VENTILATION TECHNOLOGIES IN URBAN AREAS

19th AIVC Conference, Oslo, NORWAY
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VENTILATION STRATEGIES FOR THERMAL PERFORMANCE IMPROVEMENT OF AN ATTACHED SUNSPACE

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SYNOPSIS

In this paper ventilation strategies are examined in order to improve the thermal performance of an attached sunspace of a two-storey semi-detached house in the area of Athens Greece. The ventilation strategies examined are cross and single-sided ventilation through the vertical windows of the sunspace. Simulations were conducted implementing multizone ventilation model COMIS coupled with the thermal simulation model Suncode. Wind pressure distribution is estimated using a wind pressure parametrical model and results of wind tunnel experiments.

It was concluded among others that ventilation strategies appear to be important for the energy control and for the formation of the temperature variations in the attached sunspace. Incorrect use of the windows could turn over the benefits of the bioclimatic design. Keeping the windows closed during winter makes the sunspace energy efficient and energy independent in most hours of the day for almost all of the examined mild climates (Greek and USA cities). In some of the examined climates the risk of overheating is likely to happen even in winter. The ventilation strategies during the summer period affect temperature variations significantly less, mainly because of the shading devices used to block direct incoming solar radiation. As its was derived from the thermal balance diagrams in most cases the attached sunspace contributes significantly to the heating demands of the house.

Keywords: ventilation strategies, air flow, thermal coupling, sunspace, bioclimatic design.

1. INTRODUCTION

In buildings located in mild climates, ventilation strategies utilise mainly natural ventilation techniques in order to reduce energy demand and to meet the specifications of relevant Building Regulations or Codes of Practice. The user's behaviour relating to the use of external openings and ventilation systems should also be taken in to consideration as a part of the overall ventilation design. To justify such complex strategies, it is necessary to examine all the interrelated thermal and ventilation phenomena. Design ultimately rests with factors as outdoor climate, building environment, thermal and airtightness characteristics of the building's envelope, as well as bioclimatic design.

Attached sunspaces used as passive solar systems are especially effective in mild climates. The design criteria of the attached sunspace should be seen by two points of view: during the heating period solar gains should be maximised and ventilation and conduction losses should be reduced, while during the cooling period solar gains should be minimised and ventilation strategies should be used to remove the excessive heat.

The above mentioned design criteria should always be combined with the prior mentioned factors each one consisting of various parameters. For example building environment which is mainly depended on the nearby buildings affects the wind pressure coefficients on building envelopes reducing the ventilation rates and also reduces the incoming solar radiation. It is therefore essential to simulate all thermal and ventilation phenomena with the same degree of detail, in order to examine ventilation strategies for thermal performance improvement of the attached sunspace.

