SIMULATIONS OF LOW-ENERGY BUILDING IN EUROPEAN PROJECT AN EXAMPLE IN LYON, FRANCE

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ABSTRACT

The Lyon Confluence project is an actual urban planning operation of Lyon agglomeration. It is part of a global sustainable development process, mixing economic development, social equity and preservation of natural resources. Due to ambitious requirements in term of energy consumption level and indoor thermal comfort, the project implies a new way of thinking in the design of French construction.

The consortium composed for this project brings together national and European-level expertise for finding solutions to insulate and also avoid overheating during summertime without conventional cooling system.

During the phase of building conceiving numerical simulations have been led by the CETHIL on the software TRNSYS in order to check (energy consumption and thermal comfort) each architect proposal on the whole area. In case of detected non satisfying design, Lyon consortium was in charge of imposing different way of improvement. The modeling and study of one apartment show how important is to increase the free cooling by natural ventilation during the hot period.

This paper presents the ambitious standards that have to be respected into this new project in France. It shows the propositions and the research that are actually in progress on the topic of high efficiency buildings.

KEYWORDS

Building simulation, Thermal comfort, Summer conditions, Low-Energy building design

INTRODUCTION

Recent increased of interest in the development of high-performance buildings is strongly related to the world-wide efforts to reduce greenhouse gas emissions, as well as the rising of conventional energy costs. The building sector constitutes one of the most significant energy consumers (especially of conventional energy), and energy reductions will have a major impact on the reduction of greenhouse gas emissions. The energy management is thus a key point of this process, in bond with inhabitant health especially in their dependence with the indoor air quality.

During summer 2003, The European Union published a call for bidders named “CONCERTO”. This European procedure is about a new way of thinking for the design of a city, about a more environmental urban planning using large amount of renewable energy.

The project called RENAISSANCE received the highest rank from the European experts. The community planned for is composed of two large urban regeneration projects in cities of contrasting sizes and characters: Lyon (F), Zaragoza (E).A other partner is the Lombardia (I) province in regard of its expertise in the field of biomass production (figure 1). The two cities indicated a strong political commitment to sustainable development, social involvement and public-private partnerships.

RENAISSANCE (Renewable ENergy Acting In SuStainable And Novel Community Enterprises) should lead to building with high quality of life, and demonstrate that good environmental practice makes sense in term political, economic and social aspects. The goal is to demonstrate practical solutions to satisfy local energy needs, which are applied in highly innovative ways, with a large and immediate potential for replication across Europe.

At a modeling level this project requires tools which allow to follow and to check the design of building and the efficiency of innovative integrated systems. The choice of such a code is not so obvious codes worked out starting from physical models, mathematical and numerical simplified thus fast and producing results enough accurate in comparison with the enormous stakes (financial, demonstration, political …) of this project.

Figure 1 Location of the Consortium

PROJECT SUMMARY: "LYON CONFLUENCE"

The centre of Lyon between Rhône and Saône rivers

Figure 2 An Enclave

« Lyon confluence » is a project that involves a special area of the city. Set midway between the City Hall and the confluence itself, the project area – some 150 hectares- is at the "heart" of Lyon. It is located between two rivers, the area benefits of 5 km riverbank. For long time the place was restricted to industry and transport facilities. Now the peninsula is undergoing significant transformations.

During one year, Francois Grether – an architect urbanist – Michel Desvigne – a landscape architect - and the urban office RFR have worked on this urban operation to design an ambitious program composed of constructions and public services.

The implementation of the entire Lyon Confluence project is expected to last for a few years. The project suggests a global vision with a long-term perspective over 30 years. This vision is implemented by the first phase of the project, an urban project itself, that involves the transformation of the whole site through the sale of three blocks. This phase aims to show the features of the new community in terms of sustainable development and social mixture.

These three blocks are expected to contain 61 150 m² of dwellings and 15631 m² of professional and business offices.

