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BEHAVIOURAL COMPARISON OF SOME PREDICTIVE TOOLS USED IN A LOW-ENERGY BUILDING

Adrien Brun[1], Clara Spitz[1&2] ,Etienne Wurtz[1] and Laurent Mora[3]
[1]LOCIE Université de Savoie, F-73377 Le Bourget du Lac – CEDEX FRANCE
[2]CEA-INES-RDI, Le Bourget du Lac –FRANCE
[3]TREFLE – UMR CNRS, F-33405 Talence – CEDEX FRANCE

ABSTRACT

Today, many building software tools for evaluating energy efficiency are available. More than three hundred are listed by the US Department of Energy. Despite the diversity of the tools and their users, they generally share the same goals: to reduce the consumption of energy and even to produce surplus energy.

We were interested in comparing the information provided by five softwares programmes that are widely used in France: EnergyPlus, TrnSys, CoDyBa, Pleiades + Comfie and PHPP. We used these programmes to predict the energy performance of an experimental low-energy building, currently under construction at Le Bourget-du-Lac. This building is the first one on the experimental platform of the French National Institute of Solar Energy.

INTRODUCTION

The growing trend to reduce consumption in the building sector is seen in a new generation of buildings - “low-energy buildings” - characterised by their lack of conventional HVAC systems. While many predictive tools are available today, few are specifically dedicated to these new constructions.

This trend towards the rationalisation and optimisation of energy use means that the professionals in the field need to have tools to estimate performance at all stages of design.

Taking advantage of the current construction of the experimental building, we constructed a intercomparison model based on this low energy building definition. Tools widely used in France were selected.

In this paper, we provide a description of the tools used, the experimental building and its experimental context.

Then we set out the assumptions and two variants (convective exchange and preset parameters used by tools).

Finally, we present the results obtained over 2 days (hot and cold) and the annual results for each variant.

THE TOOLS

The five tools selected are those used by a very broad panel of engineers, architects and researchers; they belong to various categories characterised by distinct level of expertises. TITTELEIN proposed classifying these tools in the following categories: those to obtain tendency {PHPP}, those for optimisation of the building envelope {CoDyBa, Pleiades + Comfie}, those for dimensioning HVAC equipment and prediction of consumption.

EnergyPlus and TrnSys:

Both are dynamic simulation tools, characterized by considerable model libraries but their building component models are distinct. These are a few examples: wall conduction model (TrnSys: Transfer function, EnergyPlus: choice between finite difference and transfer functions), Diffuse sky model (TrnSys: isotropic and anisotropic sky, EnergyPlus: anisotropic sky)

Pléiades+Comfie and CoDyBa:

Both are dynamic, “monolithic” tools developed by French laboratories (CoDyBa: CETHIL INSA Lyon and Pleiades+Comfie: *Ecole des Mines*, Paris). They use model reduction in order to decrease computing time.

PHPP:

This programme was developed by the *PassivHaus Insitut* of Darmastadt and is dedicated to passive buildings. It uses a static method based on a monthly assessment (EN13790).

Among this tools, some are internationally used (EnergyPlus: 46000 downloads since April 2001, TrnSys: 958, PHPP: several thousand in the world and 600 licences in France); others are mainly used in France (Pléiades+Comfie: 2000 licences, CoDyBa: 50 licences).

CASE STUDY

INCAS Platform

The INCAS platform resulted from the need to experimentally validate the numerical models developed by the French National Solar Energy Institute. Eventually, it will accommodate several experimental constructions. The first series will be identical in design and dimensions, differing only in the construction methods and the HVAC systems. Internal loads of these buildings will be precisely controlled and external solicitations will be measured.

Experimental construction

Figure 1: The experimental building

In the study, we have considered the "cavity wall" type of construction.

This two-storey building is well exposed to the south (34% glassed) and its ground measurements are 7.5m x 8.5 m. Its design was deliberately simplified to make easier the validation phase.

