BTPI - A BUILDING THERMAL PERFORMANCE INDEX

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ABSTRACT

The adoption of a method for evaluation of the thermal quality of buildings might be an incentive for building energy management.

In this paper, an empirical method is proposed which qualifies the thermal performance of buildings through the entire year. The thermal quality parameter (BTPI) is intended to be an instrument for the implementation of new energy regulations for buildings, especially for those that are located in areas with mild climate and no heating or air conditioning systems.

KEYWORDS

Building thermal performance; energy policy; building energy management.

INTRODUCTION

The thermal quality of buildings is an increasingly important parameter when comparing the performance of different designs: it allows the characterization of the thermal performance of a building; it represents an instrument for balancing economics and comfort; and it may help in the implementation of policies for building energy management.

Therefore, it is important to adopt a method to evaluate the thermal quality of buildings and more important yet, a method that is simple and easy enough to be implemented in a generalized manner bearing in mind the multiplicity and diversity of education levels of the people that take part in building design and licencing procedures.

The thermal performance of a building should be the result of a compromise between the quality of the structure of the building required to satisfy thermal objectives and the respective economic consequences in terms of initial investment in the building envelope and operating costs of the energy systems. In these buildings, comfort is a precondition, but one can also think about those buildings, where the comfort level is very poor.

According to the traditionally used parameters of thermal qualification, a building is designed to optimize either heating or cooling economics, respectively where heating or cooling loads predominate.

The more conventional parameters for heating purposes are the coefficients U $[W/m^2K]$ and G $[W/m^3K]$, the former taking into account the thermal resistance of the only envelope and the latter including also the air infiltration losses. Both are insulation-related parameters and include neither the consequences of solar protection in summer nor those of solar gains in winter.

The consideration of all main aspects of building thermal performance may demand the adoption of a "parameters list" related to the quality of the thermal response of buildings to the external climatic conditions, as it is proposed by C.S.T.B.* (1976, 1977). The parameters that are usually listed are, in winter: 1. Volumetric heat loss coefficient (transmission + infiltration) - G coefficient; 2. Overall heat transfer coefficient (opaque elements) - U coefficient; 3. Window transmission; 4. Window infiltration; and, in summer: 1. Ventilation requirements; 2. Shading; 3. Thermal inertia; 4. Roof condition (insulation + solar protection).

The CSTB method establishes reference values or reference intervals for the above listed parameters which correspond to acceptable or good thermal performance of the building under given climatic conditions. When any two parameters influence each other the reference values are obtained from double entry tables which lead to the definition of zones of quality regarding the mixed effect of those two parameters.

The CSTB method, in spite of considering winter and summer performance separately, seems apropriate and accurate, at least if all reference values are based on field measurements and audits. Nevertheless, it appears to be too much complicated to be of practical use by all kinds of technical people involved in the building industry.

More recently the B-coefficient (Anquez, 1979, 1981) which takes into consideration the solar heat gains in winter was introduced in France. B expresses the heating needs after the consideration of solar and internal heat gains.

On the other hand, the interest of characterizing the thermal quality of a building by a single figure has been growing. In 1982, Bondi, has proposed a coefficient P_t as an extension of the parameter U. P_t takes into accoun the envelope's thermal capacity and the maximum and minimum inside temperatures, calculated by mathematical models. Compared with the CSTB method, the P_t method still doesn't consider solar heat gains but includes thermal inertia as a winter parameter.

The National Building Research Institute (NBRI), in South Africa, has developed an empirical procedure which is referred to as the CR-method and is based on an experimentally verified correlation $(\alpha_i/\alpha_o)\ (1/R_s) = 48{,}9\ [(\sum C\,R_s)\ \exp(-0{,}903)]$ established with the ratio of the difference between the mean values of the indoor maximum and minimum dry bulb temperature (α_i) and the difference between the mean value of outdoor maximum and minimum temperatures (α_o) and the product of the active heat storage capacity of the structure as a whole (C), and the weighted or equivalent resistance to heat flow (R_s) of the exposed building envelope (Wentzel and van Straaten, 1982).

