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EVALUATION OF ENERGY CONSUMPTION RATIOS IN BUILDINGS

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ABSTRACT

The quantity of heat energy to be evacuated in a room in order to reach the optimal thermal comfort depends enormously on the type of construction, in particular of its global volume coefficient of thermal inputs G (which involves only the thermal resistance of the walls opaque and glazed), infiltration inputs and internal inputs (machines, lighting, occupants, etc.). It also depends on the ROM report ($ROM = \frac{S_V}{S_F}$) *which involves the solar gains through the glazing according to whether it is single or double. This article proposes to develop ratios for ROMs and building form factors.*

KEYWORDS: *Ratios, ROM, Form Factor, Thermal Inertia*

Article History

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INTRODUCTION

Solar radiation plays a major role in air conditioning and in bioclimatic habitat. In fact, it can represent an important, sometimes even the most important, external heat gains that the cooling installation will have to compensate.

The capacity of the materials has the property of distributing over time the different thermal loads received and evacuated. It acts as an operator through temperature fluctuations, with a memory in time of up to a few days. The effect of inertia results in the shaving of the daily temperature peaks and their offset by several hours.

Thermal inertia measures the resistance of a wall to a change of thermal state caused by two types of stress:

- Variation in the temperature of the environment,
- Solar energy flux absorbed on the surface.

It characterizes its property to accumulate or restore heat. The conductivity, the density and the heat capacity of the materials constituting the wall, are the parameters influencing its thermal inertia. The distribution of thermal masses is as important a parameter as the choice of materials in the inertial behavior of the building.

For the "heavy" walls of construction (concrete slab, breeze block, hollow body, etc.) having conductivities and neighboring capacities, their mass per unit area is sufficient to classify the premises by type of inertia: low, medium, strong.

Radiative Exchanges of Glazed Walls

Solar gains from transmission through glazing are one of the most influential factors in a room's cooling load. It is therefore necessary to have a correct estimate of these radiative contributions.

The behavior of glazing (absorption, transmission and reflection coefficients) being a function of the incidence as shown in Figure 1, direct solar radiation and diffuse solar radiation should be considered separately.

Practically the energetic transmission factors are evaluated from the energy distribution of solar radiation at ground level, defined by the PARRY-MOON curve.

The light transmission factors are calculated for a spectral composition of the incident light near a serene sky with a little sun, the source thus defined is the "illuminant C" of the CIE (T_C = 6774 K), see table 1.

When we integrate the spectral transmission coefficients on the bandwidth relative to the considered sources, we obtain the global coefficients. Examples of such values are shown in Table 1.

Table 1: Overall Transmittance and Reflection Coefficients of Some Glazings

Produits	Transmission Lumineuse	Réflexion Lumineuse	Transmission Energétique	Réflexion Energétique
Verre à vitre normale 3 mm épaisseur 5,5 mm	0,91 0,88	0,083 0,060	0,87 0,83	0,078 0,075
Verre gris 3,2 mm 6.5 mm	0,62 0,42	0,060 0,050	0,60 0,38	0,06 0,05
Poly Glass 6,5 mm - 5.5 mm Verre gris	0,55 0,37	0,090 0,066	0,50 0,32	0,084 0,058
Super Triver 3 mm- 3 mm-3 mm	0,77	0,205	0,68	0,177
Super Triver 3,2 mm- 3 mm- Verre gris 3 mm	0,53	0,091	0,46	0,087
Poly Glass 5,5 mm- 5,5 mm Verre à vitre	0,79	0,142	0,69	0,130

- In particular, when one wants to define the coefficient of a glazing with respect to diffuse solar radiation, it is necessary:
- Choose a luminance distribution model in the sky (C.I.E, covered, intermediate),
- Define the azimuth and inclination of the glazing,
- Know the law of transmission of the glazing according to the angle of incidence.

