ENVIRONMENTALLY FRIENDLY CITIES, Proceedings of PLEA'98, Lisbon, Portugal, June 1998
Pages 487-490

Hibrid ventilation in a hospital building

LIVIO DE SANTOLI AND GINO MONCADA LO GIUDICE

Department of Fisica Tecnica
Università La Sapienza
via Eudossiana 18, 00184 Roma, Italy
desantoli@axrma.uniroma1.it

Abstract

The use of air solar collector realised on the north facade of a new hospital building in Rome is hereby described. The integration of solar and structural element has been studied during the design phase; the development of air gaps integrated within enclosures is related to the possibility to activate both natural (ejecting indoor air outside) and forced (preheating outside air incoming to the air handling units) ventilation. The energy gained by the solar elements has been evaluated.

CHARACTERISATION OF A NORTH-FACING FACADE OF A HOSPITAL BUILDING

The air gaps obtained within an external wall may have the effect of controlling incoming heat flows and of activating air motion from indoors; it occurs by means of the *stack effect* which, as it is well known, increases with the height of the wall, the air inlets and outlets, the vertical temperature gradient, [1]. The paper deals with the characterisation of a north facing ventilated wall able to recover energy from solar radiation both to preheat incoming air for air handling units and to activate air motion from ejected stuffy air. Several models of facade air solar collectors have been used on the south wall of the buildings; here a ventilated wall placed in the north-facing facade of an hospital building in Rome has been presented. The air flows both in natural and forced way through a space 300 mm wide coming from the 80 m long slots realised along the wall perimeter. The wall stands 3 m on the top of the building in order to be exposed, facing south, to the solar radiation, the upper part of the wall being insulated outward and treated with metal oxides inward in order to realise a selective absorbing plate (see Figure 1,2). A 4 mm covering glass encloses the space allowing the air motion upward through appropriate adjusting dampers.

The air flows because of the vertical temperature gradient obtained between the outside air temperature and the inside air temperature heated in the solar collector. Four fans are also installed to convey the air toward the seven air handling units located on the roof. Fans in the stacks operate if passive ventilation is turned off.

The cover glass, facing south, is tilted 45°.
The cover glasses may be opened to allow:

- cleaning the glass in the inner side
- adjusting the position of the damper
- realising the air solar collector in connection with the other essential parts of a typical flat-plate collector (the black absorber plate which transfers the absorbed energy to the air and the thermal insulation which limits back losses).
- The heat fluxes written for the components of the solar collector are the following, see [2].
- *cover* glass

$$(1-\tau_g)I + h_i(T_{air}-T_g) + \frac{\sigma(T_p^4 - T_g^4)}{1/\eta_p + 1/\eta_g - 1} = \sigma(T_g^4 - T_{ci}^4) + U_A(T_g - T_{Ext})$$

where the left hand term of the equation represents the sum of received energy per unit time and per unit surface (from the sun being I the radiation and τg the trasmittance of the glass; from the internal air at T_{air}; from the absorbing plate with subscript p) and the right hand term represents the sum of heat losses per unit time and per unit surface (to the sky at T_{ci} and to the outside air at T_{ext}).

- *absorber plate*

$$(\alpha_p \tau_g)I = h_i(T_p - T_{air}) + \frac{\sigma(T_p^4 - T_g^4)}{1/\eta_p + 1/\eta_g - 1} + U_B(T_p - T_{Ext})$$

where the left hand term of the equation represents the energy per unit time and per unit surface received from the sun, being α_p the absorptance of the plate, and the right hand term represents the sum of heat losses per unit time and per unit surface (to the internal air, to the cover glass and to the outside air).

- *internal air*

$$h_i(T_p - T_{air}) = h_i(T_{air} - T_g) + m_a c_{pa}(T_{air} - T_{in})$$

- where the left hand term of the equation represents the energy per unit time and per unit surface received from the absorber plate and the right hand term represents the sum of heat losses per unit time and per unit surface (to the cover glass, to the flowing air m_a (kg/s) which allow an increase of temperature from the inlet temperature T_{in} to the actual temperature T_{air}).

