Analysis of Solar Passive Parameters Application to Housing Buildings

Ana T. Ramos[1], J. A. Mendes da Silva[2] and Vitor Abrantes[3]

[1]Superior School of Technology, Polytechnic Institute of Castelo Branco
Av. do Empresário, 6000-767 Castelo Branco, Portugal
Tel.: +351-272339300 / Fax: +351-272339399
Email: ana_ramos@est.ipcb.pt

[2]Faculty of Science and Technology, University of Coimbra
Pólo II - Pinhal de Marrocos, 3030-231 Coimbra, Portugal
Tel.: +351-239797100 / Fax: +351-239797123
Email: raimundo@dec.uc.pt

[3]Faculty of Engineering, University of Porto
R. Dr. Roberto Frias, 4200-465 Porto, Portugal
Tel.: +351-225081400 / Fax: +351-225081440
Email: abrantes@fe.up.pt

ABSTRACT: The paper presents a methodology of evaluation of buildings' solar passive performance. This methodology was developed in agreement with quality levels for thermal parameters which were chosen according to the construction's solar passive behaviour and the regulamentary concepts. A comparative study was organised in the context of a recently finished master's dissertation between the legal frames of three European countries, giving special emphasis to the Portuguese case. The results of this study allowed the conclusion that it has become essential to combine minimum regulation values to methodologies that grant an evaluation and qualification of a building in terms of its thermal performance.

Conference Theme: Low energy architecture and city planning
Keywords: energy consumption, passive solar systems, thermal efficiency, comfort levels

1. INTRODUCTION

The growing concern with the increase of the energetic consumption, verified all over the world, makes indispensable to take a look on the parameters that contribute to this situation. It also makes a profound analysis of the legal tools used in several countries in order to control and contain energy costs obligatory. This evolution is also present in the Portuguese case, as an increase in energy consumption from year to year was verified, due to the housing sector contributing about 40% of the total consumption.

The passive heating, natural cooling and natural light represents all of the strategies which, when applied, is modified by the region and the type of construction. While the passive solar energy can help replacing the traditional fuel by alternative sources of heating, cooling and illumination (environmentally benign), the energetic efficiency and the constructive practices are essential to make a better use to the available energy.

The combination between the regulamentary and environmental factors gave birth to the evaluation methodology of building's solar passive performance, presented in section 5, and to the choice of parameters that represent the behaviour of the building's envelopment in agreement with the climatic characteristics of the place where the construction is situated.

2. PRESENTATION OF RULES

2.1 Spanish code - Norma Básica de la Edificación NBE-CT-79

In this rule the buildings are analysed according to some characteristics of the envelopment, mainly the global heating transmission (K_g), the heating transmission through each element (K), the thermal-hygrometric behaviour and its permeability to the air. [1]

The verification consists in establishing the value of the K_g of the buildings, which is in the medium rate according to the surface that each element occupies in the envelopment of the building, and compares it with the determined maximum value according to the form factor of the construction (ratio between the exterior surface and housing volume).

2.2 French code – Régles Th

The French rule subdivides the comfort conditions and the terms of its application according to the occupation for which a particular construction is destined. In this study the rules applied to the housing buildings where considered. [2]

According to the general calculation principles, we proceed to calculate the waste by transmission through the envelopment (D_t) and the losses through the renovation of the air (D_r). The addition of these two parameters provides the coefficient which represents the total losses (GV). With this parameter we can determine the annual heating needs (BV) which consist in the product between GV and F. This last one (F) represents the advantage of the free gains. [3] [4]

2.3 Portuguese code – Regulamento das Características do Comportamento Térmico dos Edifícios (RCCTE)

Its final objective, is first to assure the thermal comfort conditions minimizing the energy consumption, and then, to prevent the current pathologies of the condensation in the construction elements. [5]

The study is tied to the calculation of the values related to the nominal heating needs in winter (N_{IC}) and cooling in summer (N_{VC}) characterized, respectively, by the amount of heat that will be necessary to provided and the surplus quantity to be redrawn in order to maintain the comfort conditions expressed in the RCCTE, these are: during the winter a stable internal temperature of 18 degrees, and in summer of 25 degrees. The calculated values, according to the building characteristics and with the filling of the calculation sheets will be compared with the regulamentary results of N_I and N_V obtained with reference values.

