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ANALYSIS OF THE CORRELATION APPROACH WITH-HELD IN THE FRENCH METHOD 5000

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1. Introduction

The need for comprehensive and transparant design tools, in an early stage of the design, has been felt amongst building practicians, researchers and public bodies. In recent years, correlation studies have been undertaken between dynamic multizonal thermal simulation models, and steady state single zone calculation methods for energy and comfort analysis in residential buildings. The french Method 5000 (1), writes the heat balance on a monthly base as :

$$Q_{aux} = Q_{no\ gains} - \eta(X,I) \cdot \phi_{gains}$$

with

$$X = t_{set} - t_{wh}$$

$$t_{wh} = t_e + \frac{\phi_{gains}}{G * V}$$

The recuperation factor $\eta(X,I)$ was determined by correlation with a detailed simulation model. This correlation study was partly repeated at the Brussels University using the belgian reference model LPB-1 (2).

Numerical simulations were chosen for extremely simplified configurations. Two test-cases were with-hold : a 1-zonal and a 5-zonal configuration. No night-temperature setback, no interzonal ventilation and no "user-building interaction" were considered. Climatological data was chosen according to the belgian reference year AT-36. Wall inertia was changed by displacing the insulation layer in the considered structures.
For each inertia category (heavy, medium, light and very light) some parameters were changed such as orientation, solar aperture, ventilation, setpoint temperature, casual gains.

In this way 24 configurations of the 5-zonal example were considered in each inertia category.

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2. Objectives

A systematic parametrical analysis was undertaken upon the solar recuperation factor $\eta(X,I)$. The basic question was, if there were other parameters than X and I influencing η, and secondly if X was the right parameter to be correlated.

In this parametrical analysis, attention went to :

- compensation of longwave losses and shortwave solar radiation on opaque surfaces
- nature of the considered gains : convective/radiative
- nature of the considered losses : ventilation/conduction
- distribution in time of the considered gains
- distribution in space of the considered gains
- influence of the buffer spaces
- ventilation within one inertia category, I
- parameter variation with constant X-value
- correlation consistence at several setpoint temperatures.

3. Results

Considering the balance of longwave and shortwave radiation on opaque surfaces, indicates for standard insulated houses, only a difference of 2 % on the recuperation factor. The nature of the considered gains (convective/radiative) is only important for non-insulated walls (up to 10 % on Q_{aux}). But for insulated buildings (5 cm), differences between a 100 % convective and a 100 % radiative model drop to 2 % on Q_{aux}. Also the nature of the considered losses (ventilation/conduction) proved to be of minor importance.

The distribution in space and time of the considered gains has a major impact on comfort and auxiliary heating demand. The distribution in time is hereby predominant (up to 25 % on η). However an idealized repartition of the free gains over 8 hours a day, corresponds quite well with predictions by M 5000.

Bufferspaces represent an artificial increase of the building inertia. Simulations with LPB-1 indicate an increase of $\eta(X,I)$ with about 4 % in the "medium" category. This effect is not accounted for in M 5000. Variation within one inertia category changes the recuperation coefficient up to 8 % difference in the "medium" category, and up to 3 % difference in the "heavy" category. (cfr. Table 1)

Most striking results were however obtained by holding X at a constant value, while changing other parameters : the correlation approach in M 5000 claims to be independent of such variations. In a first set of simulations ϕ and G were changed for constant X.

Several X-values (-2,0,1,2,4) were obtained for different setpoint temperatures. A remarkable dependency of $\eta(X,I)$ on G was noticed.