Decomposition of the Solar Flux on the Faces of the Envelope

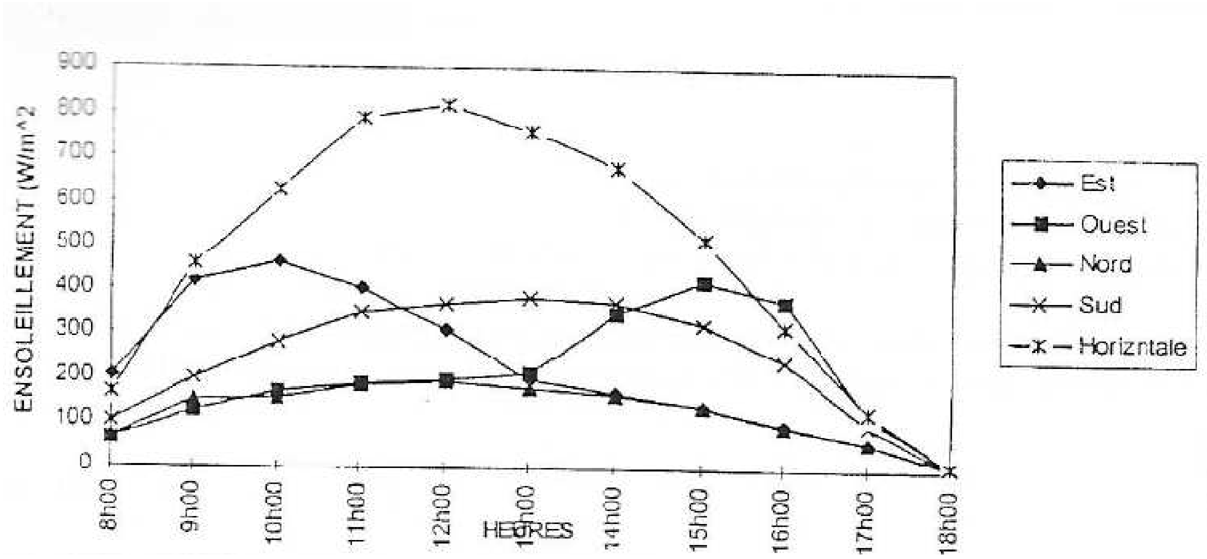

Figure 1: Decomposition of the Solar Flux on the Faces of a Building.

Figure 1 illustrates the decomposition of solar flux on the faces of the building envelope of all the parts of a building, the roof is the most exposed to the Sun. In fact, the solar radiation values measured on a horizontal surface are by far the highest.

The east and west facades are more exposed to the sun than the north and south.

The SOUTH FACING is much more exposed to solar radiation than the NORD façade.

- The results indicate an orientation towards the search for solutions of reduction of the contributions of heat by:
- The insulation of the roof through which most of these inputs seep is more than ever necessary,
- The orientation of the building so that the wall surfaces IS and WEST are the smallest possible,
- Windows and openings must be made on the north and south façades. This minimizes heat input into the building.

Approach to the Thermal Operation of the Envelope

In order to highlight the role of the envelope in the energy consumption of the building, we will present an approach to the thermal operation of a construction in hot climate and located in the NORTHERN hemisphere. For simplicity, we treat the case of an air-conditioned building with low thermal inertia, maintained at a constant temperature (T_i). We only consider gains by transmission and solar radiation.

In this case, the cooling capacity (P_f) to be supplied to the building to compensate for the heat input due to the envelope, is a function of its overall volume coefficient of thermal inputs G.

We have:

$$P_f = G * V \text{ (I)}$$

With

$$G = G_t + G_s \text{ (II)}$$

$$G_t = \frac{(\sum i\, K_O S_O + \sum i\, K_V S_V)(T_e - T_i)}{V} \quad (III)$$

$$G_s = \frac{\sum i\, R_i F_{Si} S_i}{V} \quad (IV)$$

$\Sigma K_O S_O$: contributions by transmission of opaque walls ($W.K^{-1}$),

$\Sigma K_V S_V$: contribution by transmission of glazed walls ($W.K^{-1}$).