Directly or indirectly this method takes into consideration all main factors determining the thermal response of a building: the heat storage capacity; the level of insulation of the envelope; the solar heat gains, both direct and indirect; the ventilation rate; the heat gain from internal sources; and finally, the condition of the roof.

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In spite of being a method of real interest the CR-method still seems very complicated to be broadly used for licensing of mass housing. Furthermore, while the application of this method does not leave any doubts when a certain type of climatic conditions is clearly predominant, the situation is not as clear when both heating and cooling loads have comparable orders of magnitude.

The thermal characterization (or qualification) can be useful even in those cases where neither heating nor refrigeration are considered. In these cases, the problem consists of verifying whether it is possible and useful to talk of the thermal performance referred to the thermal response of a building during the entire year in a given location.

The generalisation to the entire year seems particularly useful and applicable to the case of buildings in areas of mild climate where the thermal inertia, the sun control and envelope's thermal resistance work at the same side both in winter and in summer. Conversely infiltration is favorable in summer and unfavorable in winter.

That is why we tried to obtain an empirical building thermal performance index, that, rather than having a definite physical meaning, gives a quantitative comparison between the actual building thermal quality and the reference values recommended for given climatic conditions of a particular location.

This method will obviously need further work, including assessment through "in situ" measurements, simulations and audits. Anyway it represents the starting point of a program to define an instrument for energy regulation of new buildings, in particular, residential buildings.

METHODOLOGY

The methodology is illustrated on the flow chart (Fig. 1) and consists of:

1. Portuguese climatic zones are typified for summer and winter and the relative importance of the seasonal loads is selected establishing scenarios of climatic predominance between winter and summer conditions for a given zone. The predominance factors (p_w, p_s) are thus defined.
2. A selection of thermal quality parameters for winter and summer conditions is made, mainly on the basis of CSTB and NBIR lists. According to climatic zones each of those parameters will receive a value designated by reference value (RV);
3. The quality of a given building is characterized by the actual values (AV);
4. The comparison between actual and reference values leads to a set of evaluation values (EV);
5. The evaluation values are weighted by the predominance factors and combined to obtain the "building thermal performance index", BTPI, using the expression

$$\mathrm{BTPI} = \frac{p_w \sum_{i=1}^{n/2} E_{wi} + p_s \sum_{i=1}^{n/2} E_{si}}{n}$$

where n is the number of selected parameters with an equal number of parameters (n/2) for each season.

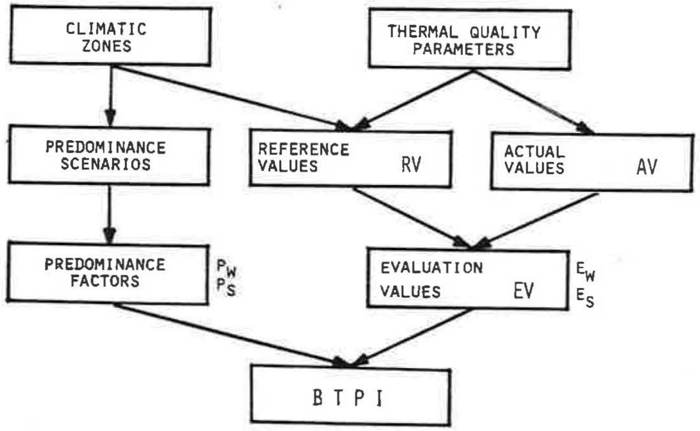


Fig. 1. Flow chart for BTPI calculation

Obviously, the values attributed to (p_W, p_S) and (E_W, E_S) are empirical. According to the criteria adopted the BTPI will vary between 0 and 2, the optimum corresponding to 1. Ideally, values of BTPI less than unity correspond to a building with insufficient thermal quality for that particular location. On the other hand, BTPI values greater than unity correspond to buildings with an economically uninteresting thermal quality. BTPI > 1 is not a statement about heating expenses but rather it means that for the particular location, the building is overinsulated, or has a superheavy structure which cannot be economically justifiable, i.e, equivalent comfort conditions can be obtained with a smaller initial investment.