- The previous three equations lead to calculate T_p, T_v, T_{air} by means of the subdivision in element of the path of the air. The knowledge of m_a is imposed in the case of forced ventilation and it can be made in an iterative way when natural ventilation occurs, see [3]:

$$m_a = 0.2\,A\left[\frac{g\,H\,\Delta T}{T_m}\right]$$

- where A is the inlet air surface, g the acceleration due to gravity, H the height of the wall, ΔT the temperature difference between inlet and outlet air, T_m the mean temperature of the air. In SI units ma is expressed in (m^3/s). The outlet temperature of the considered element will become the inlet temperature of the incoming element up to the final part of the wall.
- Calculations for the monthly mean day, (8 am - 6 pm), have been carried out. Corrections for the monthly percentages of actual solar radiation have been considered. In Figure 3, T_{ext}, T_{air}, T_p and T_g, respectively outside air, the air leaving the wall after its heating, absorber plate and cover glass temperatures, are reported as a function of the time, for the month of January.
- Table 1 shows the monthly energy (≈ 160.000 kWh per year) recovered from the sun, which represents a saving of 20% pre-heated energy in air handling units (50.000 m^3/h air flow rate, 300 m^2 solar collector area).

Table 1 - Collected solar energy

month	*Q* (kWh per month)
January	11200
February	11300
March	12400
April	12500
May	14300
June	15000
July	17100
August	16800
September	14900
October	13600
November	11000
December	10200

NUMERICAL SIMULATION OF AIRFLOW IN A DIFFERENTIALLY HEATED VERTICAL WALLS

The numerical prediction of the air distribution in the gap with differentially heated vertical walls has been carried out. Time averaged equations of continuity, momentum, and energy are numerically solved by a finite volume method; in order to simulate turbulent natural convection, the standard *k*-ε model is employed.

Low Reynolds number effects and thermal radiation are found to have important impacts on the flow pattern and the temperature distribution [4].

The computational fluid dynamics CFD solves conservation equations. The turbulent natural convection (when fans don't work) is inherently time-dependent and three-dimensional; in the considered case, the flow is assumed to be two-dimensional since the height is remarkable, so that the end effect can be neglected.

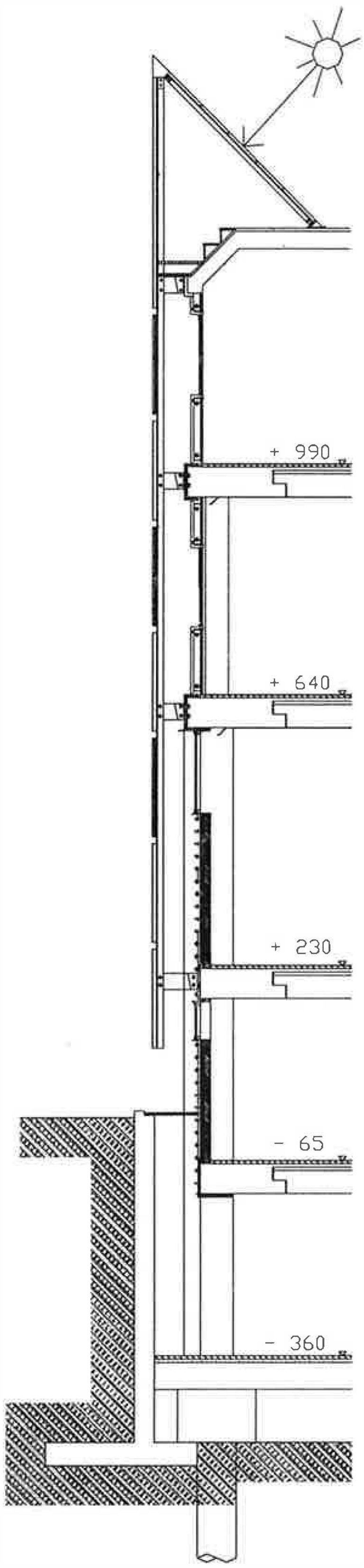

Figure 1. Section of the north facing facade.

