# HOW GOOD ARE SINGLE ZONE - MONTHLY BASED - CORRELATION METHODS FOR BUILDING ENERGY AND COMFORT PERFORMANCE ASSESSMENT

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## ABSTRACT

OBJECTIVE

Several single zone, monthly based, correlation methods have been developed at a national level, over the past few years. Although the application limits of those methods are mostly unclear or unknown, the tendency grows to promote at the international level, such correlation methods as basis for simplified thermal calculations in the design process.

The validity of a single zone, monthly based, correlation approach is analysed for residential building types in different european climate zones.

METHODS

Through numerical simulations with the CEC-reference model ESP, and using 5 european Test Reference Years - Copenhagen, Lerwick, Brussels, Milano, Trapani - a parametric analysis has been performed on different construction and building types. Simulation results are compared with calculations which follow the draft EUROCODE methodology, the IEA annex XII methodology, and the french Method 5000 methodology.

A sensitivity study was undertaken with regard to environmental parameters, building parameters and heat transfer mechanisms, in the scope of energy and comfort performance assessment.

RESULTS and CONCLUSION

Detailed results are reported in the paper. However some of the main conclusions are :

- if the objective is to predict energy and comfort in a building within a 15% accuracy band on a yearly base, then a unique correlation curve can not be derived for the wide variety of european climate zones, building types and building operations, when adopting a single zone correlation method.
- the transmission losses are strongly dependant on the net radiation balance (shortwave/longwave), especially in the Mediterranean area. Therefore assumptions about boundary heat-exchange phenomena (global/splitted h.e.-coeff., fixed/free convection coeff., absorption/emission) are extremely important together with the choice of control temperature and control strategy.

This paper contains also several indications for future design tool development, badly needed by the design profession.

## 1. INTRODUCTION

Several monthly based correlation methods have been developed at a national level, over the past few years. Although the application limits of those methods are mostly unclear or unknown, the tendency grows to promote at the international level such methods as basis for simplified thermal calculations in the design process [(1), (2), (3)]. The validity of a single zone, monthly based, correlation approach is analysed for residential building types in different european climate zones. This paper aims to highlight : the need for an appropriate use of correlation based methods.

## 2. CORRELATION PRINCIPLES

The fundamental energy balance, over a given time interval, for a controlled space, equals :
(I) input demand = losses - gains + accumulation.
On a monthly base, the accumulated energy within an occupied building is neglectable, compared to its losses and gains. When assuming that the input demand is dominated by heating, while the indoor temperature is allowed to fluctuate between a heating and a cooling setpoint, the fundamental energy balance (I) can be expressed as :

(II) $QD = QL^{d}_{ng} - \eta \times QG$, or as

(III) $QD = QL^{d}_{ng} - QG + QG^{d}_{oh}$, with

QD, QG : heat demand and free gains (solar + internal)

$QL^{d}_{ng}$ : 'design load', corresponding with design conditions

$QL^{d}_{oh}$ : 'overheating load', corresponding to the actual difference with the design temperature

$\eta$ : recuperation factor on the free gains

(IV) $QL^{d,i}_{ng} = \int (HLE^{i} \times (T^{i}_{d} - T_{e}) + \sum_{j=1}^{k} HLI^{ij} \times (T^{i}_{d} - T^{i}_{a})) \cdot dt$

(V) $QL^{d,i}_{oh} = (HLE^{i} + \sum_{j=1}^{k} HLI^{ij}) \times O^{i}$ with $O^{i} = \int (T^{i}_{i} - T^{i}_{d}) \cdot dt$

HLE, HLI : specific building loss coëff. to outside and adjacent-zones

$T_d$, $T_i$ : design and real room temperature

$T_e$, $T_a$ : external and real adjacent room temperature.

In essence the correlation principle identifies a correction coëfficient to be applied on a steady state (monthly) design calculation, in order to quantify the usable and non-usable part of the free gains. The first approach determines a correction on the free gains ($\eta$), the second approach determines the deviation from the design temperature (O). Both approaches can be applied in a multizone configuration, including non heated zones.
In both cases the correlation depends explicitly on global building parameters and average climate characteristics, and implicitly on building type and

and operation, together with the time and space distribution of all free gains. The explicit functionality is represented as f(X,I). In most methods X characterises the building/(climate + occupant) interaction. Two approaches are commonly used :

- the temperature difference approach : $X_1 = T_d-(T_e + QG/HL\Delta t)$ [(4)]
- the gain load ratio (GLR) : $X_2 = QG/QL^d_{ng}$.