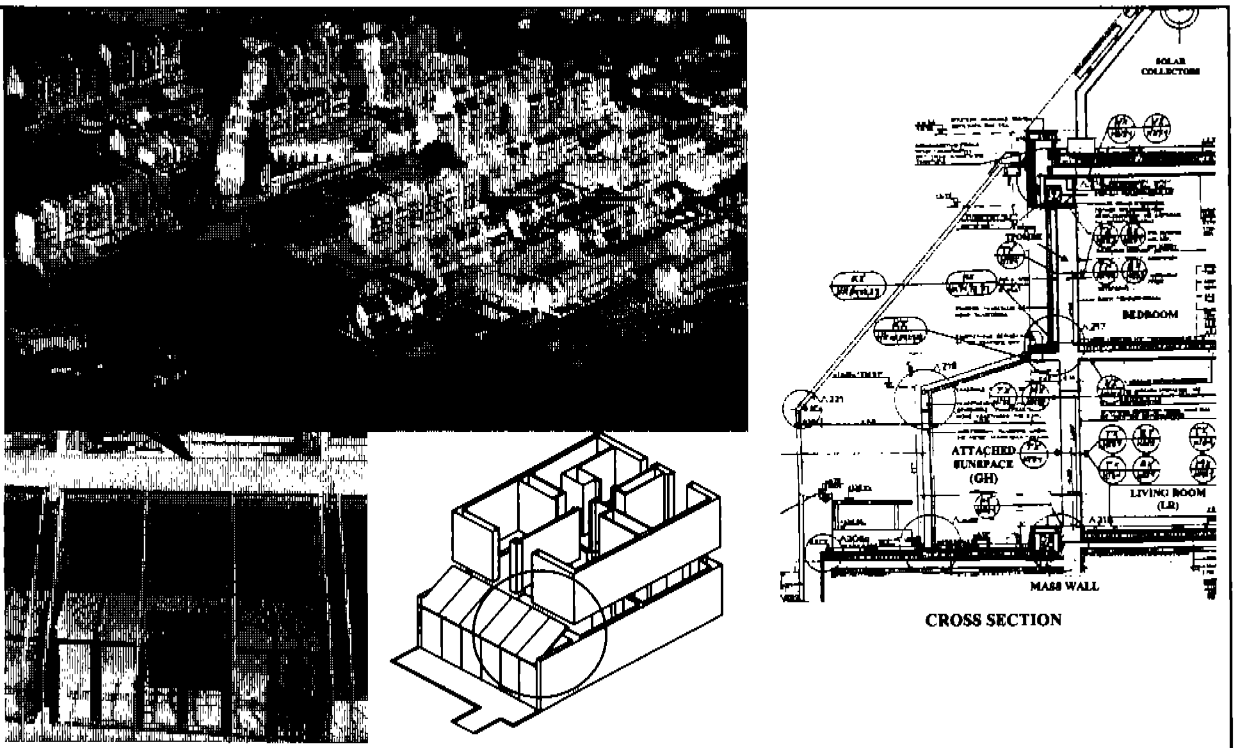
2. DESCRIPTION

The sunspace is attached to a two-storey semi-detached house (maisonette) placed at a block of five similar semi-detached maisonettes. It is located at the Solar Village, a housing project of Greek Workers' Housing Organisation (OEK) and completed in the early 90's in Pefki Athens. It consists of 435 apartments distributed in 30 buildings, an energy centre, a solar information centre and a commercial and community centre (figure 1).

The maisonette consists of a living room, a kitchen and a WC at the ground floor and three bedrooms and a bathroom at the floor, at a total area of 105 m^2. The attached sunspace covers an additional area of 24 m^2 approximately at the ground floor (figure 1 right). There are also two Trombe walls located at the south-facing bedrooms of the first floor.

The examined maisonette is heavily insulated with 10 cm of mineral wool in the external walls and with 10 cm polystyrene boards, on the roof. The inner walls are of 10 cm thick brick, covered with 2 cm plaster on each side. The outer envelope consists of 20 cm thick brick walls, 20 cm thick concrete frame and 15 cm thick concrete slabs. Increased thermal mass is placed at the sunspace by means of concrete mass walls, floor and sidefins.

The maisonette was used to validate the air flow model and the thermal model as well as the coupling of the two models (Koinakis 1998). This prior work has been implemented in this paper to study the thermal impact of ventilation strategies at the examined attached sunspace.



AERIAL AND CLOSE UP VIEWS OF THE HOUSE BLOCK, THE MAISONETTE AND THE ATTACHED SUNSPACE

Figure 1: Views and cross section of the examined attached sunspace

3. SIMULATIONS

The basis of the study of the ventilation strategies is the modelling of the air flow phenomena including infiltration and flow through large openings. Thermal and ventilation phenomena appear to be remarkably intense in the attached sunspace due to the following reasons:

- the glazed area is very increased compared to the rest of the house,
- there are various possible combinations of closed and opened windows and
- the thermal phenomena are very intense mainly due to incoming solar radiation and the risk of overheating.

The attached sunspace is used as a part of the bioclimatic design, in order to contribute to the energy demand and to be used as an additional living area attached to the living room. It is therefore important to fulfil the following demands:

- to ensure incoming interzonal thermal flows to the main house during the heating period
- to achieve air temperatures inside the greenhouse closer to the comfort temperature (e.g. 18 ^{0}C) during the heating period
- to retain air temperature inside the greenhouse between reasonable limits (e.g. between 18^{0}C and 25.6^{0}C), implementing solar shading and night cooling to avoid overheating.

In order to examine whether the above demands were fulfilled it was decided to study the sunspace during 6 day heating and the cooling periods, covering from 19 to 24 of January and from 19 to 24 of July respectively. Six indicative mild climatic regions were selected, corresponding to three main Greek cities: Athens, Thessaloniki and Herakleion, as well as to three USA cities: Los Angeles CA, New York City NY and Phoenix AR. The climatic data was derived from reference years. The Greek climatic files were based on 10 year period data (Koinakis 1998) and the USA climatic files were based on the TMY2 data (Marion & Urban, NREL 1995).