Influence of the S / V Form Factor

This coefficient represents the ratio of the total surface of the walls in contact with the outside (low floor excluded) and the total volume. It is possible to calculate an average transmission coefficient Km of the whole building. Rewriting the formula and introducing in the formula K_m, we have:

$$G = \frac{(\sum i\, K_O S_O + \sum i\, K_V S_V)(T_e - T_i)}{V} + \frac{\sum i\, R_i F_{Si} S_i}{V} \quad (V)$$

With

$$K_m = \frac{(\sum i\, K_O S_O + \sum i\, K_V S_V)}{\sum i\, S_i} \quad (VI)$$

Introduce K_m in the formula of G and as $\Sigma S_i = S$, we have:

$$G = \left[K_m (T_e - T_i) + \sum i\, R_i F_{Si} S_i\right] \frac{S}{V} \quad (VII)$$

F_{Si} represents the ratio of the heat flux due to the solar radiation passing through the wall to the solar radiation received by this same wall. For an opaque wall, we have:

$$F_{Si} = \frac{b.K}{h_e} \quad (VIII)$$

Equation in which (b) is the absorption coefficient of the wall and (h) its surface exchange coefficient.

For a given transmission coefficient Km and keeping the same solar factors of the walls, it is found that the form factor of the building S / V has a considerable importance. By choosing a building with a low form factor and having a small wall area in the orientations most exposed to solar radiation (EST and WEST), G will be weaker. Similarly, by improving the solar protection of the walls (especially glazed) F_{Si} is reduced as well as energy requirements.

Moreover, G is a function of $\Sigma R_i.F_{Si}.S_i$. However, R_i is a function of the orientation, it is deduced that to reduce this term, it would be necessary for the walls of large surfaces to be oriented so as to receive the minimum solar radiation flux.

Influence of the ROM Report

ROM is the ratio of the area of the glass walls and the total area of the opaque walls.

The average transmission coefficient of a construction can be considered as the sum of two terms:

$$K_m = \frac{(\sum i\, K_O S_O + \sum i\, K_V S_V)}{\sum i\, S_i} \quad (IX)$$

- K_0 and S_0 are respectively the heat transfer coefficient and the surface of the opaque walls,
- K_V and S_V are respectively the heat transfer coefficient and the surface of the glazed walls,
- S is the total area of the outer walls.

K_V and K_0 being fixed, since K_V is larger than K_0, it can be seen that only the ratio of the glazed area to the total area contributes to the decrease in K_m. The smaller the ratio, the lower the GV will be, and therefore the needs air conditioning will be reduced.

On the other hand, the contributions by sunshine through the glazed walls are largely superior to those of the opaque walls (5 to 8 times for the Ivory Coast), one notes (for the same orientation of the building) that the report of the glazed area on the total surface contributes to the decrease of the contributions by sunshine of the envelope.

It can be concluded that:

The reduction in glazed areas (ROM) and the building form factor (S / V) lead to a proportional decrease in thermal gains.

Evaluation of ROMs and S / V Form Factors of Some Buildings

The study was done in Burkina Faso and the list of buildings made available to us by the LOCOMAT Director as well as the different coefficients that have been evaluated are recorded in the tables below.

Table 2: ROMs and Form Factors Ministry of Finance

MINISTERE DES FINANCES

Désignation	Surf. Façades ext.	Surf. Vitrages	Volume	ROM	S/V	Orientat° faç. ext.
	m²	m²	m3			
Salle RAN	129	32,16	342	0,33	0,38	S/EO.N/EO
Salle RAS1	64,5	16,08	171	0,33	0,38	S.E/S.O
Salle RAS2	64,5	16,08	171	0,33	0,38	N.O/N.E
GrdsBureaux	29,52	2,56	73,44	0,09	0,40	E
Bureauxpays.	12,24	2,56	55,08	0,26	0,22	E

ROM moy= 0,27 **S/V moy. =** 0,35

The windows are all on the East facade for offices and require protection to reduce solar gain.

The largest facades of the building are located on the east and west sides, which increases the heat load.

Table 3: ROMs and Form Coefficients Building

IMMEUBLE

Désignation	Surf. Façades ext.	Surf. Vitrages	Volume	ROM	S/V	Orientat° faç. ext.
	m²	m²	m3			
Salon 1	9,86	3,52	93,55	0,56	0,11	E
Salon 2	9,86	3,52	93,55	0,56	0,11	E
Chambre 1	20,79	1,68	46,95	0,09	0,44	E et S
Chambre 2	8,37	1,68	28,45	0,25	0,29	S
Chambre 3	20,25	1,68	36,83	0,09	0,55	E et N

ROM moy.= 0,31 S/V moy. = 0,30

The windows in the lounges are located on the East facade and those of the rooms on the North and South faces. The building has an East-West orientation, which favors the increase of thermal loads.

