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SOLAR GAINS AND PROBLEMS RELATED TO A DOUBLE SKIN FACADE OF A LARGE INDUSTRIAL BUILDING

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ABSTRACT

This study describes and analyses the performances of a double skin type facade of an industrial building. The natural ventilation of this latter is studied and determines its thermal characteristics. It affects the specific heat loss and the indirect solar gains of the double skin facade. The influence on the heat demand is calculated on the basis of the new European Standard, after having adjusted the calculations to the measurements. A potential saving of 25% is possible. The aestival overheating problem is also treated. A simplified study shows that the use of reflective curtains reduces the internal temperature by about 2°C, but is not enough to lower temperatures which may rise up to 34°C.

KEYWORDS

Double skin facade, passive solar gains, direct solar gains, indirects solar gains, specific heat loss, solar effective area.

1. INTRODUCTION

The industrial building Marcinhès (68'000 m^3, 18'400 m^2), located near Geneva, was constructed with private means [1]. The heating design involves 940 m^2 of flat plate collectors (heating and hot water), a seasonal heat storage comprising 20'000 m^3 of moraine under the building, a gas powered heat pump of 215 kW, three auxiliary furnaces (gas/oil and wood) totalling 640 kW and 3'400 m^2 of double skin facades for passive solar gains.

The building was measured and analyzed in detail by the Group of Applied Physics at the University of Geneva, from May 89 to May 93. The solar collectors and storage have been studied carefully (see ISES 91 [2]) and are operating as expected [3,4,5]. However, their performance has been penalized by the malfunctioning of the gas powered heat pump [6], the latter being the only way of extracting the stored energy. The conventional heating system (two

230 kW gas furnaces), has an annual efficiency of 95% (condenser included) [6]. We will now concentrate on the analysis of the double skin.

2. THE DOUBLE SKIN

2.1 Description

The 3'400 m^2 of double skin facade are spread over the four sides of the building, the principal axis of which faces south-west. On each floor, the internal skin consists of double glazing, mounted on a concrete wall (11 cm thick). The external skin, also double glazed, is at a distance of 25 cm from the internal skin and is 13-20 m high (figure 1):

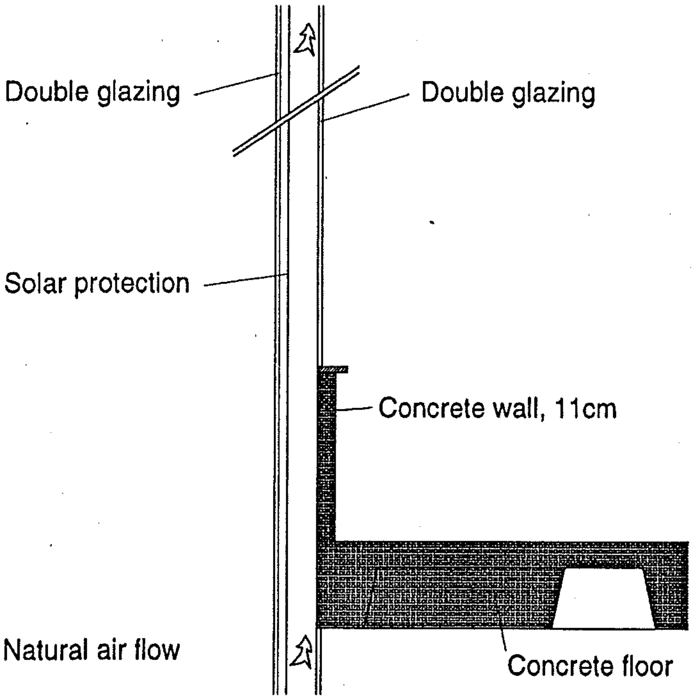

FIGURE 1. Cross section of a double skin unit

In units of 1.5 m width, the double skin can be opened outwards at the bottom and top, and thus be ventilated by the natural air flow. At present, the ventilation holes are not controlled (the units are either open or closed) and the solar protection which should be installed inside the double skin, is not in place. Window cleaning is left to the tenant (the building is half occupied at the moment).

2.2 Heating Performances

The double skin is modelled as an unheated greenhouse [7]. For an open unit, the ventilation has the effect of short-circuiting the external skin. We can define an effective thermal transmittance (U-value) which includes the losses caused by ventilation. For one unit on the S-E face (13 m high), the coefficient is calculated in function of the speed of the air flow, on the basis of the thermal properties of the double skin components (figure 2a). The decrease in performance also affects the indirect solar gains. These are defined as the fraction of thermal energy transmitted into the building due to the warming of the double skin. The reduction of the indirect gains for the same unit is calculated in figure 2b.