Three indicative ventilation strategies were examined during the simulations: all external windows closed, all half-opened and only two windows at the two corners of the sunspace half-opened. No auxiliary heating systems and no ventilators were used. Solar shading is the only control measure implemented during the cooling period in order to reduce the risk of summer overheating.

As previously mentioned, air flow was simulated implementing the nodal airflow model COMIS (Feustel 1991). Pressure distribution on building's envelope was calculated using the parametrical model cp-calc (Grosso 1992). The results for the Cp values found to be similar to those of wind tunnel experiments (Wiren 1987), for building identical to the block of the maisonettes. The modelling of infiltration as well as the flow through large openings is described in COMIS Fundamentals (Feustel 1991).

The nodal airflow model was coupled with the nodal thermal simulation model Suncode, modifying the source codes of the two models where necessary. The procedure of the thermal coupling is presented in figure 2. The thermodynamic integrity for each time step is guarded by the sequential coupling method, in which the thermal and the air flow model run in sequence: each model uses the results of the other in the previous time step. In the present simulations the air flow calculations use air temperatures calculated in the previous time step. The above mentioned technique was validated as part of another task (Koinakis 1998), using real case experimental data and found to be sufficient and accurate, giving the potential to simulate a wide range of thermal and ventilation phenomena and ventilation strategies.

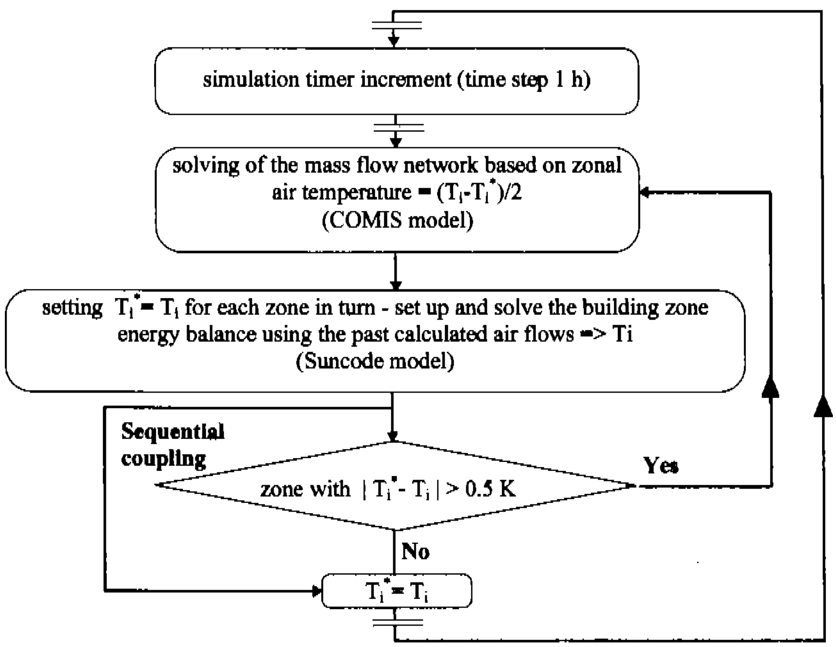


Figure 2: Schematic flow diagram showing the implementation of sequential coupling of air flow and energy balance calculations.

The energy balance equation defining the air temperature, T, of the attached sunspace can be written as:

$Qwall + Qwindows + Qinf\&vent + Qsolzon = 0$

where:
$Qwall$ is the energy flow between the sunspace and all the enclosing mass walls (=floor, mass wall of the living room)
$Qwindows$ is the energy flow through all kinds of windows
$Qinf\&vent$ is the energy flow due to air infiltration and ventilation and is given by the equation: $Qinf\&vent = UAinf\&vent*(Tamb - T)$

where:

$Tamb$ is the ambient air temperature
$UAinf\&vent$ is the infiltration/ventilation equivalent conductance value and is given by the equation: $UAinf\&vent = VOL*Cair*Pair*e^{a*elev}*AC$
where:

VOL is the zone air volume, $Cair$ is the air specific heat, $Pair$ is the air density at sea level, a is a coefficient derived fron exponential curve fit and, AC is the air change rate derived fron the air flow model.

More detailed analysis is given at the bibliography (Weeling & Palmiter 1985, Koinakis 1998).