Such features as the insulation (20cm for walls and 40cm for ceilings), the reduction of thermal bridges and cracks, the active and passive solar shading and the specific HVAC systems make this a very energy-efficient building.

NUMERICAL MODEL

Our approach

In order to compare the programmes, we established a description to be applied to all of them. One should keep in mind that the chosen interpretation was not set up to compare the numerical model with the experimental measurements, but simply the numerical models between themselves.

Assumptions

1. Heating system: Unlimited heating capacity with the set thermostat of 19°C.
2. The heat bridges were not taken in account.
3. Solar Shading: only the south fixed shading (roof overhang and balcony) is considered.
4. Heat convection transfer coefficients: at first they are constant and equal to the Pleiades + Comfie imposed value (table 1), then (Simulation2), they are calculated with EnergyPlus detailed convection algorithms and their average values (table 2) are used .

Table 1
Convective coefficient exchanges [W/(m²K)] , Simulation1

PB		PV		Pvi		PI		PH	
Int	Ext	Int	Ext	Int	Ext	Plaf	Plac	Int	Ext
1.8	3.3	3.3	14.9	3.3	14.9	3	3	4.6	18.9

Table 2
Convective coefficient exchanges [W/(m²K)] , Simulation2

PB		PV		Pvi		PI		PH	
Int	Ext	Int	Ext	Int	Ext	Plaf	Plac	Int	Ext
1.0	1.3	1.1	5.6	1.9	3.6	1.0	0.9	1.0	2.4

5. Natural ventilation: As the most of the tools do not calculate for natural ventilation, underfloor and attic spaces were not included in our model.
6. Heating recovery ventilation system: The CoDyBa version used does not integrate a recovery system; we thus considered a limited ventilation flow-rate energetically equivalent to the real ventilation system.
7. HVAC controller: regarding the energy control system, the dynamic software used can be put into at least two categories. In the first category are tools permitting the integration of their own control system algorithm. The second category includes tools with programmed schedule patterns. We carried out two series of simulations in order to obtain summer and winter performances without undertaking a system description over the year. The first, winter type, uses reduced ventilation flow (energetically equivalent to a ventilation of 0.5 [vol/h] coupled to an exhaust air recovery system) and the second (summer type) uses increased ventilation (2 Vol/h).

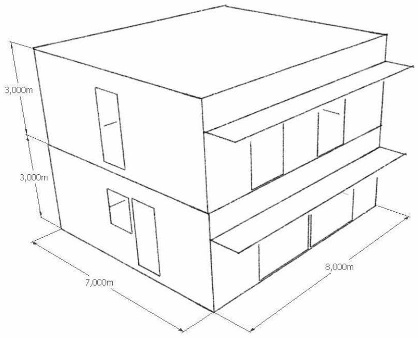

Figure 2 geometry

8. Discretization: two heat balance zones are considered, one for each storey, while aeraulic exchanges are not considerated.
9. Energetic surface: the surface energy balance is calculated on the interior surface (97.5 m ²).
10. Windows: low emissivity double glazing with argon cavity.
11. The occupation schedule corresponds to a family of 4 people having an extenal activity each day of the week: 2 people present between 5 to 6 pm and 4 between 6 pm to 8 am. A heat production of 80W per occupant was considered. Sensible loads are assumed to be entirely convective.
12. Internal loads due to equipements : This is established assuming the use of energy-efficient appliances which release 1600 [kWh] annually, exchanged by convection only. The internal gains are spread uniformly through both zones.
13. Solicitations: Weather, human occupation and appliance use are common to all tools. Their synchronisation (input parameters and calculation (solar height and azimuth)) was checked on EnergyPlus and TrnSys. Pleiades + Comfie and CoDyBa controls were limited to the available output.

Variants - assumptions

The harmonisation process leading to the definition of a common assumption indicated great disparities concerning some physical parameters and default models used by the tools.

In order to evaluate how these parameters might modify the estimation of the building performance (heating consumption and summer free-floating temperature), we carried out two additional simulations.