For the "heavy" category we obtained :

X = -2	η = -7,23.G + 85,16 (4 points)	r = 0,997	t_{set} = 16°C
X = 0	η = -7,52.G + 95,66 (5 points)	r = 0,996	t_{set} = 18°C
X = 1	η = -6,19.G + 96,17 (6 points)	r = 0,993	t_{set} = 19°C
X = 2	η = -6,21.G + 98,49 (5 points)	r = 0,996	t_{set} = 20°C
X = 4	η = -4,73.G + 99,39 (5 points)	r = 0,995	t_{set} = 22°C

Changing the inertia category from "heavy" to "medium", we obtain again a linear dependency of η on G :

X = -2	η = -6,48.G + 76,51 (4 points)	r = 0,989	t_{set} = 16°C
X = 0	η = -7,72.G + 90,16 (5 points)	r = 0,977	t_{set} = 18°C
X = 2	η = -6,37.G + 94,12 (5 points)	r = 0,981	t_{set} = 20°C
X = 4	η = -5,07.G + 96,78 (5 points)	r = 0,983	t_{set} = 22°C

As a first approaximation we may conclude that the slope remains unchanged as indicated in Fig. 1. Also, we notice that the difference on the recuperation coefficient between "heavy" and "medium" decreases, with increasing X.

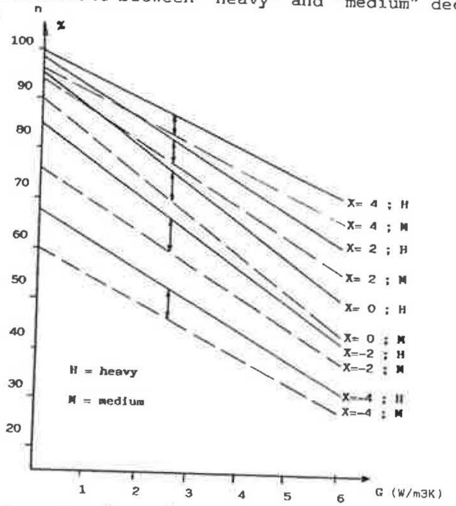

Fig. 1. Inertia categories "heavy" and "medium", simulation set 1.

In a second set of simulations (1 zone) and in a third set (5 zones), several X-values were realized for a constant setpoint (19°C), and for two insulation levels (0 cm and 5 cm insulation). By changing t_e and ϕ, we obtain several X-values. In this way, the following correlation curves could be deducted for the "heavy" category.

	1 zone	5 zones
0 cm insulation	$\eta = 56,61 + 12,49\ X - 0,81\ X^2$	$\eta = 78,39 + 9,35\ X - 0,92\ X^2$
5 cm insulation	$\eta = 91,11 + 3,37\ X - 0,35\ X^2$	$\eta = 81,66 + 6,96\ X - 0,72\ X^2$

As this should correspond to $\eta = 71 + 5,90\ X - 0,25\ X^2$, correlation suggested by M 5000, we notice that we are completely out of range.

Looking however at a dependency $\eta(G)$, for the same X-values as in the first set, we obtain again a good linear correlation

X = -2	$\eta = -10,45.G + 83,86$ (4 points)	r = 0,95	t_{set} = 19°C
X = 0	$\eta = -6,86.G + 93,88$ (4 points)	r = 0,98	t_{set} = 19°C
X = 1	$\eta = -5,26.G + 97,25$ (4 points)	r = 0,98	t_{set} = 19°C
X = 2	$\eta = -3,77.G + 99,53$ (4 points)	r = 0,97	t_{set} = 19°C
X = 4	$\eta = -1,17.G + 100,81$ (4 points)	r = 0,77	t_{set} = 19°C

Fig. 2 gives an overview of the dependency on G for all 3 sets. We see that only for X = 0 and X = 1, a reasonable agreement between set 1 and set 2+3 can be achieved, because of the equivalent setpoint temperature (18-19°C) in that particular case. This indicates clearly the sensitivity of the recuperation factor to the desired setpoint.

category	I (kg/m^2)	Q_{aux} LPB-1/Q_{aux} M5000	η LPB-1/η M 5000
very light	0	1,03	0,98
light	76	1,04	0,97
medium	152	1,11	0,95
medium	274	0,97	1,01
medium	380	0,89	1,05
heavy	456	0,92	1,04
heavy	532	0,89	1,05
heavy	600	0,82	1,08

Table 1 : Shift on η and Q_{aux}, while increasing the building inertia ($X = 1$, t_{set} = 19°, G = 2,2).