2.4 Codes synthesis

The French and the Portuguese codes adopt a similar analysis methodology of the buildings performance in its whole, in a basis of the losses envelopments calculation and the value of the current gains in the incidence of solar radiation. The major difference consists in: the first case, the analysis must be made to the whole year and, in the second case, it must be done to two difference seasons: heating and cooling.

The Spanish code presents a different philosophy by analysing the building as a whole, a volume that produces heat and loses it by the contact between the surface and spaces that present inferior temperatures. The form factor is a fundamental parameter in this application and penalizes the buildings with shape that are too exposed.

3. METHODOLOGY OF THE EVALUATION OF THE PROJECT'S QUALITY

3.1 Qualitel method

The evaluation of the Qualitel method consists in a multi-criteria analysis and involves several rubrics related to the functional quality and to the incidence of exploration and maintenance costs. These rubrics, in particular the one for summer thermal comfort, could lead to the Qualitel certification if they reach, in all rubrics, the level 3 parameter (in a quotation grid of 1 – insufficient / expensive – to 5 – excellent / very economic). Each rubric is divided into sub-rubrics, evaluated according to the same system, in which the grades are associated to the verification of determined conditions in the project. [6]

The presentation of the obtained results by the application of the Qualitel's method involves the grades given to all the rubrics, so that the building's users can evaluate the different aspects according to their particular interests.

3.2 RT2000 method

This methodology applies to the buildings that present the following characteristics: [7]

- Non heating/cooling buildings;
- Housing area inferior to 220 m2 (square meters);
- Doors and windows surface inferior to 25% of the housing surface.

To each element described (isolation of opaque envelopment, the existence of thermal bridges, the type of fenestrations, ventilation, the water warming system and the construction's place) is given a grade having as a function the thermal quality of the building's elements. The building respects the thermal demands of the winter if:

- The total of points obtained is ≥ 18;
- If each element used in housing respects the less demanding of the method;
- The demands described in the six elements which are to be analysed are respected.

3.3 Evaluation Method of the Quality of the Housing Building's Project

This method is based on the following elements for a logical structure of development: the objectives hierarchy, evaluation criteria, evaluators, evaluation procedures, describers and preference criteria. [8]

The superior goal, environmental comfort, is subdivided into four partial objectives, which one of them is the thermal comfort. This partial goal involves the evaluation criteria which are based on the thermal behaviour of the building: summer and winter's thermal comfort.

4. EVALUATION PARAMETERS

4.1 The framing

According to the parameters used in the code analysis and by the methodologies of the evaluation of the project's quality, the most relevant thermal parameters that represent the building's solar passive efficiency were selected.

4.2 Evaluation criteria used

The parameters presented in the table bellow were analysed according to their contribution to the global thermal efficiency of a constructive solution whose objectives are the optimization of the energetic wastes.

At the end of each analysis the evaluation system of each element was proposed according to the constructive solution and to the quality levels it was given a classification. This classification is presented in 4.3..

Table I: Criteria which was used

Criterion		
1	Heating nominal needs	N_{IC}/N_I
2	Cooling nominal needs	N_{VC}/N_V
3	Base temperature	Tb
4	Gross solar gains / Heating Gross needs	GLR
5	$K_{solution}$ and K_{ref} ratio	K/K_{ref}
6	Delay factor	φ
7	I_t calculation without maximum values	I_t
8	Accumulator surface / Glazed surface	S_a/S_{env}
9	Thermal bridges – external wall and roof slab	P_{ext} e L_{roof}
10	Thermal bridges – external wall and intermediate slab	P_{ext} e L_{int}
11	Thermal bridges – external wall and floor slab	P_{ext} e L_{floor}

Some of these parameters were analysed according to the previous studies. The others were studied following the thermal and solar passive principles.

