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A building integrated solar collector: Performances characterization and first stage of numerical calculation

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ABSTRACT

A new concept of building integrated solar water collector and the experimentation are described, then experimental results are shown. Numerical calculations are performed in Matlab environment using a finite difference model and an electrical analogy.

1. Introduction

The rapid increase in energy consumption in building sector is seen in many countries. In France, 30 M.housings use about 50% of final energy and produce 25% of green house gazes. For Europe, 500 M.inhabitants in 160 M.housings consume half the energy. The residential and tertiary sector is the first energy consumer in France (Fig. 1) with 69.4 Mtoe [1] the percentage (43%) stays stable but the absolute value increases (+25% in 1973–2008). In France, energy costs are mainly devoted to domestic heating (72%), followed by lighting and appliances (11%), hot water (11%) and cooking (6%) (Fig. 2) [2].

An European citizen uses 36 L of 60 °C hot water daily with tendency for increase in future. The energy to produce hot water is rising slightly because the comfort level sought now is greater than the level accepted in the past. In older buildings, this sector is only 6% of overall energy consumption, but with a reduced heating need mainly due to a better thermal insulation, the hot water production represents 30% of energy consumption in a modern housing. Using solar collectors is a good and sustainable solution for heating water. They can efficiently provide up to 80% of the hot water needs, without fuel cost or pollution and with minimal O&M expense. The solar thermal market is increasing significantly, in 2008, it grew by 51.5% over 2007 with over 4.5 Mm^2 installed (= 3172 MWth). These ascertainments explain the researches renewal for improving and conceiving thermal collectors.

- increase of the water heating part in the housing consumption and of the residential sector part;
- development of new sustainable solutions for reducing the building consumption;
- strong growth of the solar thermal market;

Introducing innovating and environmentally positive solutions is difficult, the obstacles are numerous: financial, technical, psychological obstacles, or too conservative building standards [3]. We must find an innovative concept of heating system easily building integrated, reducing visual impact (psychological obstacle), easy to install in both new and old houses (technical obstacle), not too costly (financial obstacle) and with an environmental positive solution. Our “basis” idea consists in making actives passive parts of building: in past years, a shutter was transformed into a solar air collector [4], now we develop a water collector integrated into a gutter, recovering rainwater and solar radiation.

2. New solar collector presentation

The new concept of solar water collector (SWC) patented and named H2OSS® presents a high building integration without any visual impact. The SWC is arranged so it can also be used on north oriented walls (SWC being oriented south into the drainpipe). It is totally invisible from the ground level thanks to the drainpipe integration (Fig. 3). The drainpipe preserves its role of rainwater evacuation. The canalizations connecting the house to the SWC are hidden in the drainpipe. An installation includes several connected modules. One module is about 1 m length and 0.1 m in width (individual houses). The modules number depends on the drainpipe length. From top to bottom, it is composed by a glass, an air space, a highly selective absorber and an insulation layer. First, the cold fluid from the tank flows through the inferior insulated tube and then in the upper tube in thermal contact with the absorber.

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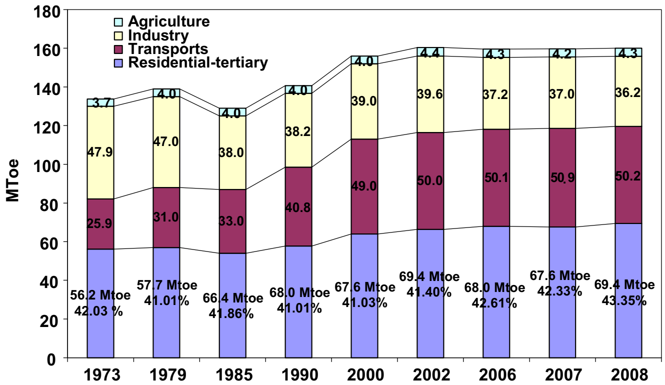

Fig. 1. Final energy consumption in France.