None heating venting or cooling system is used in the sunspace, while the rest of the house is heated and cooled all year using steady heating and cooling setpoints (20^{0}C and 25.6^{0}C respectively.

4. RESULTS

Figures 3.1 and 3.2 present the hourly variations of the air temperatures in the attached sunspace for the three indicative ventilation strategies. The ambient air temperature and the total horizontal solar radiation hourly variations are also presented, in order to allow direct comparison of thermal performance. January and July simulations are presented at the left and right columns respectively.

The daily energy balances of the sunspace are presented in figures 4.1 and 4.2. The energy balance presented in these figures, consist of five terms: i) the solar gains through the glazed area, ii) the heat flows through the ground floor slab, iii) the flows through the windows due to conduction, iv) the interzonal flows to/from the adjacent living room, v) the energy flows due to infiltration and ventilation.

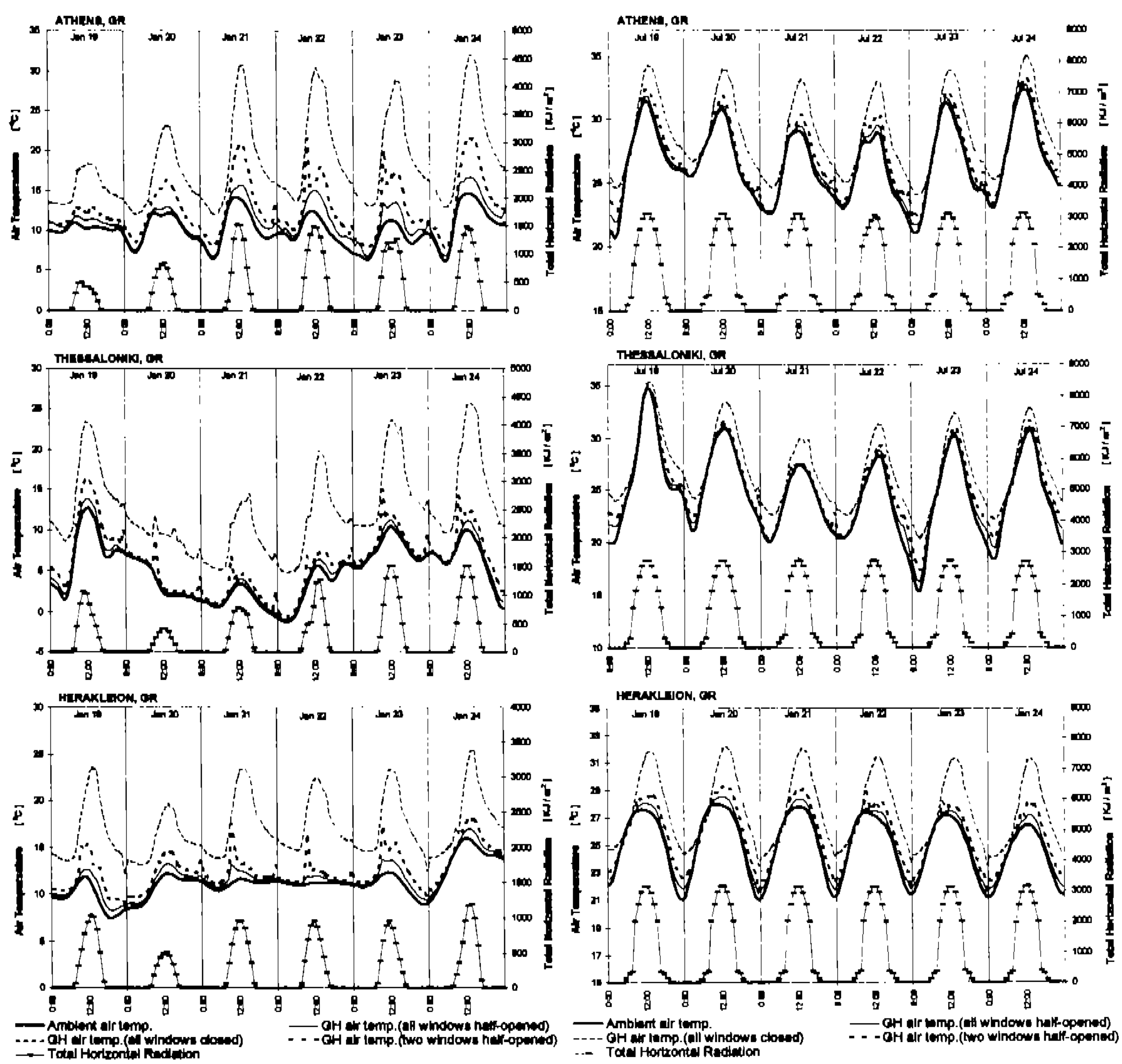


Figure 3.1: Hourly variations of the air temperatures in the attached sunspace for the selected ventilation strategies. Corresponding ambient temperatures and solar radiation. Greek climatic files.