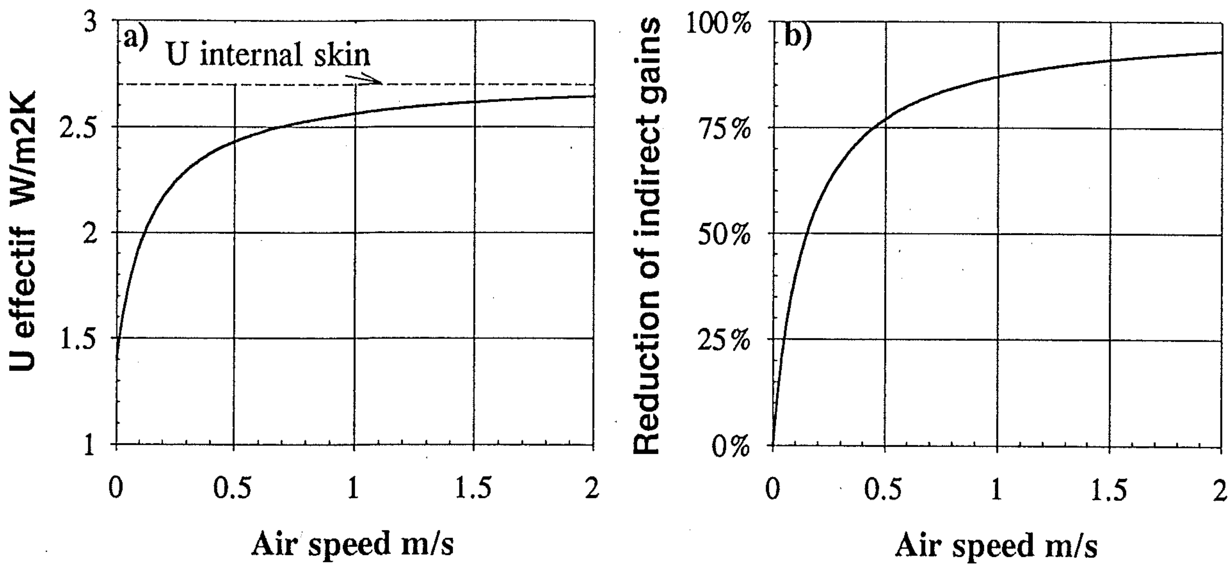

FIGURE 2. Effective thermal transmittance (a) and reduction of indirect solar gains (b) of an open double skin unit, based on the circulating air speed

Measured from 21 Aug. 92 to 2 Nov. 92 in a S-E facing open unit, the air speed is modelled according to the chimney effect. It is then recalculated in monthly means during the heating months. The values obtained are close to 0.6 m/s, with a monthly standard error of less than 0.05 m/s. Compared to the hermetically closed double skin units, the open units have a U-value which increases from 1.4 to 2.5 W/m^{2}K (+80%), and indirect solar gains which decrease by 80%. The direct solar gains, defined as the fraction of the solar radiation which crosses the double skin, are not affected by the ventilation of the latter. For a closed, curtainless unit, the passive solar gains correspond to 60% direct and 40% indirect solar gains.

3. HEATING BALANCE

The building's heating systems have been measured throughout the winters of 90-91 and 91-92. A monthly calculation of the heating demand, based on the New European Standard [8], has been directly compared with the measurements. The passive solar gains, calculated with a solar equivalent area for each side of the building, and the internal gains, estimated from the electric meter readings, are taken into account with a utilization factor.

Figure 3 shows the different heating contributions in the building for the two winters studied. The energy consumption (gas and electricity during the heating season) corresponds to 137 MJ/m^{2}year (90-91) and 147 MJ/m^{2}year (91-92). The reference area is the heated floor area.