The three blocks, named A, B and C, of the Renaissance community in Lyon are shown on the figure 3:

Figure 3 The three lots of the first phase

"Greater Lyon" Consortium

The consortium formed for the Lyon-Confluence project brings together national and European-level expertise. The Lyon Consortium is made of:

Local authorities:

- The Greater-Lyon Urban Community

- SEM Lyon-Confluence (the local public/private limited company in charge of the development project of the Confluence)

Partners:

- Hespul (an internationally recognised non-profit organisation specialised in RUE (Rational Use of Energy) and RES (Renewable Energy Systems) promotion)

- Agence Locale de l'Energie de l'Agglomération Lyonnaise (The ALE is the local Save Agency established as a non-profit organisation)

Technical experts

- Enertech (a consulting team specialised in building energy analysis studies)

- CETHIL/INSA Lyon (a research and educational laboratory specialised in thermal sciences applied to buildings and construction)

Real estate developers, architects and RUE/RES engineers

PROJECT OBJECTIVES: BUILDING ENERGY SPECIFICATIONS FOR LYON

RENAISSANCE project aims to prove that is possible to design and construct buildings at a large (quarter) scale using large amount renewable energy and providing high quality of life for occupants. Once built, the community will demonstrate high levels of performance. The design approach will combine some innovative, low-energy architecture based on bioclimatic / passive solar design, renewable energy technologies and building life-cycle analysis.

The Building Energy Specifications for Lyon consist in:

- The reduction of energy demand

- The increase of the contribution of renewable energy sources - 80% of energy demand for heating and Domestic Hot Water (DHW), and 50% of the electric demand for common spaces; this goal will be achieved by using biomass and photovoltaic and thermal solar (uniquement Zaragossa)at competitive cost.

- The decrease of emissions of carbon dioxide per inhabitant (at least 30% imposed by Cncertto program)

- The use of active systems for cooling is prohibited. The summer thermal comfort conditionsshould be satisfied, by using in priority structures with medium inertia to benefit from natural cooling at night.

Table 1 Building specification (Building category: housing)

	RT 2000	CONCERTO	DECREASE
UBat [W/m²K]	≤ 1	≤ 0.6	40%

Table 2 : Final energy demand for space heating per m2 of total used floor area [kWh/m2.yr] (Building category: housing)

	RT 2000 [kWh/m².yr]	CONCERTO [kWh/m².yr]	ENERGY SAVINGS
Total space heating	100	60	40%
RES measures (80% of RES on total space heating have to be achieved thanks to wood boiler rooms)	0	48	
Cooling (only medium inertia to increase natural cooling during the night)	0	0	-

At the time of RENAISSANCE project formulation the current French standards for energy performance of new buildings was RT-2000[1] published in year 2000. This regulation only considers the building heating needs and implicitly overestimates the performance of the building's envelope. The Renaissance objectives are around 40% more restrictive than RT2000 (tables 1 and 2).

The experience learnt from the participation in Concerto project like RENAISSANCE will certainly help to show that higher standards are feasible and cost-effective.

Note that specifications are differentiated for housing and for business offices.

One of the particularities of Lyon Confluence project is the high rate of renewable energy used for satisfying the energy demand for heating and DHW. On each lot of estate, thermal solar collectors for DHW and photovoltaic panels are planned to be installed on the roof, along with wood-fired hot water boiler.

If the energy needs for heating and DHW can be reduced through an appropriate design of the external building envelope combined with the use of renewable energy sources and technologies, it is more difficult to maintain the indoor air temperature within comfortable range during the summer.

Renaissance project intends to ensure the building internal comfort during the hot season, even if the use of active cooling systems is not allowed. This is one of the key points of the project, especially in the case of global warming. Thus the objective is to reach comfort conditions through passive design alternatives. The design for comfortable summer conditions has a special significance for this particular project. The following design conditions for summer are set:

Building category: housing

- The temperature should not exceed 28°C more than 40 hours a year.

Building category: business offices

- The temperature should not exceed 28°C, more than 80 hours a year.

SUGGESTED SOLUTIONS FOR SUMMER THERMAL BEHAVIOUR

In order to comply with the requirements of the contract of the Lyon Confluence Project, and to ensure thermal comfort conditions for occupants during summer, the following measures are proposed.

First of all, the total glazing area is limited to 20% of occupied floor area (or the whole façade surface ? il me semble) in order to reduce overheating but also heat losses. This ratio is selected because it gives a good balance between natural lighting and the reduction of solar gains in the summer. Solar protections are installed on every building to reduce solar gains through glazing.

In order to avoid the use of active cooling system, most apartments are designed with two crossing orientation, and will benefit from the free cooling by natural ventilation. Materials with high thermal inertia are recommended to control the indoor temperature and protect apartments from overheating.

SIMULATIONS

TRNSYS

Renaissance project includes a comprehensive programme of research and technical development. The research elements will produce data and new knowledge regarding public response to new strategies for energy efficiency in buildings, development of planning policies, building design and monitoring of energy systems.

The role of the INSA/CETHIL in the project includes the computer modelling of energy performance and thermal comfort of occupants with the goal of achieving low-energy buildings, the participation to the post-occupancy evaluation and monitoring of thermal parameters and the dissemination of results through the network of universities and publications.