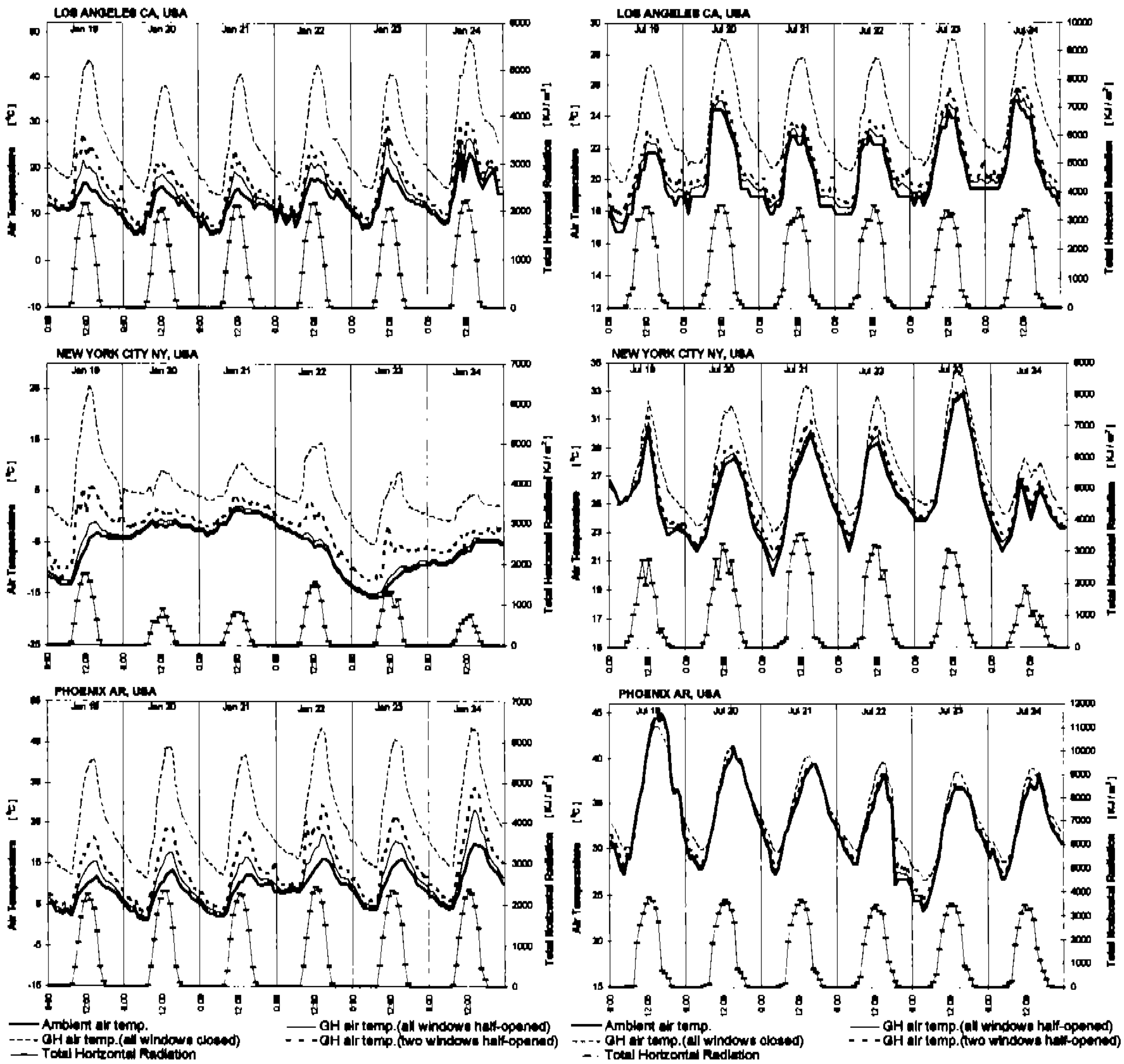


Figure 3.2: Hourly variations of the air temperatures in the attached sunspace for the selected ventilation strategies. Corresponding ambient temperatures and solar radiation. USA climatic files.