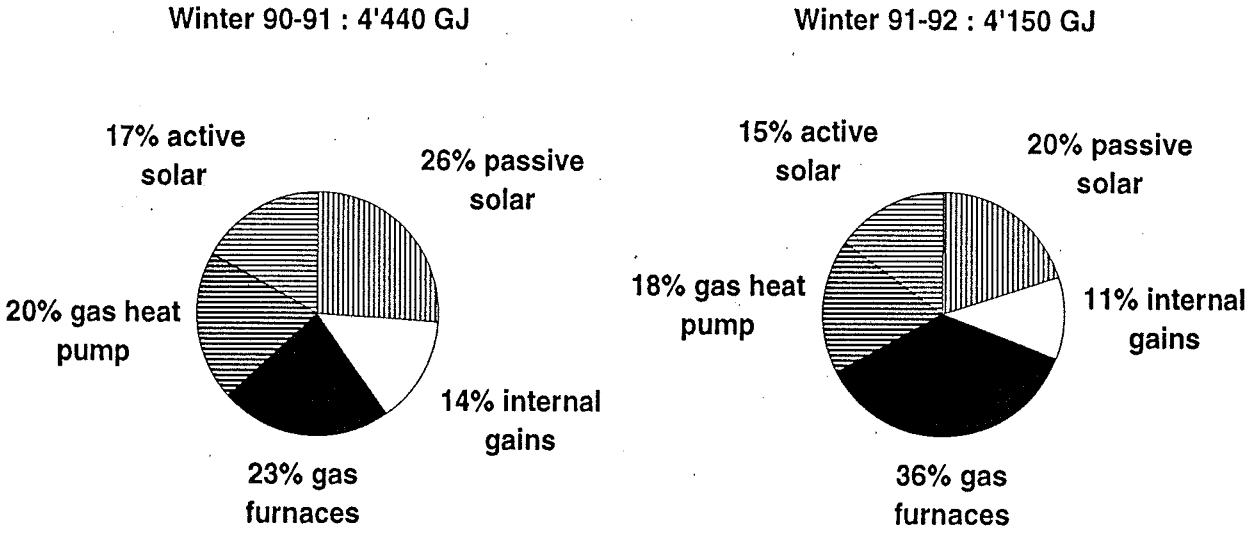

FIGURE 3. Heating distribution in the building (winter 90-91 and 91-92)

The portion of the passive solar gains is smaller for the winter 91-92. This difference can be explained by the proportion of open double skin units which increased from 10-15% in 90-91 to 60-65% in 91-92 (to limit aestival overheating).

The thermal performances of the building can be characterized by two parameters: a specific heat loss coefficient (kW/K) and a solar effective area (m^2), defined by dividing the solar gains by the vertical insolation of the S-E facade. These two parameters pass respectively from 18.1 kW/K and 740 m^2 in 90-91, to 19.3 kW/K and 650 m^2 in the winter of 91-92. The calculation of the heat demand can be made by varying the proportion of open units. Figure 4 allows us to judge the impact on these two parameters and the annual heating demand.

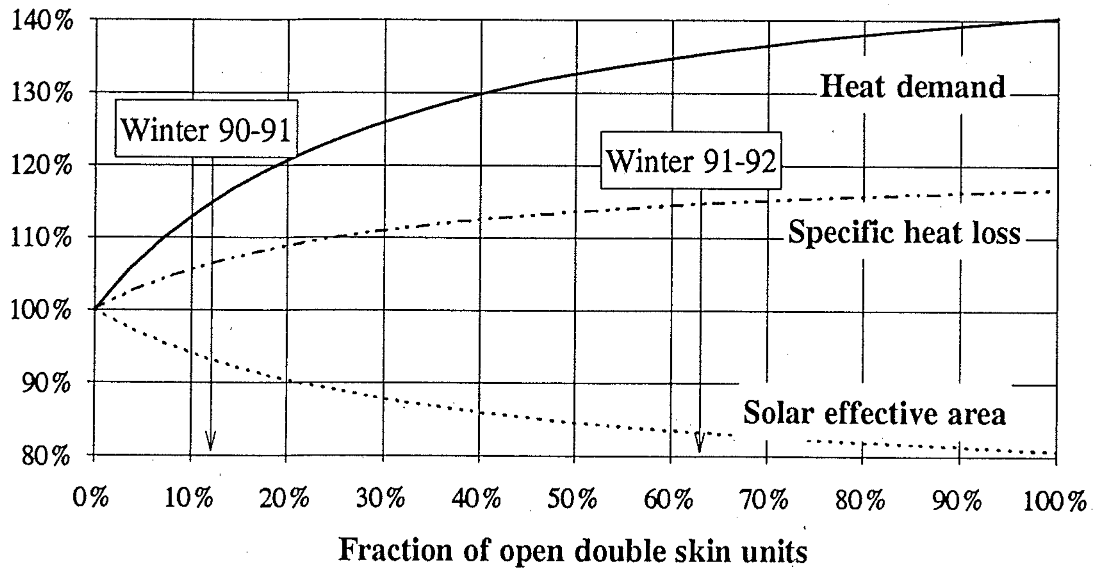

FIGURE 4. Impact of the percentage of open double skin units on the specific heat loss, the solar effective area and the annual heat demand of the building

4. AESTIVAL OVERHEATING

Trials were made with reflective curtains whose characteristics in the solar spectrum are as follows: 77% reflection, 20% absorption and 3% transmission. In an unoccupied S-E facing space on the third floor, (110 m^2 of floor space for 35 m^2 of facade), three trials were made: curtains inside the room (15 July - 6 Aug. 91), curtains inside the double skin, mounted against the internal skin (6 Aug. - 1 Sept. 91), and no curtain (1 Sept. - 14 Oct. 91). The double skin units were kept open throughout the trials. The room temperature was measured in parallel with the solar radiation and external temperature measurements.