Table 4: ROM and Form Factor Building Shops and Offices

IMMEUBLE BOUTIQUES ET BUREAUX

Désignation	Surf. Façades ext.	Surf. Vitrages	Volume	ROM	S/V	Orientat° faç. ext.
	m²	m²	m3			
Bureau 1	21	1,32	39,37	0,07	0,53	N et E
Bureau 2	10,36	2,3	59,57	0,29	0,17	N
Bureau 3	10,36	2,3	59,57	0,29	0,17	N
Bureau 4	18,48	1,32	29,79	0,08	0,62	N et O
Bureau 5	15,96	1,32	22,74	0,09	0,70	S et O
Boutique 1	27,44	2,59	63,84	0,10	0,43	N et E
Boutique 2	10,64	2,59	63,84	0,32	0,17	N
Boutique 3	27,44	2,59	63,84	0,10	0,43	N et O
Réserve 1	17,08	1,32	25,98	0,08	0,66	E et S
Réserve 2	8,96	1,32	25,98	0,17	0,34	S
Réserve 3	17,08	1,32	25,98	0,08	0,66	S et O

ROM moy.= 0,15 S/V moy. = 0,44

The windows in this building are located on the North and South facades and the building has a North-South orientation.

Table 5: ROM and Shape Coefficients Villa Patted'Oie

Villa Secteur N°15 (Patte d'OIE)

Désignation	Surf. Façades ext.	Surf. Vitrages	Volume	ROM	S/V	Orientat° faç. ext.
	m²	m²	m3			
Salon	42,66	4,32	79,38	0,11	0,54	S et E
Chambre 1	20,12	1,44	36,86	0,08	0,55	N et O
Chambre 2	16,07	1,44	23,69	0,10	0,68	S et O
Chambre 3	10,13	1,44	93,66	0,17	0,11	S

ROM moy. = 0,11 S/V moyen= 0,47

For the living room, the two windows are located on the east facade and the other on the south facade. The rest of the glazing for the building is on the south and north sides. The orientation is North-South.

Table 6: ROM and Form Coefficients Villa 1200 Dwellings

Villa 845 N°14 (1200 logements)

Désignation	Surf. Façades ext.	Surf. Vitrages	Volume	ROM	S/V	Orientat° faç.ext.
	m²	m²	m3			
Salon	28,62	4,32	73,66	0.18	0,39	N et E
Chambre 1	12,83	1,44	41,68	0.13	0,31	N
Chambre 2	18,63	1,44	31,00	0.08	0,60	S et O
Chambre 3	11,07	1,44	31,00	0.15	0,36	S

ROM moy. = 0,13 S/V moyen= 0,41

The building has a North-South orientation, for the living room the two glazings are located on the East facade and the other in the North. The glazing of room 2 is on the west facade and that of room 3 on the south side.

Results Interpretation

The average values of the different coefficients calculated for each type of construction are represented in the graphs below:

