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Use of ventilated envelopes in building retrofitting

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Abstract

The application of a continuous thermal insulation on the external face of building walls ameliorates the thermal performance of external walls and alleviates problems related to thermal bridges.

However a further improvement of this insulation system may be achieved by using ventilated walls, which consist of an open ended cavity placed between an insulating board (directly applied on the external side of outer walls) and an external cladding. The convective natural flow which occurs in the cavity, permits to cool the surface of the insulating board in summer and to control condensation problems in winter.
The use of ventilated envelopes does not reduce the living space and presents also interesting economic aspects .
The present paper compares the thermal behavior of an existing building, before and after the application of a ventilated envelope, with some references to the economic aspects of this approach.

INTRODUCTION

The energy-saving demand has produced a relevant progress in building thermal insulation technologies. Consequently, in the last 20-30 years, the thermal performances of building envelopes have been considerably improved.

This improvements are mostly due to:

- the efficiency of modern insulation materials;
- the application techniques of insulating boards, avoiding thermal bridges;
- better performances of windows (airtightness, thermal cutting, double glazing).

Nowadays the most widespread solutions for insulating the building envelope are the following [1, 2]:

A. insulating board and air cavity placed between two masonry layers;
B. external covering of walls, using thin renderings on a continuous insulating board;
C. continuous insulating board (directly applied on the external surface of outer walls), ventilated air cavity, external hanging cladding.

Solution A, particularly widespread in southern Europe, has less insulating efficiency, but is more economical and reliable.

Solution B, used in central-northern Europe, is thermally more efficient but its long-term durability, especially of the rendering layers, is questionable.

Solution C, known as "ventilated building envelope" or "ventilated wall", shows the best thermal and aesthetic results, but is the most expensive [3, 4]. It is recommendable, along with solution B, for energy improvement of recent buildings [3].

The present work aims to analyse the behaviour of the latter solution, with particular reference to building retrofitting.

In particular it compares the thermal performance of an existing building, before and after the application of a ventilated wall, and gives some hints about the economic advantages of this system.

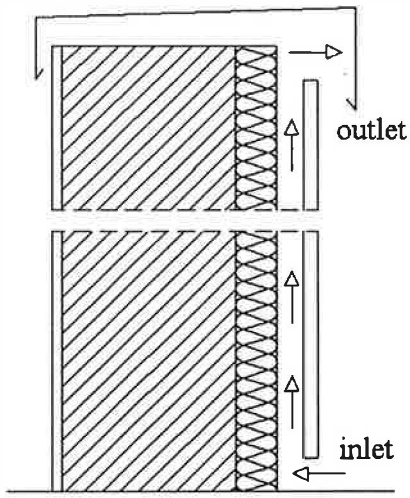

Figure 1. Sketch of a generic ventilated wall.

DESCRIPTION OF THE SYSTEM

Structure and behavior

A ventilated wall consists, essentially, of the following four layers [3, 5]:

- outer wall;
- thermal insulation;
- air cavity;
- external cladding.

The incident solar energy raises the temperature of the cavity, resulting in a natural convective flow. The air is drawn in through a bottom inlet section, heated up in the duct and discharged through a top outlet section [6] (See Figure 1).

In summer, the air flow reduces significantly the temperature of the external surface of the main wall, with beneficial effects on the thermal comfort or on the thermal load. It also can be effective in winter, by promoting the removal of the water vapor and avoiding, this way, condensation problems [3, 7].

In winter the warm air of the cavity can be introduced inside the building for heating purposes. Another possibility consists in the discharging of the indoor stale air through the cavity, which can increase the temperature of the external insulation surface [8].

Theoretical and experimental investigations reported in literature [3, 6, 9, 10] suggest the cavity size be 3 to 6 cm.