5. DISCUSION

Figures 3.1 and 3.2 indicate that the hourly temperature variations of the air in the attached sunspace are very intense overstepping the ambient air temperature. This phenomenon occurs for all climatic files during the heating and the cooling period.

The ventilation strategies affect these variations very significantly especially during winter noon. Keeping the windows closed during winter makes the sunspace energy efficient and energy independent in most hours of the day in almost all the examined mild climates (except New York City). In addition the risk of winter overheating is always present in Los Angeles and Phoenix, while it is almost avoided in the Greek climatic files. Even the slightest opening of the windows affects temperature variations dramatically.

The ventilation strategies during the summer period affect temperature variations significantly less, mainly because of the shading devices used to block direct incoming solar radiation (the shading coefficient used equals 0.7). Temperature variations were also dramatically affected by even the slightest opening of the windows.

Comparing solar radiation and air temperature variations leads to the conclusion that solar radiation could affect indoor air temperatures significantly only in the case of completely closed windows.

The effect of the examined ventilation strategies on indoor temperatures is expressed in heating and cooling degree-hours and compared with ambient temperatures at the tables 1 and 2. It is derived among others that keeping all the windows closed during the winder could reduce the heating degree-hours from 7% to 55% of the ambient temperature degree-hours, depending on the climatic file examined. Keeping all the windows open during the summer period and using the appropriate shading devices increases the cooling-hours from 102% to 125% only, depending on the climatic file. The mild ocean climate of Los Angeles helps the sunspace to be used with zero thermal surcharge during summer.