It has been shown [(5)], that the temperature difference approach restricts too much the future applicability of the correlation. The GLR approach is better suited because the ratio of (uncontrolled) temperature independant heat fluxes on (uncontrolled) temperature dependant heat fluxes is a fundamental characteristic, which in most cases also corresponds to the ratio of instantanious on delayed fluxes.

The second correlation parameter (I), describes the dynamic building behaviour. Two approaches are feasable

- the thermal mass classification : I1 (kg/$m^2$ - category)
- the thermal inertia or maintime constant : I2=E/HL (sec).

The first approach (classification of a building in an 'inertia category', corresponding to the 'useful' internal mass) is most widespread but not very suited for the evaluation of the building respons to intermittant heating profiles [(6)]. The second approach (a continuous parameter describing the ratio of potential energy storage on specific loss coëfficient) is more general [(7)], and well adapted for describing intermittant heating profiles, but not always suited for the evaluation of immediate respons to radiative sollicitations [(6)].

In itself the correlation approach is valid as far as $QL^d_{ng}$ and QG can be evaluated correctly by the user of the method, and if the implicit correlation assumptions differ not too much from the envisaged building and climate. In order to facilitate the assessment of $QL^d_{ng}$ and QG for the user, most methods oversimplify the building description and operation, so that the link with actual design decisions at zone, room or component level is lost, and that even compliance with general building regulations becomes doubtful.

The next paragraphs highlight the drastical impact of implicit correlation assumptions and oversimplifications on the overall energy and comfort predictions.

## 3. DETAILED SIMULATION ANALYSIS

In order to assess the 'accuracy' and 'credibility' of correlation based methods, it is mandatory to refer to the 'validity' of the detailed reference programmes from which they are derived, and to the used performance assessment methodology. Results in this paper refer to simulations with ESP [(8)], using 5 european Test Reference Years [(9)] - Copenhagen, Lerwick, Brussels, Milano, Trapani -, on different construction and building types (including those used in EUROCODE and PASSYS, [(1),(3)].

A sensitivity study was undertaken with regard to :

- the external/internal radiation balance (on opaque surfaces)
- the choice of indoor control temperature (air/resultant) and strategy (intermittancy)
- the multizonal building description, including interzonal air flows
- the solar interaction type (shadow, indoor solar path)
- transmission losses to the ground.

The complete results are reported in [(10,(11),(12)], some of the main results are presented here.

- The way in which the heated zone is subdivided and unheated zones are specified, affects not only comfort assessment but also the energy requirements. A comparison between a 2-zone and a 9-zone description of the EUROCODE building, indicates an overestimation from 1% to 8% in Brussels for the 2-zone configuration. In the Mediterranean area however overestimations as well as underestimations (of more than 20%) might be obtained, depending on the radiative/convective nature of the gains. It is also very true that trends valid for the whole building, are not necessarely respected in all thermal zones, which is an essential design feature.
- The solar interaction with a building is not limited to its so called solar aperture (windows and other PSC), but extends to the whole building envelope. For a typical detached building, the net (solar and longwave) radiation balance on external opaque surfaces varies from -10% in Sicily to -39% in Scotland, of the raw incoming solar gains through windows, during the heating season. Omission of the external radiation balance on opaque surfaces affects the global energy need up to 10%, because longwave radiation losses are not compensated by solar gains. This is an important aspect for building regulations, which take the 'passive' solar use into account, and which are applied in different climatological regions.
- Other crucial inputs are the with-hold heat-transfer mechanisms at the inside and outside, together with the imposed control strategy. Those aspects clearly belong to the implicit correlation assumptions. Location of a sensor in a North or South zone affects the energy need in the Mediterranean area up to 40%. Shifting from 'global' to 'splitted' heat-exchange coëfficients 'increases' the energy need in a South zone but 'decreases' the energy need in a North zone (in Brussels). Assumptions on the convective heat exchange might influence the global energy need from 10% to 40%, and reduction of internal longwave radiation up to 30%. The definition of indoor reference temperature, as air or dry resultant, might affect the energy need as much as 20%, the width of the controller deadband as much as 10%.