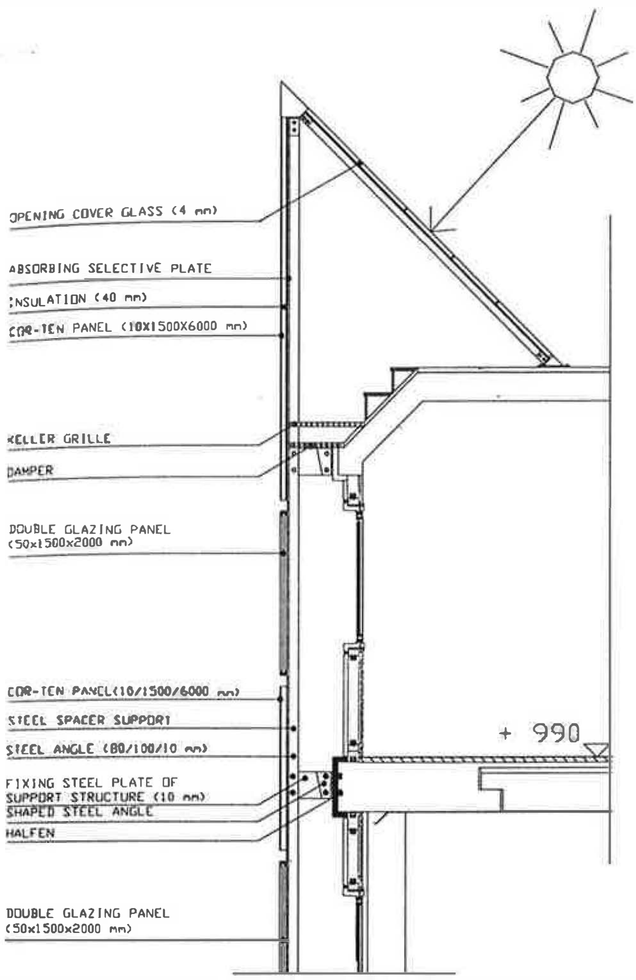

Figure 2. Section through the ventilated wall and the air solar collector.

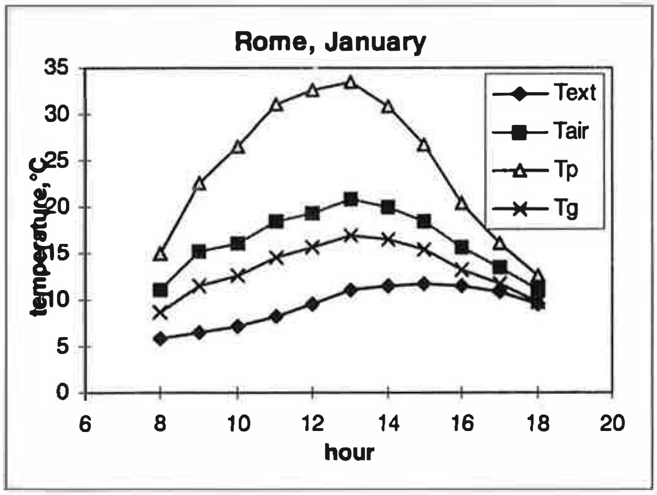

Figure 3. Temperature distributions as a function of time.

The flow can be further assumed to be steady in order to investigate the actual value of m_a in natural ventilation, and finally the assumption for buoyancy that treats density as a constant and considers buoyancy effects in momentum equation is used [5].

Based on the above analysis, the absorber plate being at 25°C, the interior wall at 20°C (winter conditions), the outside air at 4°C, the pattern observed in the experiments is shown in Figure 4. The inlet velocity is 0.4 m/s to reach in the hotter zones 0.85 m/s. The value of m_a is confirmed to be in good accordance with [3]. The stagnant zone is limited in the central part of the air solar collector (0.1 m/s).

Figure 5 shows the thermal field. The inlet air at 4°C is heated along the interior wall to 5.2°C when it is entering in the solar collector area, hence the air reaches 5.9°C at the exit, the hotter zone being beneath the cover glass (6.3°C).