4.3 Levels of quality given to the criteria

The tables II to VII present a quantitative evaluation to each of the proposed parameters. The criteria presented in tables II, III, IV, V and VII are analysed in agreement with the references values of the RCCTE or with concepts presented in the code (Table IV).

Quality levels were given to the eleven evaluation criteria that vary from N_0 to N_4, being the N_0 level corresponds to the solution's behaviour below the acceptable minimum, and the N_4 to a high performance.

Table II: Nominal needs

Quality levels	$X=\frac{N_{IC}}{N_I}$	$X=\frac{N_{VC}}{N_V}$
N_0	X > 1,0	X > 1,0
N_1	0,85 < X ≤ 1,0	0,75 < X ≤ 1,0
N_2	0,75 < X ≤ 0,85	0,6 < X ≤ 0,75
N_3	0,60 < X ≤ 0,75	0,4 < X ≤ 0,60
N_4	X ≤ 0,60	X ≤ 0,40

The N_1 level corresponds to solutions which are limited to the code values without contributing with benefits that allow a better performance in what concerns the thermal behaviour of the building.

Table III: Base Temperature

Quality levels	Inside temperature obtained with the heat system (Tb)
N_0	Tb < 15 ºC
N_1	15 ºC ≤ Tb < 16 ºC
N_2	16 ºC ≤ Tb < 17 ºC
N_3	17 ºC ≤ Tb < 18 ºC
N_4	Tb ≥ 18 ºC

Table IV: Gross solar gains and heating gross needs ratio

Quality levels	$GLR=\frac{\text{Gross solar gains}}{\text{Heating gross needs}}$
N_0	1,2 < GLR / GLR < 0,2
N_1	0,2 ≤ GLR ≤ 0,5
N_2	0,5 < GLR ≤ 0,8
N_3	0,8 < GLR ≤ 1,0
N_4	1,0 < GLR ≤ 1,2

Table V: $K_{solution}$ and K_{ref} ratio

Quality levels	$X=\frac{K}{K_{ref}}$
N_0	X > 1,0
N_1	0,9 < X ≤ 1,0
N_2	0,7 < X ≤ 0,9
N_3	0,5 < X ≤ 0,7
N_4	X ≤ 0,5

Table VI: Delay factor

Quality levels	φ (hours)
N_0	2,0 > φ
N_1	2,0 ≤ φ < 3,5
N_2	3,5 ≤ φ < 5,0
N_3	5,0 ≤ φ < 7,0
N_4	φ ≥ 7,0

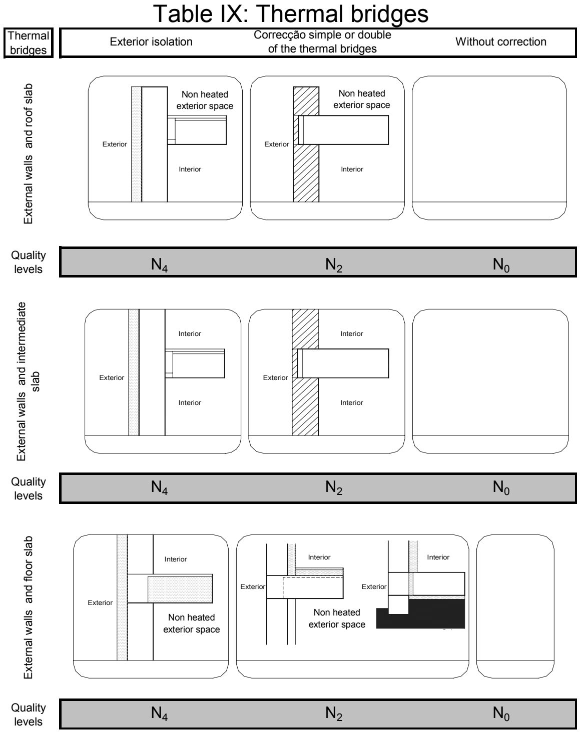
Table VII: Thermal inertia (without maximum values)

