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Performances of double-skin envelopes in Mediterranean Areas

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Abstract
The advent of modern architecture has fundamentally changed the role and the appearance of building envelopes. The progressive substitution of traditional materials with highly-technological ones, is an especially clear evolution in office buildings, for which the façade is considered more than a simple barrier between interior and exterior and assumes a promotional role. For these building typologies totally-glazed external surfaces are frequently adopted that satisfy aesthetic and technological needs but, at the same time, cause glare and overheating in the internal spaces, especially in Mediterranean climates, where summer solar radiation reaches very high values. There is an increasing employment of double-skin façades in commercial buildings, especially when vertical external closure becomes a technological element to be integrated with other building subsystems, such as horizontal enclosures and HVAC systems. In this way the employment of advanced systems, instead of traditional glass surfaces, enables us to obtain significant energy savings, creating a comfortable internal environment. Various solutions can be evaluated, choosing suitable boundary conditions such as climate, exposure and height of the building that differ with respect to the parameters of ventilation, shape and dimensions of the airspace, and the characteristics of the glass pane. Summarizing the earliest results of simulations of the energetic behaviour of office buildings, the paper will present a classification of the performances offered by double-skin systems in relation to the different parameters used. This could guide the designer in the evaluation of the efficiency conditions of the different systems.

Keywords
Double-skin envelopes, Mediterranean areas.

1. Introduction

Historically mankind has based home construction on the observation of surrounding environment and knowledge of the basic climatic parameters.

In trying to minimize energetic exchanges between the interior and exterior, traditional Mediterranean houses were characterized by a high closure outwards. Also for these reasons, historical buildings of Mediterranean areas are characterized by few and small openings, and by great masonry masses with a significant thermal inertia that limits solar radiation, respectively absorbing or transferring it during the hot and the cold hours of the day. With the advent of modern architecture, new architectural languages have been developed, and building envelopes have progressively lost their original characteristics, gaining transparency and becoming lighter.

In continental climates, wide glazed surfaces, technologically developed thanks to the use of light materials such as steel and glass, are able to optimize the absorption of direct solar heat gains.It is unacceptable to transfer these technologies to Mediterranean climates, in the same way they are developed for continental climates, owing to the dangerous consequences during summer of increasing glare and overheating.These negative effects are even more evident in office buildings, which are mainly used during daytime, and they produce significant energetic losses. For all these reasons, the design and rehabilitation of modern building envelopes, must tend to increase the use of active and passive solar systems, better able to tap solar radiation.
Especially in continental areas, where the energetic optimization of totally-glazed façades has an important role in the envelope's design phase, double-skin technology with natural or forced ventilation has been developed.

The early results of this research, which are summarized in the following paragraphs, tend to determine whether double-skin technology could be applied in Mediterranean areas, for new and existent building envelopes. For this aim, we have defined the basic parameters that influence its behaviour, and, through a critical analysis of the results, it is possible to suggest technological changes, with the final aim of increasing the control of solar radiation.

2. Double-skin with natural ventilation: simulation parameters.

The heart of double-skin envelopes is the cavity between the internal and external glazed surfaces. This air space has a fundamental bioclimatic role for the building, due to its characteristics of ventilation (natural or forced), width, and geometry of interior and exterior openings.
In detail the functioning mechanism of natural ventilation in double-skin envelope systems depends on the chimney effect that takes place in the cavity, as a consequence of the pressure gradient between air entering and leaving.

Advanced typologies of double-skin systems with forced ventilation have been studied and designed, also regarding HVAC integrations, especially in office buildings. For these systems, an air extractor is placed on the upper side of the cavity, increasing natural ventilation and controlling and directing the air flux in the interior spaces as a function of internal comfort needs.

In this developing research, the performances of naturally ventilated double-skin envelopes have been evaluated in Mediterranean areas, firstly examining the changing system performance as a function of boundary conditions and system dimensions such as air space width and height of building, then comparing different solutions of double-skin systems with traditional ones, characterized by the employment of neutral or solar control double glazing.

The final aim is to evaluate the system's efficiency in Mediterranean climates; for this reason, the façade's plane was south-facing so as to maximize solar luminosity and energetic gains.

All the results, documented in the following paragraphs, essentially concern the analysis of the following parameters, used also for the comparisons.

- g: solar factor, expressed as a percentage, as the sum of total direct transmission through glass surface and secondary thermal exchange factor of the glass wall toward the interior (heat transmission by convection and irradiation in infrared of the absorbed fraction of direct radiation);
- T_{em}: temperature of air that flows out of the air space through upper openings;
- v: velocity of air flowing out;
- $T_{g,int}$: superficial temperature of internal glass pane (the glass surface that is in contact with the interior.