The choice of the tool has been made under following considerations. In theory, the computer codes incorporate models whose refinement is coherent on the space and the time step. The different levels of precision considered according to the codes depends according to: the spatial dimension (1D definition, 2d...), the phenomenological dimension of description (stationary, dynamic, heat and mass transfers, real couplings, systems and buildings, real couplings with urban environment), localisation in the object or systems (boundary layer, walls, housing, building, set of buildings...). It can be noticed that many modelling tools do not present homogeneous refinement in regard of this 3 levels. The main reason is the modelling complexity of certain spatial localisation of the object and the multi-scales considered through phenomena to buildings including systems and energy management. Finally, Moreover we sought open tools allowing us to develop during the operation models of innovating (almost prototype) in order to be able to quantify their real thermal or energy impacts on inhabitants. For all these reasons the choice is to carry the computer modeling using the TRNSYS (TRaNsient SYstems Simulation) program that has become a reference software for researchers and engineers around the world [2]. The modular nature of TRNSYS provides interesting flexibility in applications and in development of new models for special components or systems. Figure 4 shows, in a generic form, the input and output data.

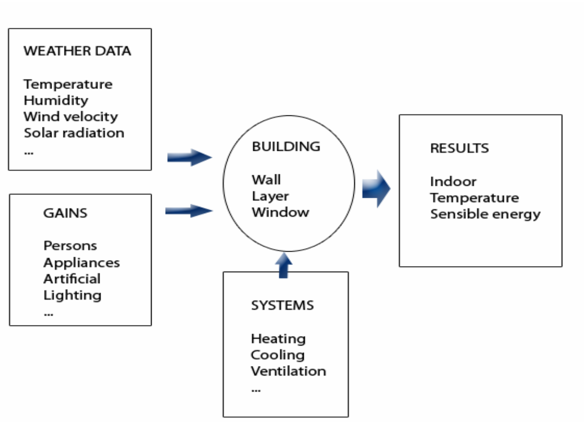

Figure 4 Input and output data used with TRNSYS

In a project at such a large scale as RENAISSANCE, simulations can not be ignored. They offer the possibility to compare the effect of coupling between systems and building. It allows to evaluate the performance of innovative architectural design alternatives with respect to energy demand and thermal comfort.

Scenario

In order to be as close as possible to real conditions with respect to building operation and weather conditions, the following scenario is developed.

- **Weather data**

The weather data came from the METEONORM file from the Lyon-Bron site. It contains hourly values of all meteorological parameters needed for such modelling.

- **Internal gains**

Internal gains are quite difficult to be accurately estimated. On the other hand, they may play a noticeable role on the results. Hence, they should not be neglected.

For the Lyon Confluence project, the scenario considers the hourly variation of internal gains, in W/m² from appliances (e.g., computers, TV, …), artificial lighting, cooking, DHW loop, and people. Figure 5 shows, as an example, the hourly variation of heat gains in an apartment.

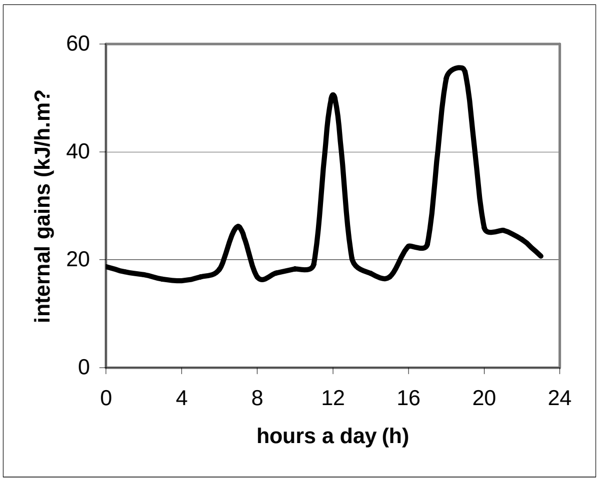

Figure 5 Internal gains for an apartment

Example

This section shows, as an example, the analysis of energy performance and thermal comfort of one apartment on a typical floor of Block C of the Lyon Confluence Project. This apartment is chosen because of its small size (36m²), its West Orientation and its single façade that reduce the effect of free cooling during summer season. Thus, this apartment shown on the figure 6, will have difficulties to satisfy summer conditions.