Without a more accurate verification of the meaning of the reference values and predominance factors a range of BTPI = 1 ± 10% is considered to be acceptable.

EXAMPLE

Tables 1 and 2 list the parameters that were used in this example. Compared with a previous stage of development (Abrantes and Fernandes, 1982) two new parameters were considered: "solar gains" in winter and "wall absorptivity" in summer.

Fig. 2 shows what kind of evolution results to the BTPI after introducing a specific modification such as the reduction of glazing area; better insulation: the orientation of the glazing area predominantly to south. It is also possible to compare the evolution of the coefficients B and G according to modifications introduced. Only relative values are shown for coefficient B.

For a typical example of a portuguese dwelling the method leads (fig. 3) to the conclusion that the thermal quality of the building is clearly below the acceptable value (BTPI = 1) all over the country.

As described here, Fig. 3 compares results obtained with 8 parameters with the previously referenced 6 parameters. As we could expect the introduction of a fourth pair of parameters smooths the variation of BTPI.

TABLE 1 - REFERENCE VALUES FOR THE WINTER THERMAL QUALITY PARAMETERS

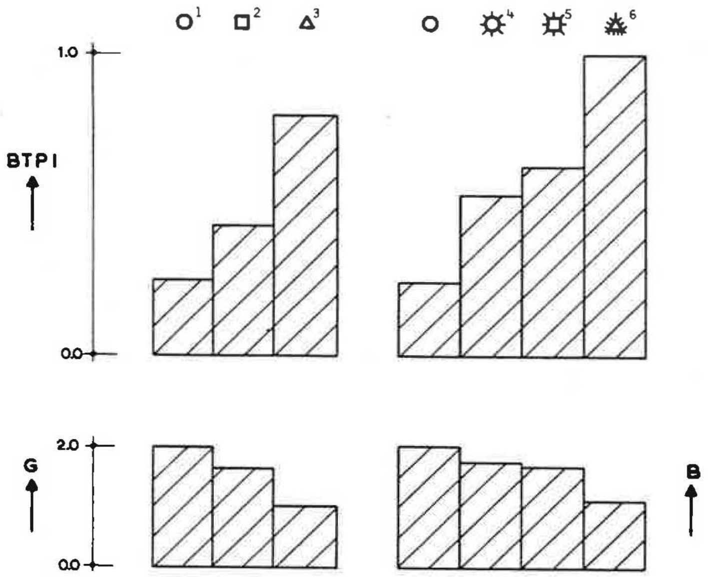
CLIMATIC ZONES[1]			HIII	HIV	HV
1. Overall Heat Transfer Coefficient [$w/m^2.k$]					
	Walls (> 100 Kg/m^2)		1.00	1.15	1.35
	Walls (< 100 Kg/m^2)		0.85	0.85	0.85
	Roof		0.50	0.70	1.00
2. Window Transmission[2] [$w/m^2.k$]					
	Ag/Af < 1/5		4.20	5.80	5.80
	Ag/Af > 1/5		3.10	4.20	5.80
3. Window Infiltration[3] [$m^3/h.m$]					
	A'g/Af < 1/6		6-12	6-12	-
	A'g/Af > 1/6		2-6	2-6	6-12
4. Solar Gains[4] [%]					
	Inertia	High	14	12	10
		Medium	12	10	8
		Low	10	8	6

[1] Climatic zones according to UEAt$_c$; [2] Ratio between glazed area and floor area; [3] Ratio between operable window area and floor area. The flow rates were adapted from a UEAt$_c$ classification (1976) and are referred to $\Delta P = 100Pa$ and a window placed less than 6 m above ground level; [4] The reference values listed are ratios between south-facing glazed area and floor area.