3. The results of conducted simulations

As mentioned in the previous paragraphs, the carrying out of computer simulations is necessary for the purpose of verifying the functioning mechanisms of double-skin envelopes. This is indispensable both to verify which are the chief parameters that most influence the behaviour of the system, and to define energetic savings that can be produced by its employment. The simulations have been carried out with the aid of WIS software developed by the EU Thematic network Win Dat. WIS is a simple software that allows accurate values to be obtained of the solar factor and of the parameters that rule natural ventilation in cavities. Different research programs (Colombari et al., 2003) have compared simulations on double-skin envelopes carried out with WIS software and in-situ monitoring, and have recognized that WIS software produces reliable results.

The city chosen as location for simulations is Bari (41° 7' N – 16° 46' E), in the south of Italy. For this location, implementing solar radiation models (Muneer, 2004), mean values of hourly direct, diffuse and total solar radiation have been estimated. Furthermore external hourly mean temperatures have been obtained. An initial simulation was carried out on a double-skin envelope, perfectly oriented to the south, and formed by an external tempered and stratified glass pane, and an internal neutral double glass.

In the summer the air space between the internal and external glazed surfaces exchanges air with the exterior, so as to expel hot air. During winter, thermal dispersions must be limited, and, to this end, air space in communication with the interior enables us to introduce pre-heated air.

The first simulation tested a 15 metre high double façade (representative of five typical building floors), endowed with lower and upper openings, each 50 cm wide. As a consequence of the changing of air space width, the following figures 1 and 2 show the variations of out flowing air velocity, temperature, and solar factor. These evaluations were carried out at 12:00 on a typical day in the months of August and December. Both in summer and winter, the air velocity reaches maximum values for a 200 mm wide air space and decreases for widths greater than 200 mm, reaching values close to zero for high depths. This is a demonstration of the decreasing influence of external surfaces in heat exchange in the cavity. The temperatures of out flowing air and solar factors are only slightly changeable and almost constant.

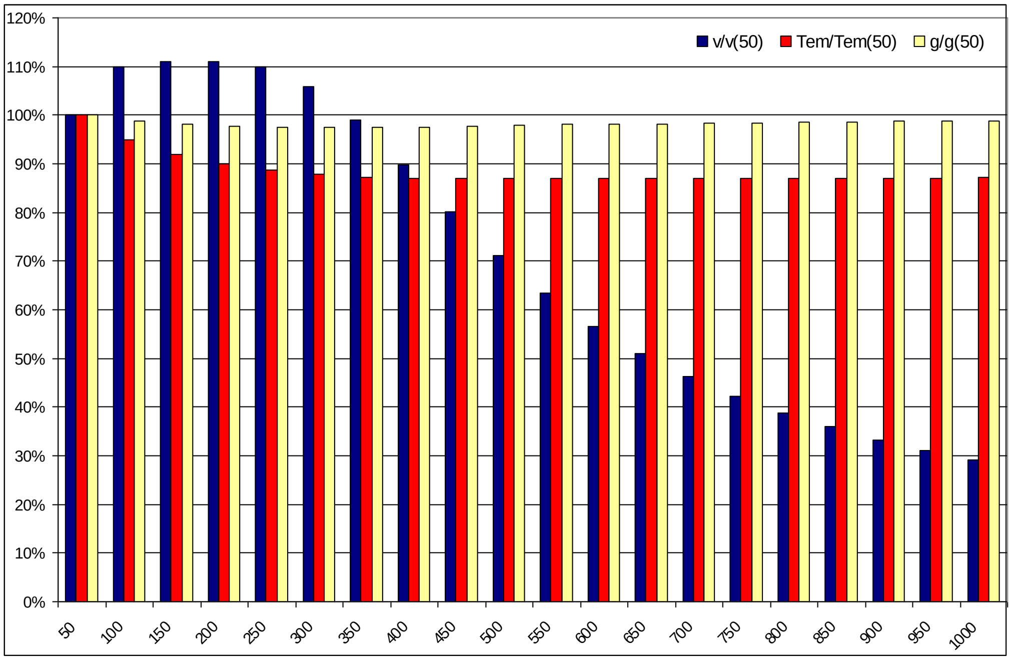


Figure 1: Summer Case: Variability of Ventilation, Temperature and Solar Factor with the Increase of Width of Hollow Space