Also the duct height must be controlled [11]. In fact an increase in duct height produces a double effect: the temperature rise of the duct air and the increase in turbulence. As a consequence the height should not exceed 9 m, in order to prevent overheating, when cooling purposes are predominant, and should not be lower than 3 m, to foster the air flow [12]. For this reason, openings, balconies and other obstacles must be avoided. This system is thereby more suited for offices than for residential buildings [6, 12].

Characteristics of the employed materials

Bearing walls

In general, almost any type of wall can be adopted, both for new constructions and for building refurbishment.

The main requirements must be the airtightness and the mechanical resistance. Other requirements can be satisfied by the characteristics of the other layers.

Insulation

The insulating board is directly applied on the external surface of outer walls, after the application of a thin rendering layer, in order to regularize and to seal the support. The panels are normally fixed to the wall through adhesives and resin anchors.

The most common insulation materials are:
- fiberglass;
- rock wool;
- polystyrene;
- polyurethane.

The requirements of the insulation are:
- good insulating properties;
- mechanical resistance;
- fire resistance;
- impermeability;
- vapor-permeability.

External cladding

Nowadays there are plenty of materials that can be used for the external cladding:
- anodized aluminum, stainless steel and copper panels;
- marble and limestone slabs;
- lateritious, ceramic and slate tiles;
- wood, glass, PVC etc.
-

These materials are anchored to the wall with anodized aluminum or stainless steel sections, or through wood elements.

Recently [11] also photovoltaic (PV) panels have been employed as cladding for ventilated walls, combining the thermohygrometric benefits of this system with the energy production of PV components. Owing to the cooling effect of the air flow that occurs in the duct, the PV cells may work even better, with a significant increase in the electrical output.

Technical benefits

Besides the thermal benefits mentioned above, ventilated envelopes ameliorate the following characteristics:
- acoustic insulation;
- fire resistance;
- protection from rain and seepage of water;
- protection from wind pressure;
- protection from aggressive chemical and atmospheric agents (especially of structural elements, such as pillars, beams, bearing walls, etc.).

They also allow good aesthetic effects, flexibility of aesthetic solutions, facility of maintenance and are particularly indicated for the refurbishment and retrofitting of recent buildings, without reducing the living space.

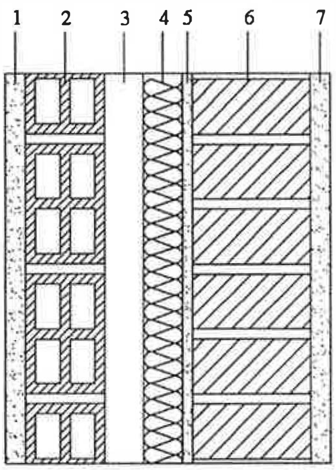

Figure 2. Outer wall constitution of a generic building in southern Italy.

RETROFITTING

Model description

In order to assess the benefit of adopting the proposed solution for building retrofitting, it seemed reasonable to evaluate the thermal response of a building before and after the application of a ventilated envelope. The case study was an office building, with outer walls made of (See Figure 2):
1. internal plaster (2 cm);
2. hollow bricks (8 cm);
3. air cavity (4 cm);
4. fiberglass (4 cm);
5. rendering (1 cm);
6. bricks (12 cm);
7. external plaster (2 cm).

The ventilated facade, applied on the previous walls, consists of (See Figure 3):

8. polystyrene (4 cm);
9. air cavity (4 cm);
10. marble slabs (3 cm).

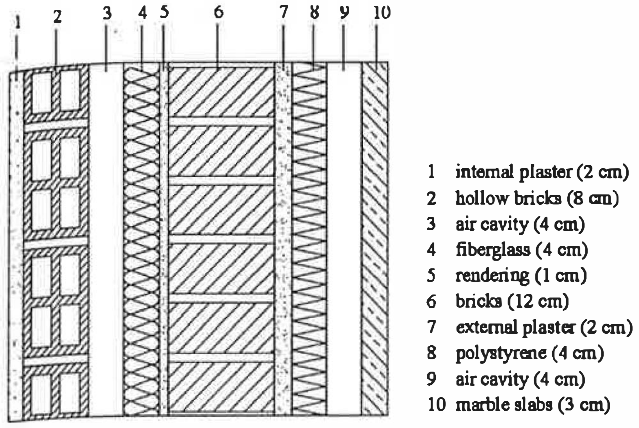

Figure 3. Application of a ventilated envelope on the wall of Figure 2.