In the second series of simulations, the convective exchange was modified according to table 2. In the third series of simulations, default settings or imposed approaches were used.

Table 6 : Recapitulation of variants considered

Simulation 1 : ◆ Pleiade ■ EnergyPlus ▲ TrnSys ● CoDyBa ✖ PHPP	Reference Assumptions
Simulation 2 : ▣ EnergyPlus △ TrnSys ● CoDyBa	Simulation with modified convective Exchange
Simulation 3 : ☐ EnergyPlus △ TrnSys ✚ PHPP	Defaults parameters

RESULTS AND DISCUSSION

Air interior temperature and heating power evolution over 2 winter days

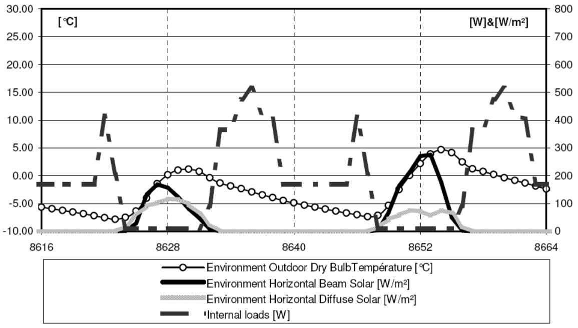

Figure 3: Meteorological solicitations and ground floor internal load

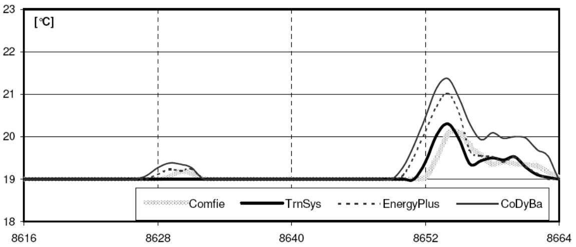

Figure 4: Ground floor air temperature evolution

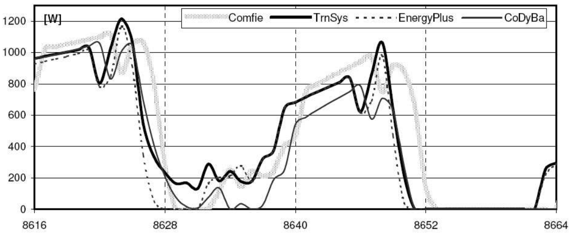

Figure 5: Ground floor power heating evolution

Figures 3, 4 and 5 indicate weather solicitations, ground floor internal load, air temperature and heating power over two cold winter days. During the first 12 hours (8616 to 8628), air temperature corresponds to the minimum set internal temperature (19°C), so the heating power rises above zero until it reaches a maximum of 1200W. For the next 12 hours, internal temperature exceeds the set point due to internal load as well as the solar contribution compensating losses. The heating power is then nil.