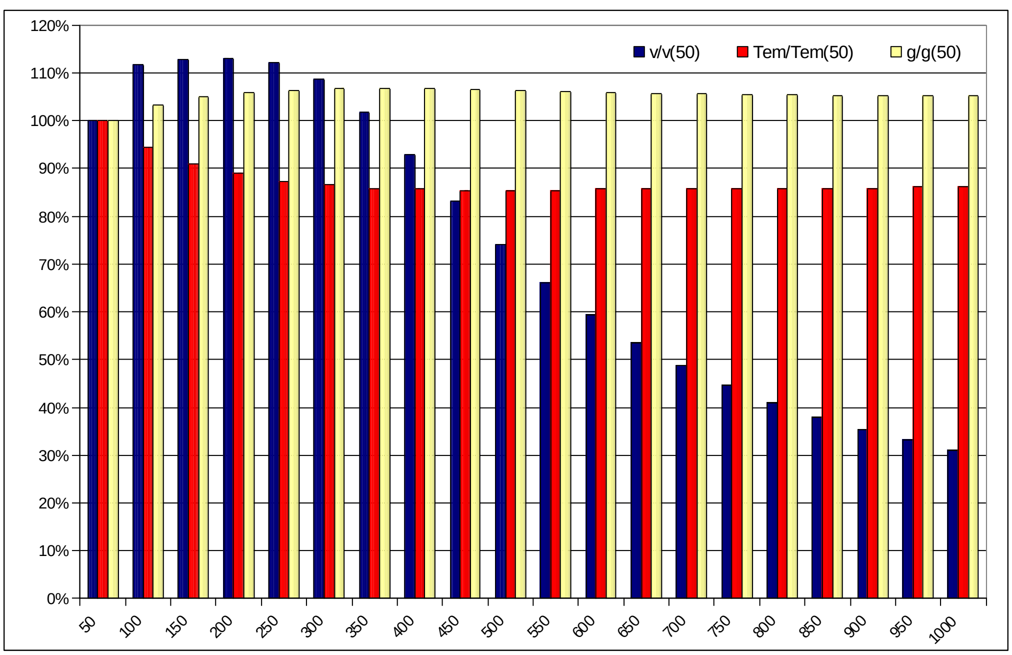


Figure 2: Winter Case: Variability of Ventilation, Temperature and Solar Factor with the Increase of Width of Hollow Space

Finally, with the aim of verifying all the potential energetic savings, obtained with the employment of double-skin envelope systems, different technological solutions were simulated:

- single skin (neutral and solar-control double glazing)

- double skin (transparent, with internal blinds, and with solar control and internal blinds)

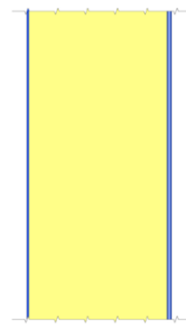
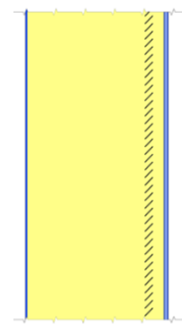
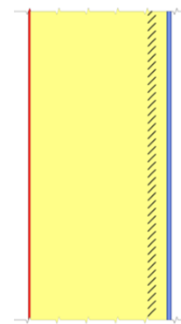
The respective characteristics are shown below in table 1.

For the definition of ventilation parameters, as well as for the calculation of the solar factor, a 15 metre high façade plane was considered, exposed to the south, and for the double-skin systems, endowed with 50cm wide lower and upper openings.

The comparison between summer and winter, carried out considering both superficial temperature variability and solar factor variability, has enabled us to obtain the results reported below, explained by means of the following figures 3 and 4.

Table 1: simulated glazed systems.

	Neutral Double-glass	**Solar control double glass**	**Double-skin naturally ventilated**	**Double-skin with internal blinds**	**Double-skin with internal blinds and solar-control external glass**
(a) external glass	-	-	tempered and stratified glass (12mm)	tempered and stratified glass (12mm)	tempered and stratified glass whit solar control film (12mm)
(b) hollow space	-	-	naturally ventilated (900 mm)	naturally ventilated (900 mm)	naturally ventilated (900 mm)

(c) shading devices	-	-	-	aluminium blinds, 45° tilted	aluminium blinds, 45° tilted
(d) internal double-glass	neutral double glass (6+16+6)	solar control double glass (6+16+6)	neutral double glass (6+16+6)	neutral double glass (6+16+6)	neutral double glass (6+16+6)
	d	*d*	 *a b d*	 *a b c d*	 *a b c d*