To carry out the computations a computer code was used, previously developed by the authors and experimentally validated. The program is based on the state space analysis and can predict the thermal response of buildings in the time domain [13] in terms of either thermal load (for buildings under thermostat control) or indoor air temperature (for buildings with internal floating temperature).

The performance of the ventilated envelope was firstly assessed by preliminary investigations carried out through numerical fluid dynamic models [14]. There is indeed a complex interaction between the air stream and the walls delimiting the cavity. The physical model, which the simulations were based on, included temperature-type boundary conditions on the outermost surfaces of slabs, i.e. the indoor air temperature acting on the surface delimiting the room space and the sol-air temperature acting on the surface facing outdoors. This is a complex heat transfer problem to be studied in the time and space domain and dealing with natural convective flow in an open ended cavity. As a result, the heat transfer coefficients depend, among other elements, upon the z-abscissa.

Nevertheless, by averaging over the wall height and over time, it was possible to evaluate the global heat transfer rate (U value) for the ventilated wall. Finally the mentioned computer code was used for the thermal assessment of the whole building.

The building was assumed to have two external walls due south and north. The south side of the building was provided with a glazing. The window surface area was such as the window to floor area ratio was 10%. The climatic conditions were those of a typical Mediterranean area.

The results

The thermal load before and after the application of the ventilated wall for both winter and summer conditions is shown in Figure 4.

As to the winter load the amelioration is within 10%. Such a fairly low improvement may be explained by observing that, although the reduction in the overall heat transfer coefficient (U value) of the external walls , the surface area of such walls is relatively low with respect to whole

