Improvement of summer comfort in wood frame buildings

G. Fraisse, V. Trillat-Berdal and B. Souyri
Design Optimization and Environmental Engineering Laboratory (LOCIE)
Civil Engineering and Housing Team, University of Savoy, ESIGEC

ABSTRACT

Wood construction presents numerous advantages on the environmental impact. Envelopes of wood frame houses already have air gaps. We wish to use them in systems aiming at to reduce the energy loads in winter and to improve the thermal comfort in summer. We so decided to couple a façade integrated solar air collector with a heavy and ventilated internal wall. The envelope of wood frame houses being light, it is possible to store solar energy in the internal wall. The internal wall justifies itself with regard to summer comfort as we considered it is important to increase the thermal inertia of the house in a sensitive way. Furthermore, the cooling of the house can be obtained thanks to a night-ventilation of the internal wall.

1. INTRODUCTION

In France, timber frame construction represents only 5 % of residential housing. However, the timber construction gives numerous advantages for sustainability: CO_2 fixation … The advantage of using timber frame for ventilated walls is that air gaps already exist in such buildings. The main purpose of this study was to develop a system which aims at reducing the energy demands and improving thermal comfort in summer. Previously, we studied dynamic insulation (Fraisse, 2004) and here it is a question of recovering heat losses within the walls (Cadiergues, 1986) or windows (Paziaud, 1997) (Baker, 1999) (Schmidt, 2002). The aim is to preheat fresh air in one or two air gaps and thus to reduce energy demand in winter. We give evidence, by means of numerical simulations, that recovering solar energy is currently much more efficient than using dynamic insulation within new buildings (Fraisse, 2004). Furthermore, the new thermal regulations (CSTB, 2001) aim at reducing heat losses. It is also stated that the implementation of a dynamic insulation system requires a careful installation (causing additional costs).

Because it is more efficient to recover solar energy, we therefore decided to study an integrated solar air collector. The existence of an air gap and of thermal insulation, plus the modular structure of timber frame houses makes the installation of our system within the envelope easier. These houses being low thermal mass, it is necessary to be able to store solar energy. Besides, increasing the thermal mass of the house improves summer thermal comfort. We have also initiated the installation of a heavy and ventilated internal wall (HVIW) within an existing house. This wall is made up of two prefabricated concrete walls and in winter warm air circulates from a solar collector. In summer, night-ventilation of the HVIW allows to reduction of the internal room temperature.

2. STORAGE OF SOLAR ENERGY WITHIN THE BUILDING ENVELOPPE

The collection and storage of solar energy can be carried out with only one envelope component. This is the principle of the Trombe wall which is a heavy and glazed external wall warming the room air (Trombe, 1971). Internal air enters the lower part of the wall, is warmed between the glazing and the wall, rises by natural convection and is returned into the room.

The solar collector (without thermal mass) and the storage system are generally two different components of the envelope. The integration of the solar collector in the envelope allows to make financial savings by substitution (Pottler, 1999) (Ubertini, 2003). The collector is very often glazed to increase energy retrieval performance. Nevertheless, an unglazed collector (Solarwall) was successfully developed in Canada (Hollick, 1996).

Heat storage in a building envelope is not a new system. The Romans circulated warm air in walls and slabs (hypocaust and murocaust heating). Warm air from fire chambers circulated in the envelope (Potier, 1998).

The literature presents numerous buildings where the coupling a solar collector with ventilated floors or walls is used (Bansal, 1999) (Howard, 1999), (Imessad, 2003) (Gütermann, Web) (Lee, Web) (Nordstrom, Web) (Rahbek, 2001) (Schuler, Web) (Takase, Web). It is very difficult to compare the energy performance of various systems because of the way data is given and of the variable weather conditions. Finally, several systems reducing heat loads are often used simultaneously. Thus it is difficult to know the contribution of each system.

3. NUMERICAL STUDY

3.1 Modeling

It is obviously necessary to consider the thermal mass of the walls in the numerical simulations. The outlet air gap temperature can be calculated from the relation :

$$Tout = (\alpha_1 \cdot T_4 + \alpha_2 \cdot T_6) \cdot \lfloor 1 - \exp(-\alpha_3 \cdot H) \rfloor + Tin \cdot \exp(-\alpha_3 \cdot H)$$

with: $Tout$ outlet air gap temperature
Tin inlet air gap temperature
T_4 T_6 surface wall temperatures
H air gap height
$\alpha_{1..3}$ heat transfer coefficients

The conductive heat transfers are modeled thanks to the electrical analogy based on a 3R2C model (3 resistances and 2 capacities). The modeling of the solar collector and the envelope of the building has been presented in (Fraisse, 2002) and (Plantier, 2003).

