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The use of a heavy internal wall with a ventilated air gap to store solar energy and improve summer comfort in timber frame houses

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Abstract

This paper considers supplementary heating and cooling within timber frame houses. The transmission of solar energy to an internal concrete cavity wall by air is analyzed. The objective of this work was initially to study the dynamic insulation in timber frame houses. The initial studies showed that it is more efficient to recover solar energy rather than heat losses, which is the principle of dynamic insulation. Clearly, the thermal regulations lead to lower heat losses through walls by conduction. Due to these factors we have decided to study a wall with an integrated solar air collector and a heavy ventilated internal wall. This internal wall, which is used to store solar energy will allow the reduction of heat demand in winter and will improve thermal comfort in summer because thermal mass increases and ventilation during the night will cool the internal wall. We have selected a closed loop air circulation system because, with an air to air heat exchanger, it can be proved to be more effective and the risk of unhealthy air pollution is reduced because the flow of fresh air will not pass through the ventilated air gap. We are constructing an integrated air collector prototype.

Keywords: Solar air collector; Heat storage; Ventilated wall; Comfort

1. Introduction

In France, timber frame construction represents approximately 5% of residential housing. However, the timber construction gives numerous advantages for sustainability: CO_2 fixation, a renewable raw material, the reduction of construction site waste, and material with lower embedded energy. 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 [1] and here it is a question of recovering heat losses within the walls [2] or windows [3–5]. 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 [1]. Furthermore, the new thermal regulations [6] aim at reducing heat losses. It is also stated that the implementation of a dynamic insulation system requires a careful installation (causing additional costs). Moreover, the control of air flow rate within the building envelope is very difficult because of air infiltrations. In practice, energy savings are often less than theoretical estimation [7]. Furthermore, fresh air quality with dynamic insulation is not guaranteed because air gaps accumulate dusts over time and cleaning is almost impossible. The additional costs and the unpredictable performance were important reasons why the system did not develop in France.

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

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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. The HVIW consists of a heat source of large area and at low temperature; it is ideal for the thermal comfort. In summer, night-ventilation of the HVIW allows to reduction of the internal room temperature. Finally, this system will reinforce the load bearing capacity of the overall structure and the possibility of a supporting heavier floors.

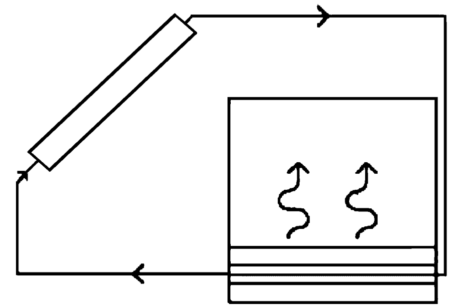

Fig. 2. Closed loop circulation and heating.

2. Storage of solar energy within the building envelope

2.1. Principles of use

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 [8]. 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 thermal mass of the wall allows restoration solar energy during the evening. The use of more insulation (glazing and heavy wall) leads to better energy performance and summer comfort [9,10].

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 making financial savings by substitution [11,12]. The collector is very often glazed to increase energy retrieval performance. Nevertheless, an unglazed collector (Solar wall) was successfully developed in Canada [13]. It consisted of metal cladding full of small holes by which fresh air enters into the air gap located between the metal skin and the insulation. This application is most often used in industrial buildings.

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 [14]. Vestiges still remain as detached houses in St. Romain-en-Gal (first and third century) and in Constantin Thermal Baths in Arles (fourth century). Similar systems were used centuries ago in Nepal, Korea, and Japan [15,16].

At present, systems with a solar air collector and separated heat storage can be classified as follows [17]:

- Air circulation in a *closed loop* (*CL*). If the storage is within the outside walls, heat losses are partially recovered (Fig. 1). In the case of internal walls or slabs, the absorbed solar energy allows a reduction of heat demand (Fig. 2).
- Air circulation in an *open loop* (*OL*) *for heating* (Fig. 3). Such as the system Bara-Constantini [18]. The ceiling, made of concrete, is used for heat storage and room heating. Air movement is due to natural convection.
- *An open loop for warming fresh air.* The storage of energy in wall or floor controls the temperature and solar energy is recovered during the evening. The air circulation is by a mechanical ventilation system.

At present, manufactured systems are available for energy storage. Such as air circulation in hollow masonry [19] and slabs [20–22].

The function of a closed loop system (Fig. 2) is similar to the water heating system ‘‘solar direct floor’’. In this case, water with glycol circulates within the collector and also in the heating floor. Even if energy transference is better with water, the air systems are cheaper and they do not cause leaks, frost or corrosion problems. Furthermore, air systems will allow the cooling of buildings during summer for a lower cost (night-ventilation).

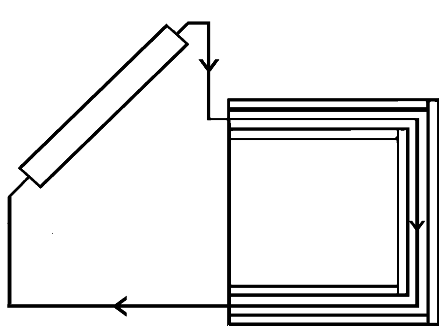

Fig. 1. Closed loop circulation, wall heat losses recoved.

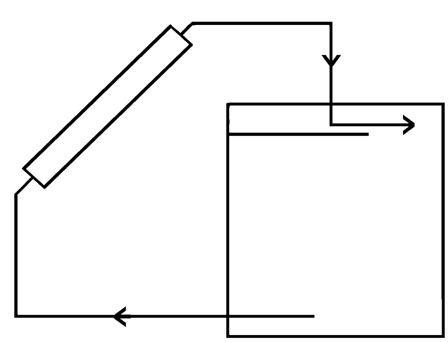

Fig. 3. Open loop circulation, heating system (Bara-Constantini system).