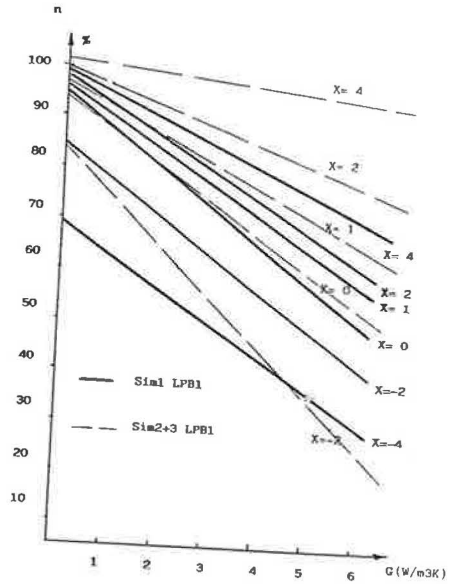

Fig. 2. Simulation sets 1 and 2+3.

4. Interpretation

As M 5000 considers η independent from G, at constant X-values, we clearly see that LPB-1 doesn't, which is logical. Taking ϕ/G as a constant, we have to consider for low insulation levels, high gains, in order to reach the same X-value.

Those increased gains are spread out over the same time-interval, which implies a lower recuperation factor. The Method 5000 averages all this out. For small G-values, LPB-1 gives higher recuperation factors, and vice versa. High and low values of G are unfortunately depending on the X-values as indicated in Fig. 3.

It should be stressed that all solar gains considered in this study originate from ordinary window systems. The solar magnitude was spread out, in all cases, following an idealized harmonious repartition of an "average" day. Basic assumptions of M 5000 were carefully respected, such as conduction losses to the ground and the internal distribution of the raw gains.

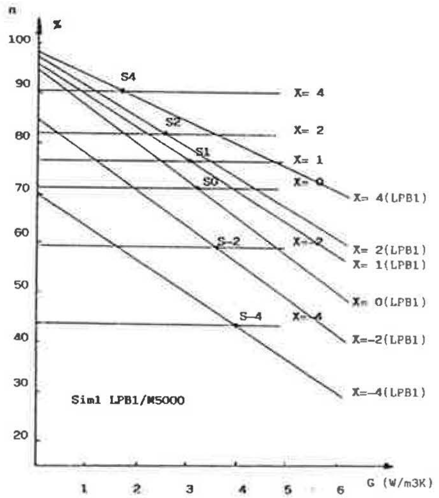

Fig. 3. Simulation set 1.

The dependence of η on t_{set} (or $t_{set}-t_e$ for a given climate) is obvious.

In this study G varied within a very large band (0,5 up to 5,5 W/°Km^3), in order to illustrate clearly the fundamental correlation laws. But even in the normal building practice, large discrepancies between M 5000 and LPB-1 results do occur, (cf. Fig. 3).

5. Conclusion

We proved with the LPB-1 simulations that the solar recuperation factor, as defined in the french Method 5000, not only depends on X and I, but also on G and the set-point (for a given climate). The whole set of simulations is too limited to make final conclusions, but anyway it shows that the correlation should be represented as $\eta(t_{set}-t_e, GV, \Sigma\phi, I)$ in a linear form for constant values of X, I and t_{set}.

6. Nomenclature

Q_{aux} : auxiliary heating (monthly base)

$Q_{no\ gains}$: steady state determinant losses (monthly base)

ϕ_{gains} : steady state raw solar and raw internal free gain (monthly base)

$\eta(X,I)$: recuperation factor on the raw gains, determined by correlation

t_{set} : setpoint temperature

t_{wh} : temperature without heating

t_e : outside temperature

G : volumetric loss coefficient (W/m^3°K) of the heated volume

V : heated volume

I : inertia category.

7. References

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