Quality levels	I_t
N_0	150 > I_t
N_1	150 ≤ I_t < 400
N_2	400 ≤ I_t < 600
N_3	600 ≤ I_t < 800
N_4	I_t ≥ 800

Table VIII: Storage surface and glazed surface ratio

Quality levels	$X = \frac{Storage\ surface}{Glased\ surface}$
N_0	X < 1,0
N_1	1,0 < X ≤ 3,0
N_2	3,0 < X ≤ 5,0
N_3	5,0 < X ≤ 7,0
N_4	X ≤ 7,0

Table IX: Thermal bridges



5. EVALUATION'S METHODOLOGY OF THE BUILDING'S SOLAR PASSIVE PERFORMANCE

5.1 Application principles

The building evaluation will give birth to the elaboration of a graphic which will demonstrate the thermal performance of the building, based on the analysis of the chosen evaluation criteria. This option is based on the fact that a graphic methodology will be more easily interpreted when the interested person hasn't any knowledge on this subject.

The use of a global final grade will be connected to the previous concept, although many times the user doesn't have the knowledge to interpret it. Firstly, the graphical method would make it easier for the non-expert person who seeks the acquisition of his house from an extremely vast set of supplies; Secondly, the use of a global grade makes easier the classification of the different buildings and the comparison among them, of the different thermal performances.

The calculation of the global grade, attributed to the general performance of the building, is given through the application of the following expression:

$$NG = \frac{\sum_{i=1}^{11} n_{crit}}{11} \qquad (1)$$

In which:

NG	- Global grade
n_{crit}	- Grade attributed to each criterion

So, according to the table X the quality levels are classified with a number of points to be given to each solution of the several indicators.

Table X: Quality levels

Quality levels	Number of points
N_0	- 4
N_1	0
N_2	2
N_3	3
N_4	4

The attainment of a quality level 0 (N_o) in any of the indicators penalizes the global grade in four negative points, i.e. it would be the same to say that it will annul a level of quality four (N_4). The quality level one (N_1) in spite of not penalizing the global performance characterizes itself as a satisfactory solution, however, it doesn't contribute to a best thermal performance, there so the existence of a null points to this quality parameter.

The maximum global grade would be 4, which means that a building with a negative performance would represents a thermal efficiency bellow the one considered a satisfactory comfort level. This would be similar to a building with a null NG (the minimum global grade which would be possible to attribute is -4).

The graphical design is made using the table filling, as it is presented in figure 1, which includes the partial grades of each constructive solution and the building's global grade.

	Evaluated Parameter		Quality Level N4	N3	N2	N1	N0	Points
1	Nominal needs (R.C.C.T.E.)	N_{IC}/N_I	□	□	□	□	□	
2		N_{VC}/N_V	□	□	□	□	□	
3	Base temperature	Tb	□	□	□	□	□	
4	Gross solar gains / Heating gross needs	GLR	□	□	□	□	□	
5	$K_{solution}$ and K_{ref} ratio	K/K_{ref}	□	□	□	□	□	
6	Delay factor	Φ	□	□	□	□	□	
7	I_t calculation without maximum values	I_t	□	□	□	□	□	
8	Accumulator surface / Glazed surface	S_a/S_{glaz}	□	□	□	□	□	
9	Thermal bridges - external wall and roof slab	P_{ext} e L_{roof}	□	□	□	□	□	
10	Thermal bridges - external wall and intermediate slab	P_{ext} e L_{int}	□	□	□	□	□	
11	Thermal bridges - external wall and floor slab	P_{ext} e L_{floor}	□	□	□	□	□	
	Global evaluation:	____	Good		Satisfactory		Weak	
			Performance					