The study is carried out by means of TRNSYS (Klein, 1996) which is a software widely used by the international scientific community in the energy and thermal fields.

3.2 Principles of the selected system

The two aims are to reduce heating energy consumption and to improve thermal comfort during summer in timber frame building. Only active systems (fan) with HVIW are studied. The air circulation is a closed loop in winter (between the integrated air collector and the HVIW) or an open loop in summer (night over-ventilation).

During summer (Figure 1), the cooling of the building is obtained by blowing outside air in the HVIW at night. The HVIW outlet air is rejected outside.

3.3 Case studies

The building is a single-family dwelling of 120 m² and it is located in Mâcon. The vertical south façade receives 500 kWh/m². The thermal mass is very low as we have considered a timber frame (the time constant is 25 h). The thickness of insulation is 12 cm for outside walls, 13 cm for the floor (over a ventilated space) and 17 cm for the ceiling. The window conductance is 2.0 W/m².K

3.4 Numerical results

3.4.1 Thermal mass of the building

The heavy internal wall will allow an increase in the time constant of the building. Without this wall (CLAS), the timber frame house time constant is only 23 h. With the heavy internal wall of 50m² (HnVIW), the time constant is 56h. The contribution of the internal wall is thus important. The thermal comfort in summer is improved thanks to the reduction of the maximal temperatures. Nevertheless at night, the temperature is lower in the case without internal wall (CLAS) as a result of the lower thermal mass.

3.4.2 Improvement of the thermal comfort in summer

The Figure 2 shows the number of hours for which the room temperature *Tro* exceeds a given value. Six solutions are shown. Two do not use the night over-ventilation of the HVIW in summer: CLAS (no heavy wall) and HnVIW. The other solutions use the night over-ventilation (1000 m^3/h):

- standard ventilation system: CLAS V1000 (0-6h) and HnVIW V1000 (0-6h)
- ventilation of the heavy internal wall : HVIW 1000 (0-6h am) and HVIW 1000 (if *Te* < *Tro*)

With regard to cases without night over-ventilation, the case HnVIW is more interesting only beyond 29°C. This is due to the thermal mass of the internal wall which limits the maximal values whereas the temperatures are lower at night for CLAS. All the solutions with night over-ventilation offer a sensitive cooling compared to these two non ventilated cases.

Of course, the standard night over-ventilation leads to better performance beyond 26 °C with the heavy internal wall (HnVIW V1000), compared with CLAS V1000. The house internal mass is better recovered when over-ventilation is within the building heavy components.

Concerning HVIW case, the Figure 2 shows that it is the best solution. The optimization of the ventilation control is interesting as HVIW 1000 (if *Te* < *Tro*) gives the best comfort. In this case, the temperature is greater than 28°C during only 21 h (CLAS : 940h). Another interest to optimize air ventilation functioning is to reduce the fan energy consumption.

The Figure 3 shows the temperature distribution above 26°. The two solutions without night over-ventilation have the biggest number of hours for all the temperature ranges. The internal wall is interesting only for temperatures above 30°C.

The standard night over-ventilation is more interesting with the internal wall (HnVIW V1000 : 195h above 28°C and 11h above 30°C), compared with CLAS V1000 (437h and 105h).

The optimized solution HVIW 1000 (if *Te* < *Tro*) gives the best result: only 21 h above 28°C. The temperatures are enough low to prevent over-heating and not to use an air conditioning system. Depending on the weather and internal gains, it is possible to ventilate the concrete slab too.

4. CONCLUSION

The initial aim to improve thermal comfort and to reduce energy demand in timber frame houses led us to use an integrated collector and an heavy ventilated internal wall. The objective is at the same time to increase the thermal mass and to store solar energy. During summer, the HVIW thermal mass and its night ventilation leads to low room temperatures. We think that using wood and concrete materials is a neat way of improving summer thermal comfort, and of reducing energy consumption and environmental impact.

Energy savings during winter depend on the performance of the collector. It is important to reduce collector heat losses (selective absorber, glazing for greenhouse effect, air circulation below the absorber) and to increase heat exchanges between the absorber and air with fins or a waved absorber (Pottler, 1999) (Ammari, 2003).

A compromise must be found between cost, system reliability, energy savings, summer comfort and aesthetics. Specialists of timber frame houses (the technical industrial center for timber and furniture companies CTBA and a builder CUILLET) are currently making an integrated solar air collector prototype with the HVIW.

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