TABLE 2 - REFERENCE VALUES FOR THE SUMMER THERMAL QUALITY PARAMETERS

CLIMATIC ZONES[1]				EII	EIII	EIV
1. Ventilation Requirements[2]						
	Inertia	High		S/D	S(ns)/D	D
		Medium		S(vp)/D	D	D
		Low		D	D(ns)	*[4]
2. Shading Coefficient[3] [%]						
	Inertia	Ag/Af[1]	Orientation			
	High/Medium	< 1/5		45	25	15
		> 1/5		25	15	10
	Low	< 1/5	E S(W)	25(15)	15(10)	*[4]
		> 1/5	E S(W)	15(10)	10	*[4]
3. Wall Absorptivity						
	Density	< 100 Kg/m^2		-	0.3-0.5	0.2-0.3
		> 100 Kg/m^2		-	-	0.3-0.5
4. Roof Conditions [$w/m^2.k$]						
	Inertia	Absorptivity	Density			
	High/Medium	$\alpha < 0.3$	-	-	-	0.70
		$0.3 < \alpha < 0.7$	> 200 Kg/m^2	1.15	0.95	*[4]
		$0.3 < \alpha < 0.7$	> 200 Kg/m^2	0.95	0.70	*[4]
		$\alpha < 0.7$	-	0.70	*[4]	*[4]
	Low	$\alpha < 0.3$	-		0.70	0.70
		$0.3 < \alpha < 0.7$	-	0.70	*[4]	*[4]

[1] See table 1; [2] S-envelope openings in only one wall; D-idem in at least two walls; (ns)-opening must face north or south, (vp)-small openings only; [4] Percentage of the radiation incident on a glazing which enters the space; [4] Those combinations are not recommended.



[1]typical example
[2]smaller openings
[3]plus better insulation
[456]with solar gains

Fig. 2. Evolution of BTPI with envelope modifications

CONCLUSIONS

The BTPI method leads to results that are within the expectation regarding calculations and previous experiences.

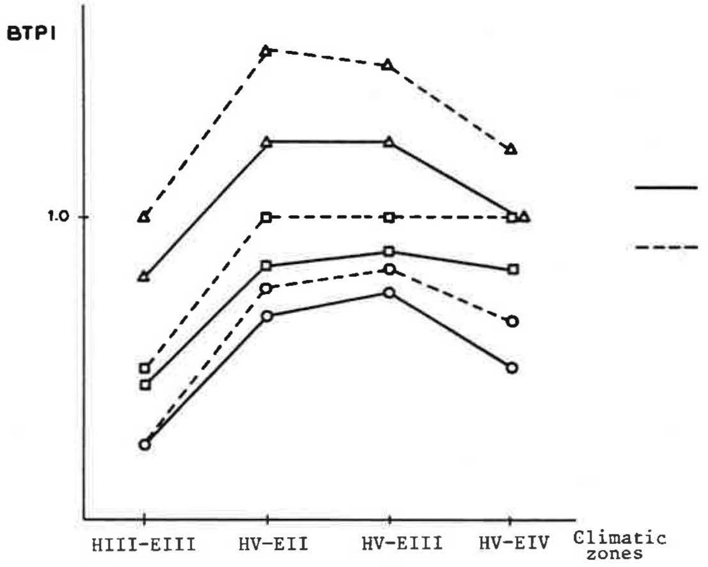
The BTPI is a method that may have application restricted to countries with mild climate, specifically, mediterranian climate.

The BTPI answers several questions posed before: it gives a single figure; it covers the entire year; it considers the sun control, the inertia, the ventilation requirements and the infiltration.

The major limitations associated with the BTPI - method are the difficulties related with:

- the generalisation to the entire year
- the right choices of the number, nature and degree of interdependence of parameters and the subjectivity of establishing climatic scenarios and predominance factors.

Further studies and experiments will allow to check and, eventually, to perfect the method.



— 8 parameters
--- 6 parameters
more symbols on fig. 2

Fig. 3. BTPI values for different climatic conditions

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