque walls, as well as infrared losses emitted to the sky, are neglected in a first approach. They will further be integrated, through an outdoor equivalent temperature (§3), considering only the walls where their value is significant.

Hourly weather data concerning outdoor temperature, as well as global and diffuse solar intensities measured on an horizontal plane, are considered for an average climatic year.

Simulation is then performed on a set of differential equations expressing the balance of the different network nodes. For example, the heat balance of node 4 provides:

$$dU_{c4\backslash dtau} = \dot{Q}_{24} + \dot{Q}_{14,vent} + \dot{Q}_{14,transm} + \dot{Q}_{4} - \dot{Q}_{43} \tag{4.1}$$

$$\dot{Q}_{24} = \frac{t_2 - t_4}{R_{22}}$$

$$\dot{Q}_{14,vent} = \frac{t_1 - t_4}{R_v}$$

$$\dot{Q}_{14,transm} = \frac{t_1 - t_4}{R_1}$$

$$\dot{Q}_{4} = \dot{Q}_{heating} + \dot{Q}_{sol,gl} + \dot{Q}_{occ} \tag{4.2}$$

$$\dot{Q}_{43} = \frac{t_4 - t_3}{R_3}$$

$$U_{c4} = U_{c4,init} + \int_{\tau_{initial}}^{\tau_{final}} (dU_{c4\backslash dtau}) \, d\tau \tag{4.3}$$

$$t_4 = \frac{U_{c4}}{C_4}$$

The outputs from the building model are the indoor temperature t_4 and the heat flow provided by the heating system to the zone ($\dot{Q}_{heating}$). The determination of those two outputs requires the connecting of the building model to a model of the heating system.

4.3. Two zones building model

An R-C network can also be built for each building zone. Both resulting RC networks are then connected to each other as represented on fig. 4.6, through a set of resistances and capacities:

- Resistance R_4 models the effect of light wall such as doors.
- Resistances $R_{5,z1}$, $R_{5,z2}$ and capacity C_5 represents the massive partition walls connecting the zones.

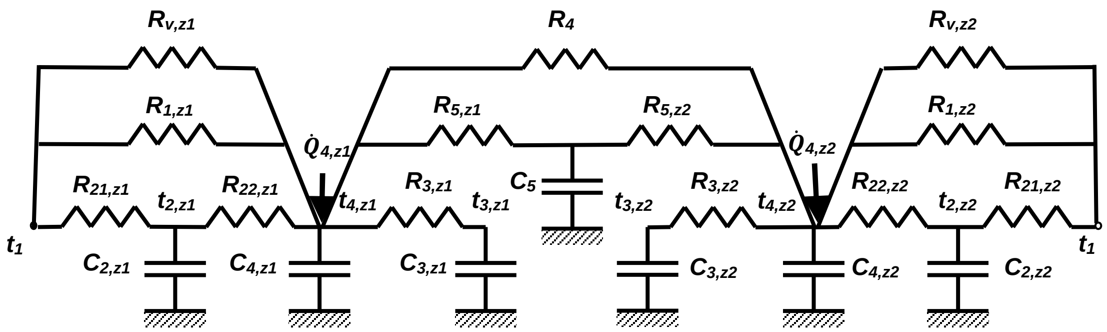

Fig. 4.6 Two zones dynamic simplified building model