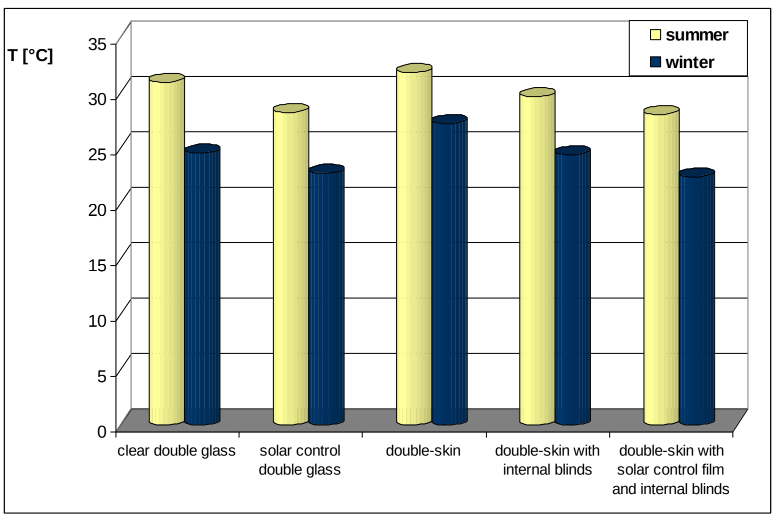


Figure 3: comparison between superficial internal glass temperatures.

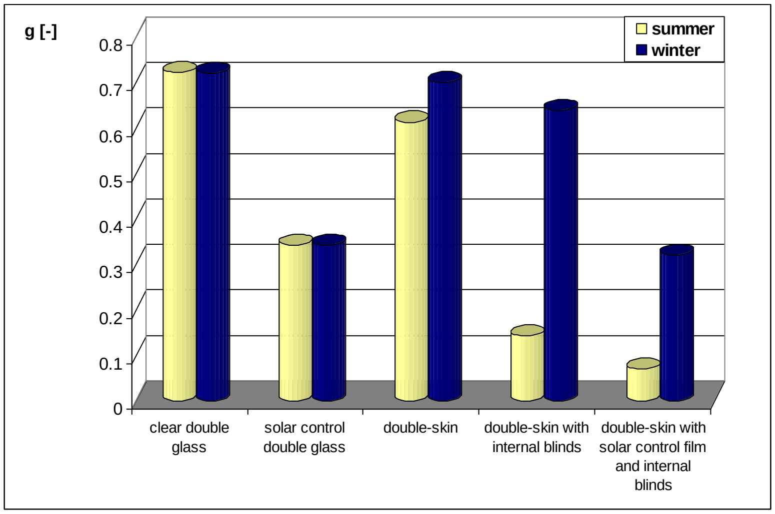


Figure 4: comparison between solar factors.

Comparison of the different tested systems and the basic system, formed by a clear double glass surface, demonstrated that with the aid of an external solar control surface, we could decrease internal glass temperatures by 10%, and, consequently, reduce the solar factor by 50%. As also shown in the previous figures, these reductions are substantially constant both in summer and in winter. Using a system formed by a naturally ventilated double skin, a small increase of winter and summer superficial temperatures can be obtained, but the solar factor can be reduced by 15% during summer and can be kept constant during winter. Using a double-skin with aluminium blinds, tilted 45° on a horizontal surface, it is possible to stop a lot of incidental summer solar radiation, and, at the same time, to use a significant amount of solar energy in winter, thanks to natural ventilation. As a consequence it is possible to obtain a reduction of superficial temperature in summer, while in winter it can be kept constant. The proof of the improvement of solar radiation control is obtained focusing attention on the solar factor, which, thanks to the influence of cavity air, is decreased for double-skin envelope systems greatly during summer and not so much during winter.

4. Conclusions and future developments of the research.

In conclusion it can be noted how double-skin envelopes are able to control solar radiation dynamically, ensuring, by a combination of natural external ventilation (during summer) and internal ventilation (during winter), dynamically changeable solar factors, as a function of external boundary conditions and internal comfort levels. In addition, through the analysis of the data obtained from simulations, it is noted that, for totally glazed double-skin surfaces, the increase of the temperature in the cavity could not be obtained through natural ventilation alone.For this reason, as an alternative to forced ventilation, the system should be equipped with internal shading devices able to stop the transmitted solar radiation. It is necessary to continue to implement other models in which different double-skin systems are evaluated, changing both the characteristics of glass surfaces, and the characteristics of shading systems.

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