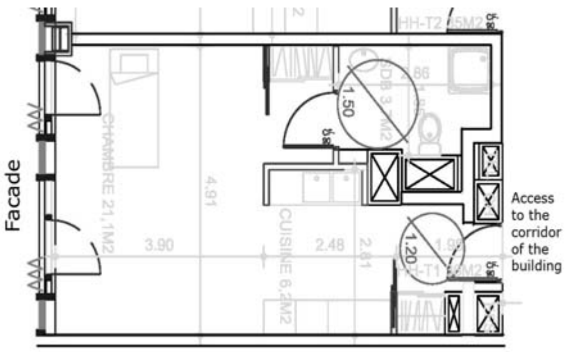

Figure6 Plan of the apartment

- **Description:**

- External wall: U = 0,22 W/(m².K)

composed of (from inside to outside):

concrete 10 cm (k=2 W/(m.K)) ;

rock wool 15 cm (k=0,035 W/(m.K))

- There is no thermal exchange through the ceiling and floor, because the apartments above and below are considered at the same indoor air temperature. Only the thermal inertia of the ceiling and floor is considered.

- Window : U_w=1,5 W/(m².K) (double glazing 4/15/4 such as Saint Gobain Climaplus Futur)

- In summer, solar protections are efficient during day time (shading factor of external device: 90%)

- **Systems:**

- Thermostat setting: 19 °C at night and 21 °C by day;

- Heating system: radiators with hot water

- Central mechanical supply ventilation: total ventilation air flow rate supplied in the apartment is 35m^3/h (90 m^3/h during cooking), in compliance with RT-2000. The air is extracted from kitchen and bathroom.

- **Results (TRNSYS)**

- Cold Season: from November the 1st to April the 1st

Sensible energy demand for heating of the apartment : **22 kWh/m².yr**

- Hot Season (from June the 1st to September the 15th):

In summer, natural ventilation by opening windows is simulated between 6 am and 8 am (Airchange of infiltration = 2Vol/h).

TRNSYS evaluates the number of hours during which the indoor temperature exceeds 28°C.

Table 3 and Figure 7 show the number of hours when the indoor air temperature in the apartment exceeds a given value.

Table 3: Number of hours with T>x

Number of hours with T > 28°C	Number of hours with T > 27°C	Number of hours with T > 26°C	Number of hours with T > 25°C
5	207	588	967

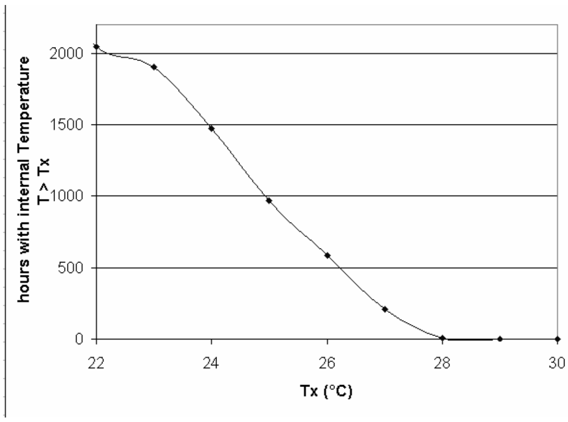

Figure 7 Number of hours with T>x

The sensitivity of the thermal model to different parameters and systems is obtained by comparing the results corresponding to each parameter with a base case or reference model.

The following cases are analysed:

- **Variation of the duration of natural ventilation**

Natural ventilation by opening windows is simulated during different period. The objective is to see the importance of increasing free cooling during the hot period. The effect of night cooling is shown on figure 8.

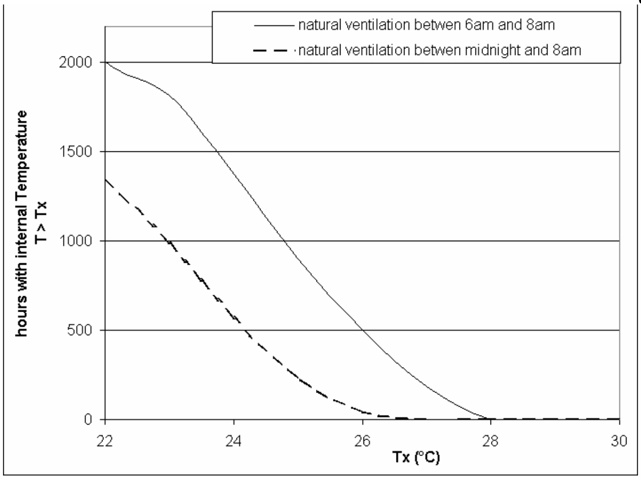

Figure 8 indoor temperature of the apartment with different duration of natural ventilation

- **Change of the mechanical ventilation (central mechanical supply ventilation or mechanical balanced ventilation)**

In this case, the use of different mechanical ventilation is simulated. First of all, the apartment is equipped with a central mechanical supply ventilation; then with a mechanical balanced ventilation (Heat transfer coefficient of the cross flow heat exchanger: 70%). This simulation gives some specifications to reduce the energy needs.