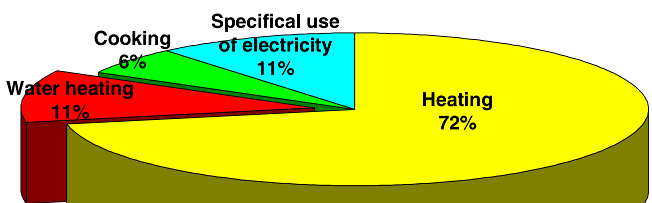

Fig. 2. Part of energy (housing sector).

3. Experimentation

An experimental wall is built in Ajaccio with 3 objectives: testing the thermal behaviour, validating a thermal model and increasing performances by parameters adjustments. A drainpipe comprises 18 serial modules (about 2 m^2) split in two rows (Fig. 4). The input fluid temperature is taken constant by a control loop which heats the fluid if it is too cold and cools it in the other case. Every minute is collected: solar irradiance, ambient temperature, humidity, wind speed and direction, fluid flow rate and input and output fluid temperatures (for each module). The flow rate was fixed at 0.120 $m^3\ h^{-1}$.

Fig. 5 shows inlet and outlet collector temperatures, ambient temperature, wind speed, solar irradiance and instantaneous efficiency defined by:

$$\eta = \rho.Q.Cp.(T_{outlet} - T_{inlet})/I.Ac \tag{1}$$

The maximum gap between inlet and outlet temperatures is 9 °C. T_{in} is not constant in this experiment. The instantaneous efficiency, up to 60% at the steady-state, decreases rapidly after noon because the wall is south-east oriented. We measured temperatures located on the upper tube between each module. The profile is linear (Fig. 6). The maximal useful length has not been reached because the temperature continues to increase, thus we can install efficiently more than 18 serial modules. If the output temperature begins to stabilize, it will be necessary to modify the configuration in using parallel modules. In the input tube located into the insulation, the fluid temperature increases by 1 °C for 18 m length before entering in the absorber.

Efficiency (η) at stationary state is plotted (Fig. 7), (European standard) vs. reduced temperature, Tr (2) [5]. We calculated the linear regression and we obtain with a correlation coefficient at 0.96 (3):

$$Tr = \frac{T_m - T_{amb}}{\Phi} \tag{2}$$

$$\eta = -15.085.\mathrm{Tr} + 0.83 = -K.\mathrm{Tr} + B \tag{3}$$

with Φ the solar irradiance, T_m the average temperature of the SWC, T_{amb} the ambient temperature, B the optical efficiency and K the thermal looses [6] higher than for conventional SWC with simple glass and highly selective absorber (Fig. 7). The average value of K is usually 5 $W.m^{-1}.K^{-1}$ [5]. This difference is due to the geometry of the H2OSS® modules. The thermal looses on the sides of the modules are more important and so the performances decrease rapidly when the reduced temperature increases. This point will be optimized through a future work, using numerical calculations.

4. Thermal model

We present a nearly bi-dimensional model with the thermal transfers; it is composed of a serial assembling of one-dimensional elementary models. Each model is based on a nodal discretisation

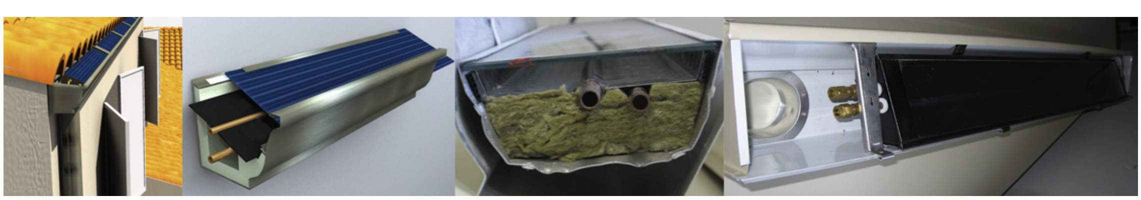

Fig. 3. A H2OSS® module.

Fig. 4. Experience & temperature control loop.