Further developments of this study will regard the task of room air distribution, including its flow and temperature characteristics, in order to define the behaviour of the heat wall as regard the natural ventilation effect of ejected indoor air.

ACKNOWLEDGEMENTS

The authors thank Prof. Massimo D'Alessandro, responsible of the hospital building design.

REFERENCES

1. CIBSE, '*Natural ventilation in non-domestic buildings application manual*', AM10: 1997
2. D. Aravonitch '*Heat transfer processes in solar collectors*'in Energy and Buildings, Vol.3, n.1, May 1981, 31-48
3. P.R. Warren, L.M. Parkins, '*Window opening behaviour in office building*' in Build.Serv.Eng.Res.Technol. 5(3), 1984, 89-101
4. W. Xu, O. Chen, '*Numerical simulation of airflow in a room with differentially heated vertical walls*' in ASHRAE Tran action 1998, Vol.104, pt. 1.
5. P.V. Nielsen '*The selection of turbolence models for prediction of room airflow*' in ASHRAE Transaction 1998, Vol.104, pt.1.

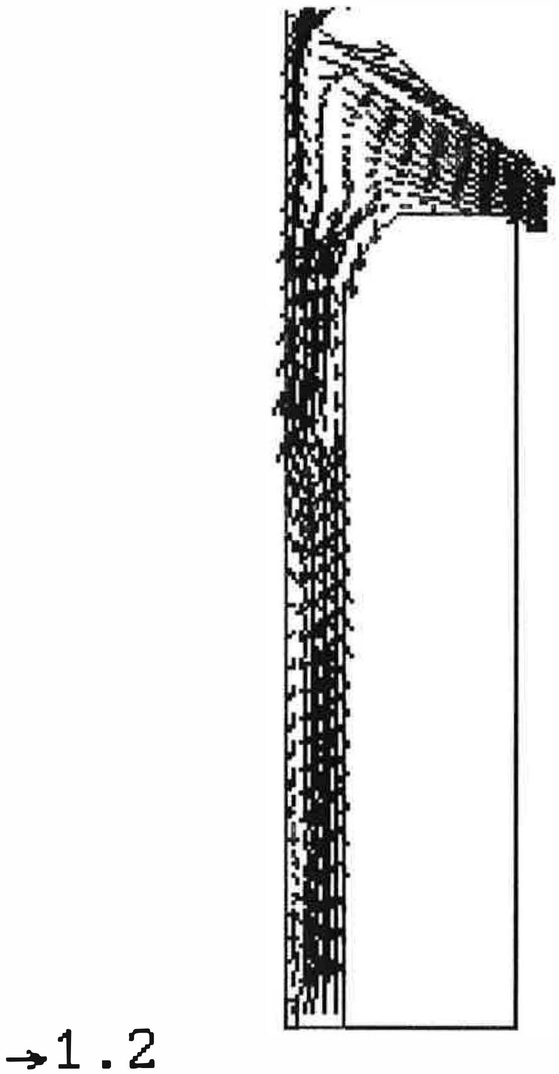

Figure 4. CFD velocity vectors in the ventilated wall (natural ventilation).

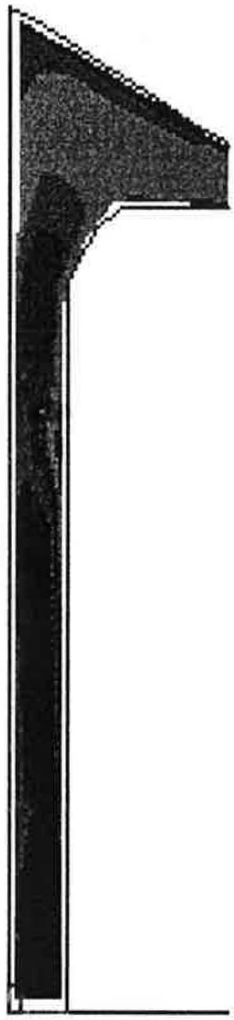

Figure 5. CFD thermal field in the ventilated wall (natural ventilation).