- Cold Season (from November the 1st to April the 1st):

Table 4: sensible energy demand for heating with different mechanical ventilation

	SENSIBLE ENERGY DEMAND FOR HEATING (KWH/M²/AN)
Central mechanical supply ventilation	22
Mechanical balanced ventilation	15

The Table 4 shows that the use of a mechanical balanced system in winter, leads to 32% decrease of sensible energy demand for heating.

- Hot Season (from June the 1st to September the 15th) :

In summer, the mechanical balanced ventilation is not an efficient system because the delivery air would be warmer than the external air and so it would favour the warming of the apartment. Therefore, if the mechanical balanced system is installed, it should be disconnected during the hot season. Figures 9 and 10 show the hourly variation of outdoor air temperature, of indoor air temperature and delivery air temperature.

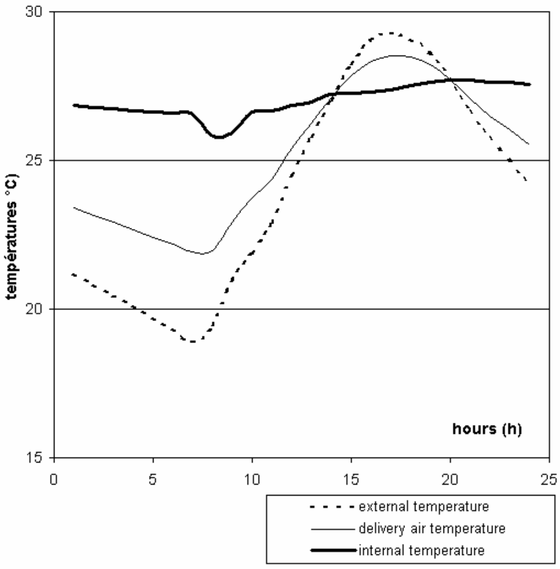

Figure 9 variation of external temperature, delivery temperature and internal temperature during one day in summer August, the 15th

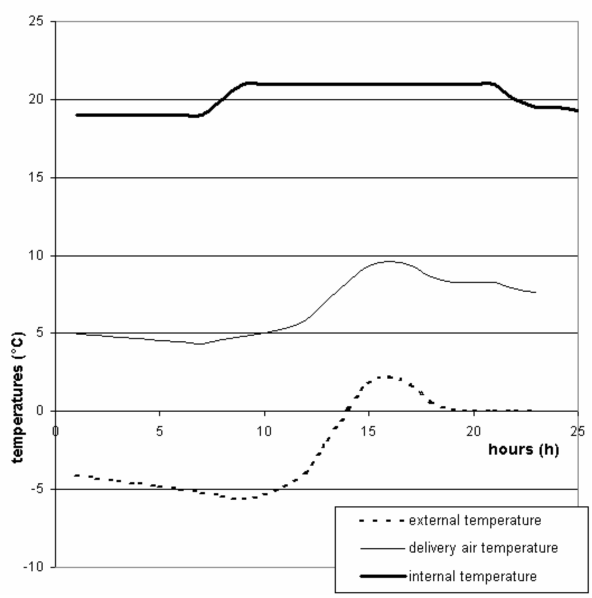

Figure 10 variation of external temperature, delivery temperature and internal temperature during one day in winter January, the 15th

CONCLUSION

If in one hand the conventional energy needs for heating can be reduced through an appropriate design of the buildings and the use of massive renewable energy resources, in the other hand, the control of internal temperature during hot periods without conventional cooling systems is much more difficult to achieve.

However the winter conditions are strongly guiding the design of the apartment. Until now in France, it was the main point. (déjà dit).

The so called “winter optimization” of the building could lead to overheating in the summer, if the design does not consider both seasons. The control of indoor air temperature in the summer, without active air cooling, is presently the new objective in France. The goal should be the optimization for building design for both seasons.

The analysis of results shows that it is very difficult to limit the indoor temperatures to the recommended values without mechanical cooling systems during the warm period. Some solutions like the night over-ventilation may reduce the indoor air temperature during day time, however, other solutions should be tested in the RENAISSANCE project.

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