Avereage level

Figure 1: Final table of evaluation

5.2 Methodology in practice

The use of this method would be linked to the correct application of the characteristic's code of the building's thermal comfort behaviour, respecting the solutions presented in itself, although considering all the others that, from the point of view of passive solar solutions, could be used as tools allowing the increase of the building's thermal performance. With the goal of demonstrating the application of the building's evaluation sheet, concerning a passive solar approach, it will be completed considering a fictitious solution, for example:

	Evaluated Parameter		Quality Level N4	N3	N2	N1	N0	Points
1	Nominal needs (R.C.C.T.E.)	N_{IC}/N_I	■	□	□	□	□	4
2		N_{VC}/N_V	□	■	□	□	□	3
3	Base temperature	Tb	□	■	□	□	□	3
4	Gross solar gains / Heating gross needs	GLR	□	□	□	■	□	0
5	$K_{solution}$ and K_{ref} ratio	K/K_{ref}	□	■	□	□	□	3
6	Delay factor	Φ	□	□	■	□	□	2
7	I_t calculation without maximum values	I_t	□	■	□	□	□	3
8	Accumulator surface / Glazed surface	S_a/S_{glaz}	□	□	□	□	■	-4
9	Thermal bridges - external wall and roof slab	P_{ext} e L_{roof}	□	□	■	□	□	2
10	Thermal bridges - external wall and intermediate slab	P_{ext} e L_{int}	□	□	■	□	□	2
11	Thermal bridges - external wall and floor slab	P_{ext} e L_{floor}	□	■	□	□	□	3
	Global evaluation:	2	Good		Satisfactory		Weak	
			Performance					

Avereage level

Figure 2: Example of table's filling

The example of the completed table shows that the application of the methodology to a building which mainly presents the constructive element's behaviour higher than level 2 (N_2), but that has a level 0 (N_0) – -4 points, will be given a final grade of 2. This quoting process reveals a building with an average thermal comfort behaviour that was penalized by a very weak performance of one of its solutions. This means that a bad solution doesn't exclude the possibility of a medium result, having in consideration that the building is analysed as a whole.

6. CONCLUSION

Although this methodology doesn't aim to bind or give a negative report or present any kind of difficulties to the inherent legal procedures that the projects must follow, it can be considered a surplus to the user when he makes one of the most important acquisitions of his life, which is responsible for a direct impact on the family's economy for a long time. The constructor can also use this methodology as a seller's argument and as an instrument for the commercial promotion of the investment.

From the point of view of energy saving, the application of this method would impose conditions to the building's global quality according to the quality level of each constructive element, granting the decrease of consumes to obtain interior comfort. So, this consists in an important tool that allows the characterization and control of the energetic wastes in housing buildings.

REFERENCES

[1] *Manual de Aislamiento en la Edificacion*; Cristaleria Españhola, S.A.; Madrid; 1999.

[2] Document Technique Unifié; *Régles Th – Régles de Calcul des Caractéristiques Thermiques Utilies dês Parois de Construction, des Déperditions de Base des Batiments et du Coefficient G des Logements et Autres Locaux D'Habitation*; CSTB; Paris; 1977.

[3] Document Technique Unifié; *Régles Th-BV – Régles de Calcul du Coefficient de Besoins de Chauffage des Logements*; CSTB; Paris; 1988.

[4] Document Technique Unifié; *Régles Th-BV – Régles de Calcul du Coefficient de Besoins de Chauffage des Logements*; CSTB; Paris; Correcção de Jul/1989.

[5] *Regulamento das Características de Comportamento Térmico dos Edifícios* – Decreto-Lei n.º 40/90, de 6 de Fevereiro; Porto Editora; Porto; 1991.

[6] Association Qualitel; *Guide Qualitel*; Association Qualitel; Paris; 1980.

[7] Centre Scientifique et Technique du Bâtiment; *Solution Technique RT 2000 – Reglementation Thermique 2000*; CSTB; Paris; 20.

[8] Costa, Jorge Moreira da*; Métodos de Avaliação da Qualidade de Projectos de Edifícios de Habitação* – Tese de Doutoramento; Universidade do Porto; Porto; 1995.