For Brussels and Trapani, Table 1 indicates the range of impact of several 'hidden' assumptions on the variation in yearly energy need, for a non solar and air-leaky building (infil = 1 ac/h) without detailed window modelling, represented as a single zone.

Table 1. Variation in yearly energy need due to changes in modelling assumptions

| modelling assumptions | UCL from - to | TRA from - to |
|---|---|---|
| h.e. coëff.(global/splitted) | -11%/+4% | -57%/+7% |
| control temp. (res/air) | -14%/-2% | -25%/+8% |
| solar interaction(air/floor) | - 5%/0% | -10%/+14% |
| internal longwave $\varepsilon i(0,9/\phi)$ | - 6%/+1% | - 8%/+5% |
| ground coupling (soil/air) | 14%/22% | 12%/52% |

4. CONCLUSIONS ON SINGLE ZONE CORRELATIONS

Even if single-zone correlation methods were perfect (i.e. results close to detailed one-zone simulations), they remain useless because they give an answer to an unexisting problem, corresponding to an oversimplified and unrealistic building. Therefore a multizonal approach for correlation methods is mandatory. Besides that they should also be able to deal with intermittant heating and operation. For this, many of the existing methods are far from perfect, as indicated in Table 2.

Table 2. Range of energy savings predicted by ESP and EUROCODE due to intermittant heating (in %)

| climate | UCL | | TRA | |
|---|---|---|---|---|
| method | ESP | EUROCODE | ESP | EUROCODE |
| range | from-to | from-to | from-to | from-to |
| int.heating | 8/16 | 14/15 | 9/40 | 3/15 |

Too many implicit assumptions are hidden in existing methods making it difficult to judge when the method is applicable or not. Building operation should be made explicit. This should lead to a variety of correlation methods/curves valid for different building operations, (and building types). It is not for sure that one single correlation curve can be obtained for the different climatological regions in Europe. However, the following framework is proposed

a) for free gains recuperation (2 zone configuration)

$$QD^1=QL_{ng}^{d,1}\cdot(1-GLR+Z) + UA(O_1-O_2 + DH_1-DH_2)$$

with

$$Z = (A+B.GLR).e^{-(C+D.GLR).\tau} = \frac{O_1}{DH_1}$$

$$\tau = E/_{HL}$$

$$GLR = QG/QL_{ng}$$

UA = conductance to other zones
O = overheating in zone (cfr. infra)
DH = degree-hours.

In a multizonal configuration, gains from other zones are best represented in the steady state formulation, (and not taken into account in the correlation), for reasons of their time delay when the occur.

b) for intermittant heating savings

$\Delta QD = \Theta \cdot \Delta QD_{max}$ (real set-back saving)

with

$\Delta QD_{max} = \beta\cdot QL_{ng}^{d}$ (max. set-back saving)

$$\beta = \frac{\Delta time \cdot \Delta temp}{DH} \text{ (set-back descri)}$$

$$\Theta = \frac{a\cdot\beta + c}{a\cdot\beta + c + \tau}$$

5. RECOMMANDATIONS FOR FUTURE WORK

It is felt that a correlation principle based upon the 'GLR' approach and the 'inertia' concept, for predicting indoor temperature evolutions, has the best chance to cope with both problems of free gains recuperation and the correct estimation of $QL_{ng}^{d}$ in case of intermittant heating. This approach, [(7)] developed at the Ecole des Mines in Paris, is for the moment being analysed and validated in a multizonal context amongst other correlation methods, in the framework of the CEC-concerted action PASSYS-subgroup Simplified Design Tools. Most attention must be given to an adequate description of the timedistribution of the free gains, and to the radiative/convective nature of those gains. According to the framework described in §4, a set of correlation curves for different buildings and climates in europe, is now extracted from detailed simulation runs.

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