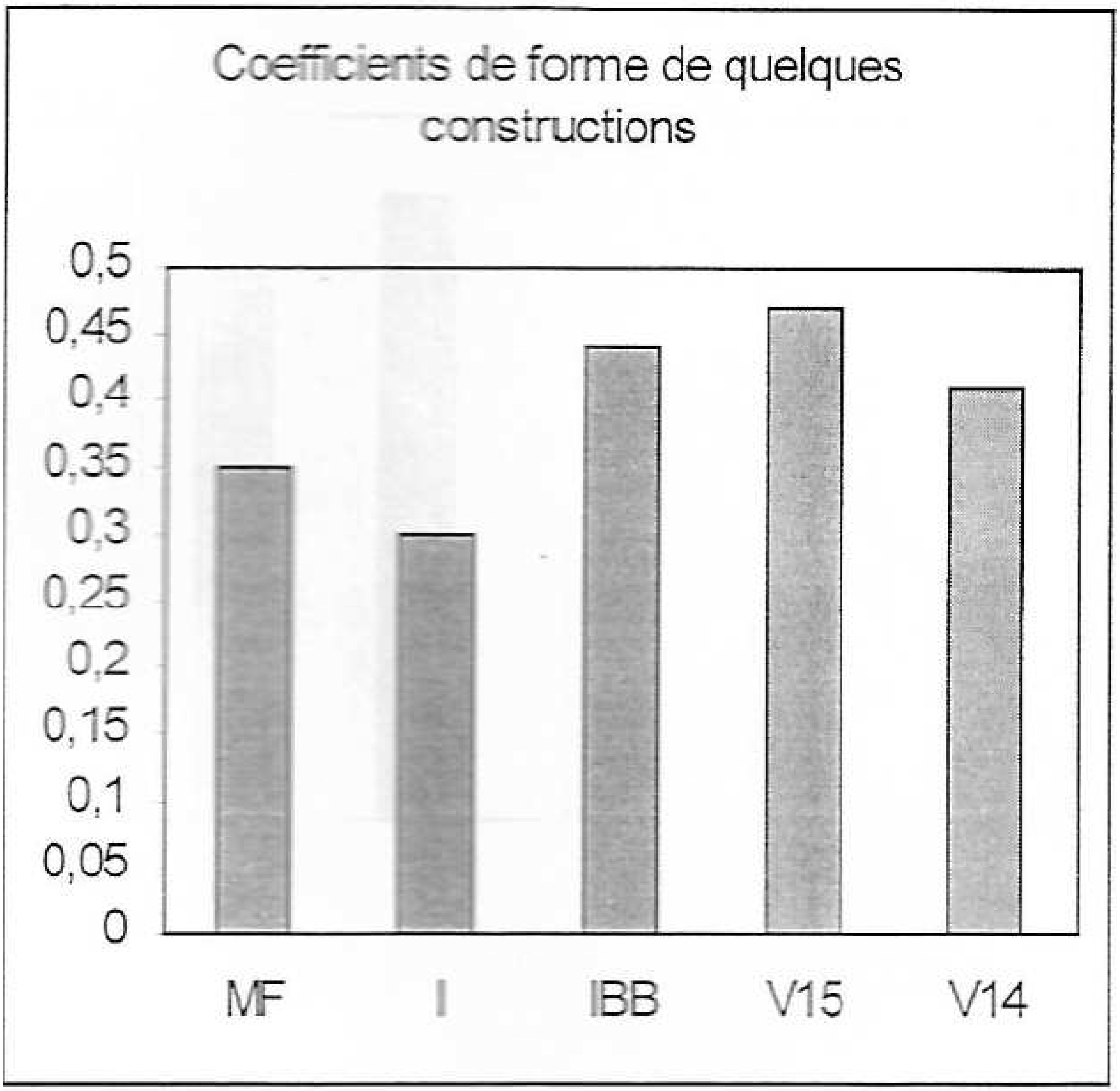

Figure 2: Coefficients of form of Some Constructions

The form factors of small buildings are higher and this is due to the fact that the number of premises in these buildings is very small, which favors the exposure of the facades to the outside environment.