A one node study was made in daily means, thus avoiding the complex evolution of variables in a day (effect of heat absorption and emission from the concrete wall, etc.). A daily heat balance of gains and losses (using the concept of a solar effective area S and a specific heat loss coefficient K), determines the temperature variation of the room, which is characterized by a thermal capacity C. Making a linear adjustment in each case allows us to evaluate K/C and S/C. The inverse of the first term corresponds to a time constant, close to 130 hours for the three situations. The second term, proportional to the effective area, is 20% weaker when curtains are used. This rather rough experiment does not allow us to make a comparison between the two trials with curtains. However, the ventilation of the double skin should take place between the solar protection and the internal skin. This would "short circuit" the external skin and curtains which absorb nearly 50% of the incident solar radiation.

The room temperature can be recalculated more precisely in hourly values, on the basis of hourly meteorological measurements and the adjusted parameters. Figure 5 shows classified room temperatures, calculated with and without the use of curtains, from 15 July to 25 Sept. 91.

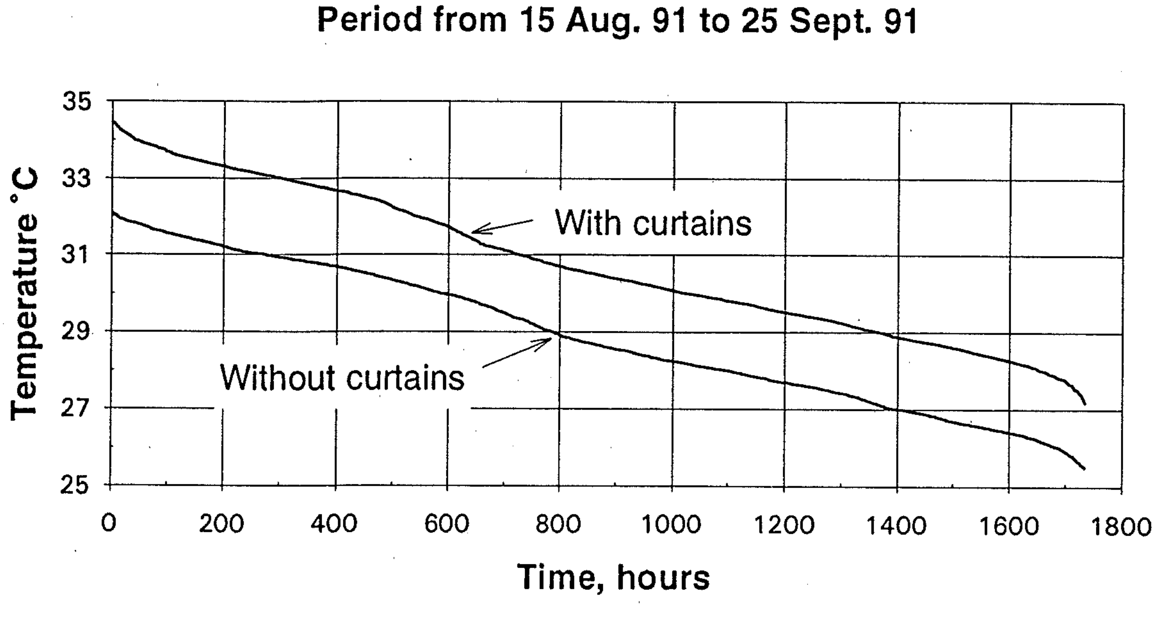

FIGURE 5. Room temperatures classified with and without the use of curtains

The use of good solar protection results in a temperature drop of only 2°C, what is insufficient.

5. CONCLUSION

The unfinished state of the double skin has permitted a simple examination of its thermal performances (units either open or closed, and no curtains). The performances depend greatly on the ventilation of the double skin. The heat demand is reduced by 30% if the double skin units, initially open, are all closed hermetically. The aestival overheating, with temperatures reaching 34°C, remains a great problem which cannot be solved by using reflective solar protection as the only solution.

ACKNOWLEDGMENTS

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