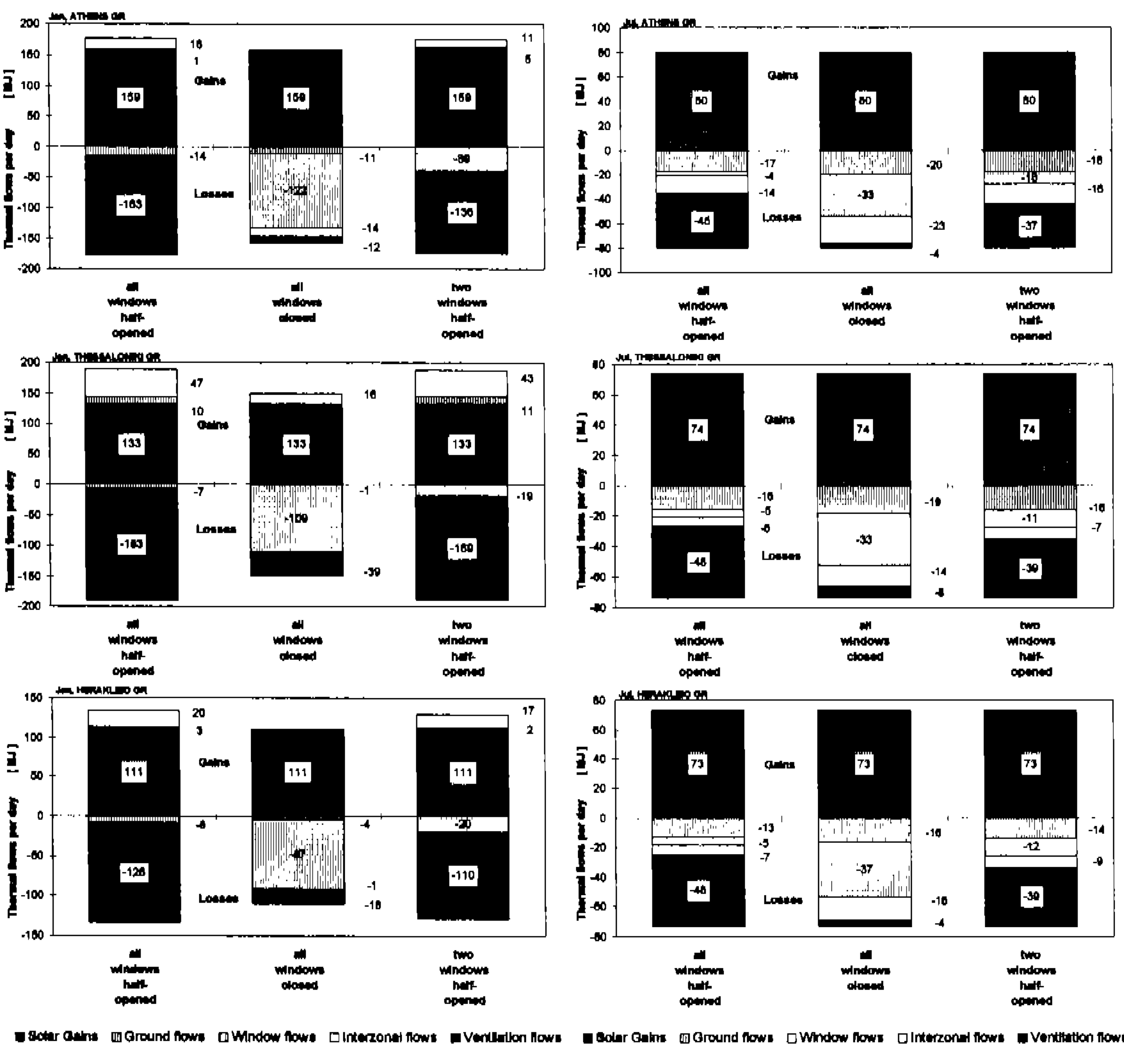


Figure 4.1: Daily thermal balance of the attached sunspace for the selected ventilation strategies. Greek climatic files.