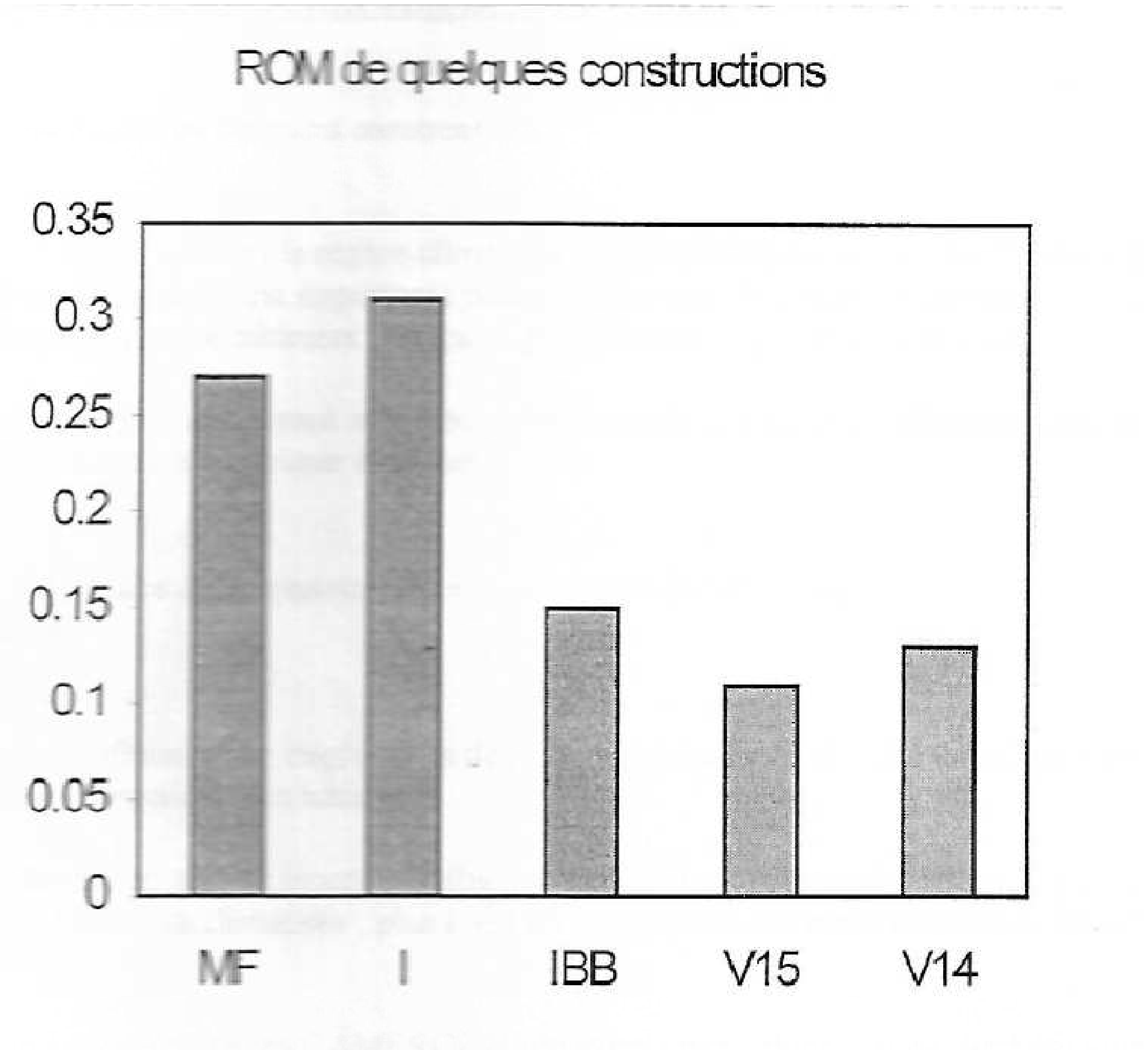

Figure 3: ROM of some Constructions

Legend

- MF: Ministry of Finance
- I: Building
- IBB: Building shops and offices
- V14: Villa N ° 14
- V15: Villa N ° 15

The ROMs vary in the opposite direction of the S / V form factors. They are higher for buildings than for small and medium-sized buildings.

However, their influence on the calculation of thermal loads is very important and this explains why the energy consumption ratios for buildings and large buildings are high.

CONCLUSIONS

Solar gains can represent sometimes more than 50% of the total contributions of the building, it is more than ever necessary to use solar protection. However, the external protections are by far the most effective because on the one hand, the reflected heat is sent before entering the room, and on the other hand, the absorbed heat is dissipated to the outside.

From an energy point of view, the optimal window has the following characteristics:

- A mobile protection placed preferably outside,
- An insulating glass (double glazing) allowing a maximum of natural light to pass so as not to be forced to use artificial lighting.
- As the ROM's influence on the energy consumption of buildings is very important, research needs to be directed in this direction towards building standards.
- A ROM of 15 to 30% depending on the type of building is a good ratio in very sunny areas.

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