Air interior temperature and heating power evolution over 2 summer days

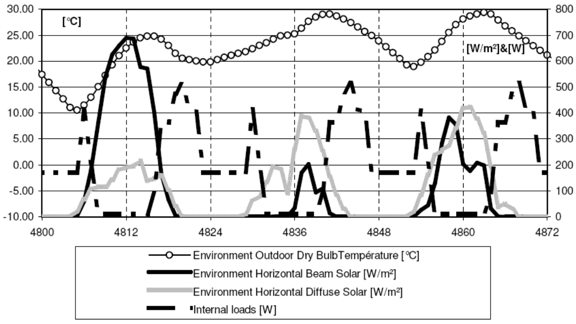

Figure 6: Meteorological solicitations and ground floor internal load

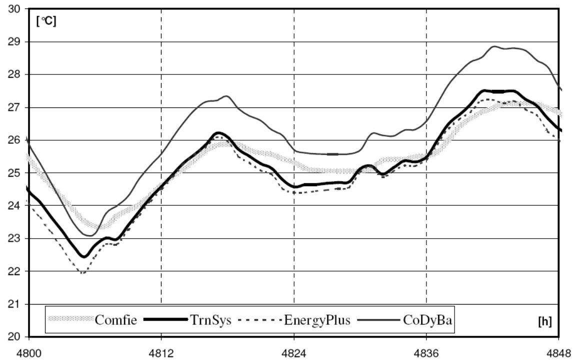

Figure 7: Ground floor air temperature evolution

For a given variant (Simu1), the profiles in terms of temperature and power of heating are similar. The temperature and power heating responses of TrnSys and EnergyPlus are particularly similar. Taking them as reference, it is seen that the CoDyBa median value and phase differ slightly. These differences could be due to the variety of physical models used or to uncertainties on parameter homogenization.

Annual energy balance and overheating

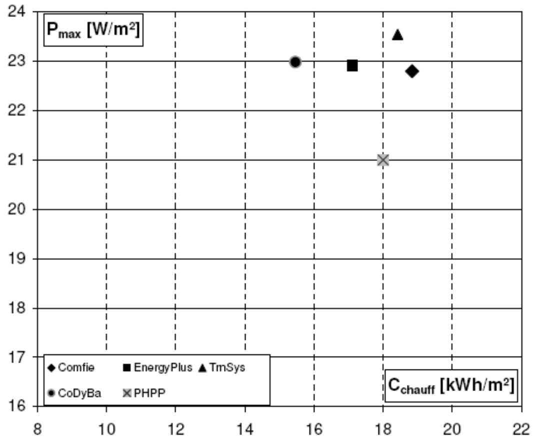

Figure 8: Specific space heat requirement, Simulation 1

Figure 8 shows the results for Simulation 1. The heating needs range from 15 to 19 [kWh/(m².an)] and the heat load varies between 22.5 and 23.5 [W/m²]. The results are completely satisfactory despite the level of uncertainty regarding the selected physical parameters and on the imperfections of the models. As the preceding remarks, CoDyBa shows lower heating needs than the other programmes.

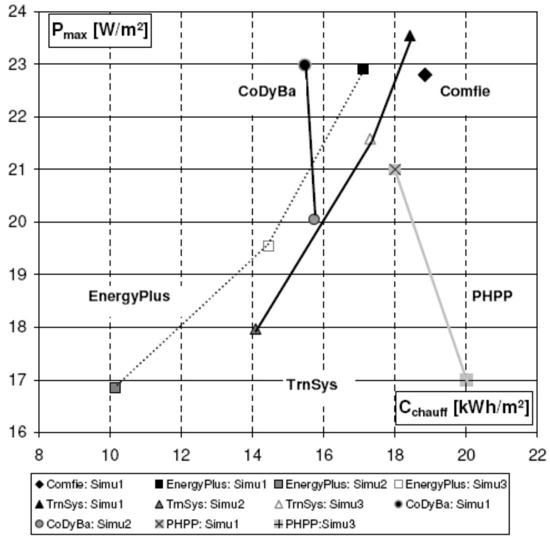

Figure 9: Specific space heat requirement

Figure 9 shows the results of all Simulations. The results of Simulation 1 are the same as in figure 8.

In Simulation 2, the coefficient of convection heat transfer is defined according to the default value or the value suggested by the software. It can be seen that its modification leads to a wide variation in responses.

CoDyBa shows a slight increase in heating needs and EnergyPlus shows a reduction of almost 60%. The heating needs vary between 10 and 17 kWh/(m².year) for EnergyPlus, Trnsys and CoDyBa.

The Simulation with the default parameters shows heating needs at 14.4 kWh/(m².year) for EnergyPlus, 17.3 kWh/(m².year) for Trnsys and 20 kWh/(m².year) for PHPP. By using the default parameters, the variation between results is greater than in Simulation 1.