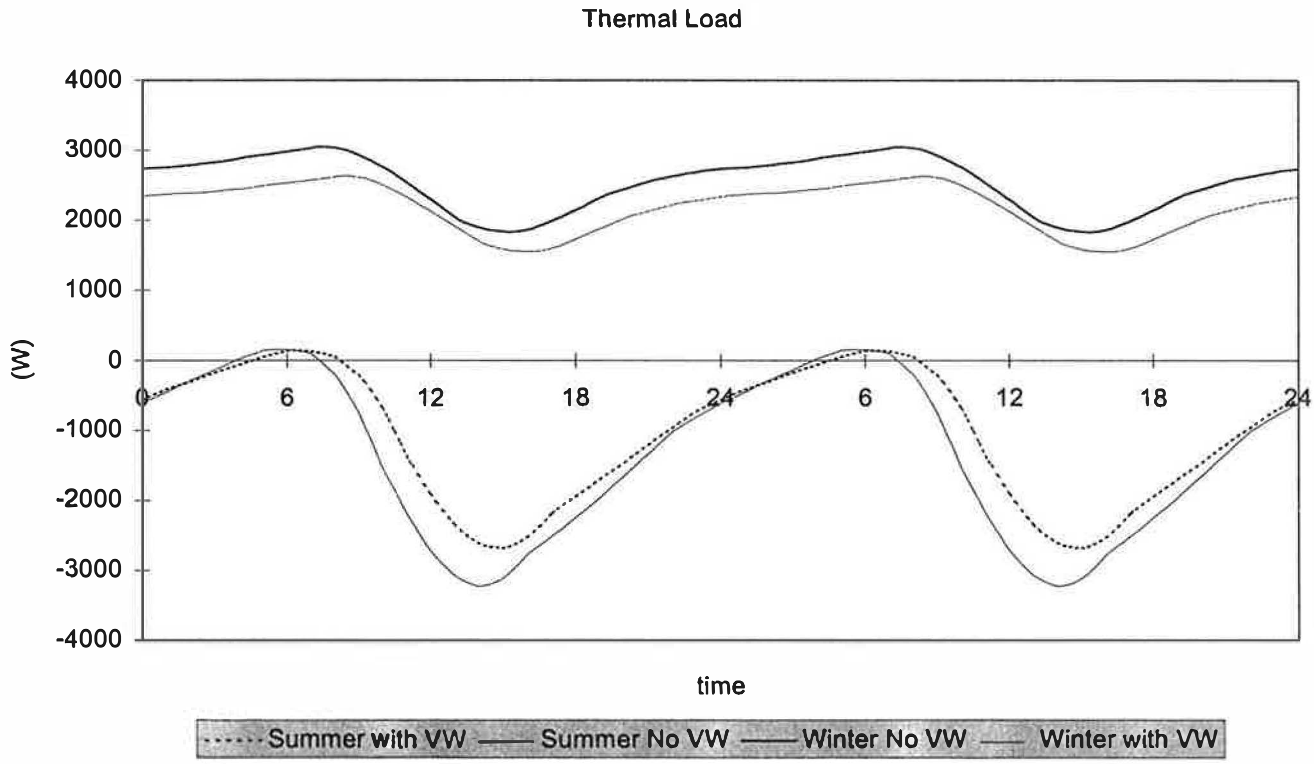

Figure 4. Winter and summer thermal load for buildings with and without Ventilated Wall (VW).

room envelope, thus the effect of changing the U value is moderate.

Better performance is shown in the summer condition. The more consistent reduction in the thermal load is due to the substantial protection from incident solar radiation and to the very effective heat removal from the external wall. In the average such a reduction is within 20%.

Similar results are reported in literature [15].

The assessment of the thermohygrometric performance is a problem even more difficult to face in analytical terms. Indeed, besides the energy and momentum equations in 2-D, it is necessary to consider the continuity equation to account for water vapor migration through the multilayered structure.

Such a problem deserves more specific treatment and was then deferred to later investigations.

Nevertheless some results are predictable. The application of a ventilated envelope should be beneficial, essentially because during the day time the internal flow is active and provides moisture removal from the cavity, whereas at night time the external envelope prevents form freezing and heats up radiatively the main wall, avoiding condensation problems.

Economic evaluations

The application of a ventilated facade for building refurbishment may result as expensive as 500 ECU per square meter in the average. If compared with the relatively low energy savings, the technical–economic feasibility may appear hardly achievable. Nevertheless for the final judgement, other issues must be considered, such as those mentioned in section 2.3 and namely the substantial improvement in the aesthetic appearance. If these aspects, although hardly quantifiable in monetary terms, are taken into account, such a practice will appear beneficial as far as the urban environmental quality is concerned.

CONCLUSIONS

The practice of building retrofitting by means of ventilated envelopes has many advantages, and does not imply significant drawbacks. Actually it ameliorates the thermal resistance of external walls, lowers the incidence of thermal bridges, prevents condensation problems and reduces the winter and summer thermal load.

The outcomes of the computer simulations show that the benefit of ventilated envelopes may appear relatively low. Reductions in the thermal load resulted up to 20%. However the reader should be aware that these results hold for mild climates; higher benefits are expected for winter time in more severe climatic conditions.

In mild climates indeed, better performance are achievable in summer; the reason is twofold: the ventilated wall results in a higher thermal resistance (with respect to an ordinary masonry wall) and shades effectively a large percentage of the building envelope.

Also in terms of functionality, ventilated walls may deserve a positive judgement, since, for instance, their adoption does not reduce the living space.

In conclusion ventilated walls may be well suited for those cases of building rehabilitation where the energy conservation is a prominent issue.

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