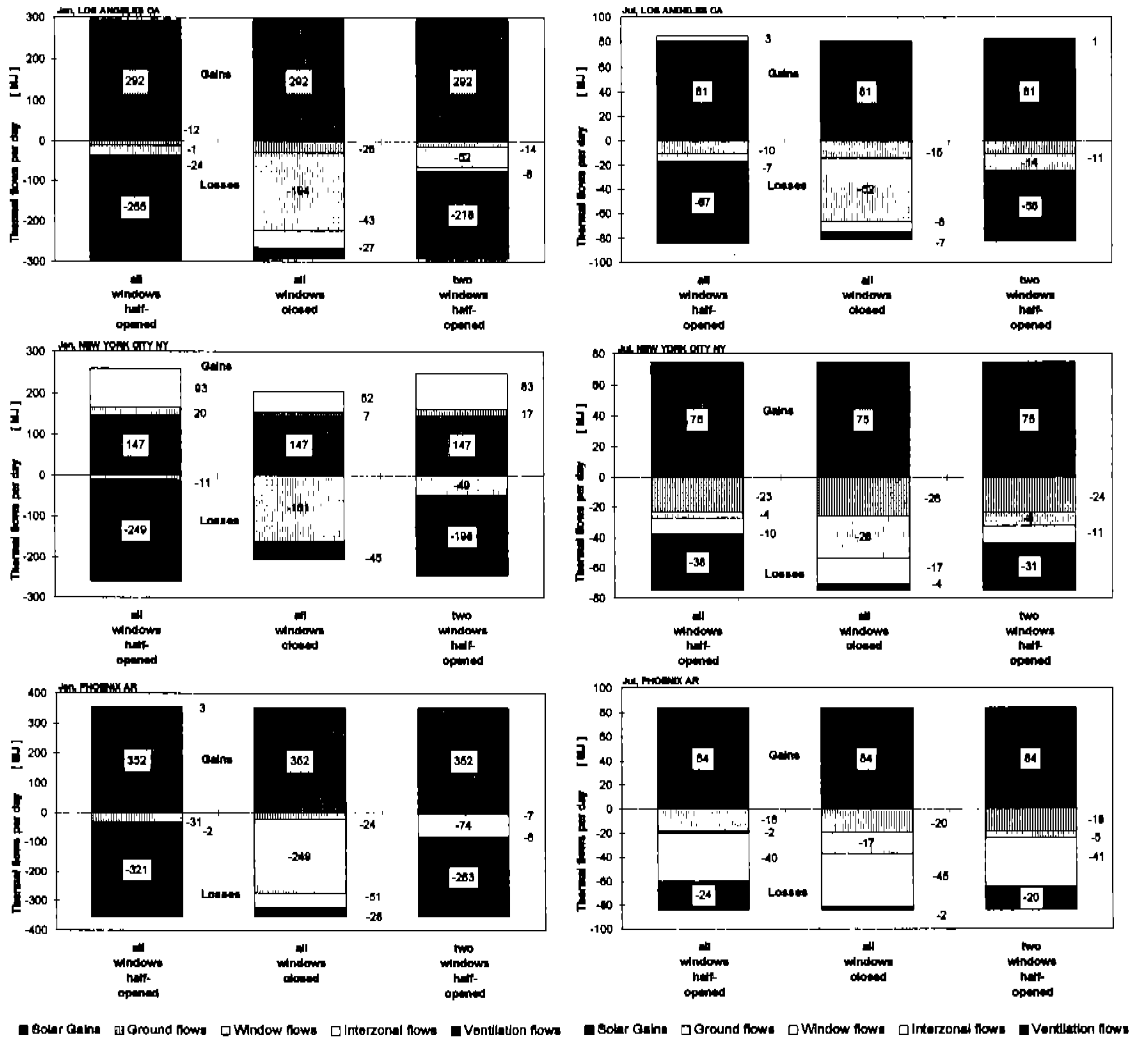


Figure 4.2: Daily thermal balance of the attached sunspace for the selected ventilation strategies. USA climatic files.

Figures 4.1 and 4.2 present among others the increased importance of the energy flows due to ventilation and infiltration in winter as well as in summer. The other important term of the thermal balance is solar gains. In most cases the attached sunspace contributes significantly to the heating demand and does not increase cooling loads significantly.

Table 1: Heating degree-hours. Mean daily values (base temperature 18 ^{0}C)
(% - compared to ambient air temperature)

Climatic file	Ambient air temp.	Air temperature in the attached sunspace		
		all windows half-opened	all windows closed	two windows half-opened
Athens GR	189.9	166.5 (88%)	45.9 (24%)	131.4 (69%)
Thessaloniki GR	315.2	303.9 (96%)	150.5 (48%)	284 (90%)
Herakleion GR	163.4	150 (92%)	44.8 (27%)	130.6 (80%)
Los Angeles CA	136.7	109.1 (80%)	9.5 (7%)	83.3 (61%)
New York City NY	580.5	562.1 (97%)	317.8 (55%)	499.2 (86%)
Phoenix AR	220.1	177.5 (81%)	21 (10%)	133 (60%)

Table 2: Cooling degree-hours. Mean daily values (base temperature 25.6 ^0C)
(% - compared to ambient air temperature)

Climatic file	Ambient air temp.	Air temperature in the attached sunspace		
		all windows half-opened	all windows closed	two windows half-opened
Athens GR	42	45.8 (109%)	81.3 (194%)	51.9 (123%)
Thessaloniki GR	29.3	31.2 (107%)	52.5 (179%)	34.5 (118%)
Herakleion GR	15.3	19.1 (125%)	52 (340%)	24.6 (161%)
Los Angeles CA	0	0	13	0
New York City NY	25.9	28.6 (111%)	53.4 (206%)	32.7 (126%)
Phoenix AR	181.1	184.2 (102%)	208.1 (115%)	188.5 (104%)

6. CONCLUSIONS

Ventilation strategies appear to be important for the energy control of the attached sunspace. The incorrect use of the windows could turn over the benefits of the passive solar design. Even the slightest opening of the windows affects the air temperature in the sunspace. Keeping the windows closed during winter makes the sunspace energy efficient and energy independent in most hours of the day for almost all of the examined mild climates.

The ventilation strategies during the summer period affect temperature variations significantly less, mainly because of the shading devices used to block direct incoming solar radiation (the shading coefficient used equals to 0.7). Comparing solar radiation and air temperature variations leads to the conclusion that solar radiation could affect significantly indoor air temperature only in the case of completely closed windows.

Keeping all the windows closed during the winder could reduce the heating degree-hours from 7% to 55% of the ambient temperature degree-hours, depending on the climatic file examined. If all the windows kept half-opened the heating degree-hours are dramatically increased reaching 80% % to 97% of the ambient temperature degree-hours. Keeping all the windows open during the summer period and using the appropriate shading devices increases the cooling degree -hours from 102% to 125% only.

As it was derived from figures 4.1 and 4.2 in most cases the attached sunspace contributes significantly to the heating demand. The use of solar shading is absolutely necessary in order to keep down the cooling loads.

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