Incidence of the convection heat transfer coefficient

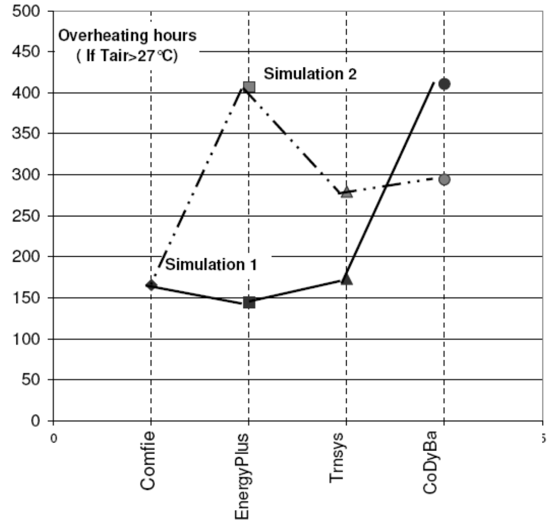

Figure 10: Overheating

Figure 10 shows the rate of overheating with in ordinates the number of hours when the indoor air temperature exceeded 27°C.

From the results of Simulation 1, we see that CoDyBa has double the overheating time of the three others due to the fact that its temperature is always higher (see Figure7). After modification of the convective coefficient, it is EnergyPlus that diverges most from the group.

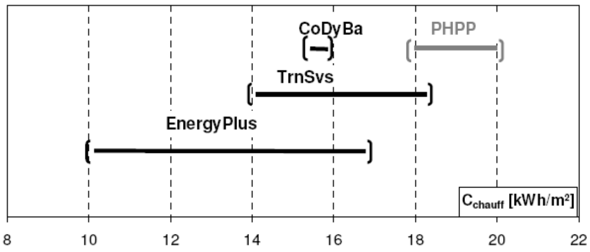

Figure 11: Heating consumption interval

Figure 11 shows the interval that separates the calculated need for heating (Simulation 1) with values from convective coefficients used by these tools (Simulation 2). The upper and lower limits correspond respectively to “Simu1” and “Simu2”. In PHPP, Simulations 1 and 3 limit the interval.

The heat convection transfer coefficients used by these tools can be significant on indicators such as the yearly consumption of heating or the number of hours of overheating. EnergyPlus was the most sensitive on this point: its consumption prediction came down from 17 to 10 [kWh/(m^2.year)]

The variation of a physical parameter, such as the value of the heat convection transfer coefficients used, leads us to relativize the reliability of the indicators in terms of absolute values.

CONCLUSION

The goal of this exercise was to compare the results of simulations for a low-energy building, currently under construction, of five different simulation tools widely used in France.

The need to first define a set of common parameters led us to a simplified description of the case study. Due to the fact that not all the considerate tools afford the HVAC system in the same way, we were forced to disregard dynamic energy management systems.

The limitations or impossibility of modelling HVAC with some of the tools is an important problem in the prediction of the thermal behaviour of these low-energy buildings. Indeed, the combination of internal gain and strategies of passive cooling requires regulation and control. To overcome these problems, the monolithic-type software should be adapted so that they can be used by engineers and architects who value their speed and ease of use. These professions are increasingly solicited for information on the behaviour of such buildings.

The behaviour was evaluated in winter and summer from two simulations with different ventilation flows.

The observation of two Simulation extracts showed a definite harmony in the results for air temperatures and heat load (between 22.5 and 23.5 [W/m ^{2}]) whatever the tools used. The same results were found for the specific space heat requirement (between 15 and 19 [kWh/m ^{2}.year]) and the number of hours overheating (temperatures over 27°C).

A second Simulation was tested: the modification of a physical parameter of the model (the coefficient of convection heat transfer). The values selected were those imposed or suggested by some of the tools.

The modification of the physical parameters resulted in a variation relative to the basic case of up to 60 [%] for specific space heat requirement. These observations of a simple case confirm the great sensitivity of the computer codes to variation in the physical parameters. These parameters have not been well identified, so further study on the uncertainties both on the level of validity of these parameters and on the imperfection of the models is necessary. The metrology which is to be installed in the houses of the INCAS platform should be of assistance in carrying out this work intended to take into account the uncertainties in the computer codes.

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