

## 618: Thermal performance of an office building with a double skin façade in a Mediterranean climate

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### Abstract

Office buildings in Santiago de Chile normally show higher cooling than heating energy demand. Overheating and high cooling energy consumption are recurrent problems in this type of buildings in the mentioned city during summer periods. Santiago (33°S) presents a Mediterranean climate, with a high temperature oscillation between day and night during summer. On the other hand, office buildings of the country have been incorporating some design patterns of certain developed countries, without considering the particular climate of Chile. In fact, double skins façade have been lately used in this type of buildings without previous studies in order to know if it is an appropriated strategy for Chilean climates. No studies have been made to identify physical phenomena that regulate their behavior in the country. This paper shows the thermal performance of an office building with a double skin facade in Santiago, comparing it with an identical building in which this type of facade is not used. Simulations showed that double skin is not necessarily an effective strategy for energy efficiency. When using other strategies like the solar protection, nocturnal ventilation in office buildings without double skin, energy efficiency may be reached, tending to low energy cooling demand.

Keywords: double-skin façade; office building, natural ventilation, cooling demand

### 1. Introduction

In Chile, there is no thermal regulation to establish requirements for an appropriated thermal behavior of buildings according to their different climates. There is only a regulation which requires a maximum thermal transmittance for ceiling, floors and walls in residential buildings. There is also a requirement for a maximum window area according to their U value. There is no requirement for tertiary buildings so most of them do not show any efficient design strategy in order to achieve comfort with energy efficiency.

Office buildings in Chile show foreign design strategies even if some of these strategies remain questionable in Central Europe due to overheating problems like double-skin façades with a completely glazed external skin [1]. On the other hand, some studies carried out in Belgium, show that day natural cross ventilation that may be generated by a double-skin façade, highly depend on the wind direction and use of wind protection. According to this study, some air from the double skin zone may come into the offices (mainly to those of last floors of the building) increasing risk of overheating [2].

More recent studies have showed that use of a double skin façade may cause a cooling load increasing. When this type of façade is used, a natural cooling strategy is recommended [3].

In the country, double skin façades have been mainly used due to aesthetic reasons without any consideration on the physical phenomena that

occurs within them, affecting significantly comfort and energy efficiency.

Most of cases show no ventilation control through the double façade, with no operable windows and with apertures that remain opened throughout the day and year.

This means that double-skin façades does not make any contribution to improve ambient conditions inside the building during winter, because over ventilation between the two skins evacuates solar gains that may increase the temperature in this zone. In some cases, there is no criterion on orientation of double skin and solar gains that go beyond the first one will be transferred to the inside through the internal skin, when glazed elements do not count with solar protection, which is very common in our tertiary buildings. No studies about the use of north oriented double skin façades and their effect on environmental conditions inside the buildings have been made in Santiago de Chile nor in the rest of the country.

For the city of Santiago, in case of office buildings, cooling energy demand is more important than heating demand. Even if there are low temperatures in winter period of the year, high internal gains make that heating energy demand become low.

Previous studies have showed that office buildings in Santiago reach a high cooling energy demand. Cooling demand for two different buildings of this city reached 55 and 110 kWh/m<sup>2</sup> year. The latter correspond to a completely glazed façade building [4].

The main aim of this paper is to study the effect that a double-skin façade may produce in the inside ambient of an office building during summer, when this type of façade is north oriented in the city of Santiago de Chile (capital of the country; 33°30'S). A comparison with other strategies will be made in order to recommend the most effective ones for achieving summer comfort with energy efficient use in office buildings in the city.

Climate of Santiago is Mediterranean, showing high temperatures during spring and summer. The city is located between the coastal and the Andes Cordillera. Mean value of maximum temperature is 29,7°C and mean minimum is 13°C for the warmest month of the year (Jan.) [5].

## 2. Methodology

The study was developed with simulations in order to make a thermal analysis of an office building using TAS software. This software permit a complete study of thermal behaviour of the building, estimating heating and cooling energy demand and variation of internal conditions like dry bulb temperature relative humidity , mean radiant and resultant temperature.

### 2.1 The building: a general description.

The building, with a north oriented double facade and with some modifications, corresponds to that proposed by Subtask A of Task 27 (Performance of solar facade components) of the International Energy Agency, Solar Heating and Cooling Program [6]. . Figure 1 shows a plan of the building and figure 2 shows a 3D drawing of it. Each of the 5 floors of the building have 30 identical offices. The north and south facades have windows as the one observed in Figure 3. Between each office and the central corridor there is an operable window above the door. At the bottom and top of the external glazed facade of the double skin there is an aperture. At the top there is an opening to the north and one to the south.

### 2.2 Specifications

Main thermal properties of wall and windows are the following:

Roof:  $U = 0.47 \text{ W/m}^2\text{K}$

External walls:  $U = 1.2 \text{ W/m}^2\text{K}$  (concrete walls with internal insulation of 20 mm of EPS)

Windows: Double glazing;  $U = 2.9 \text{ W/m}^2\text{K}$  (for building windows and for double skin).

Intermediate floor:  $U = 2.8 \text{ W/m}^2\text{K}$  (Concrete slab)  
Partition walls of light construction (timber frame panels).

Ground floor with no thermal insulation.

Air cavity width: 1.2 m.

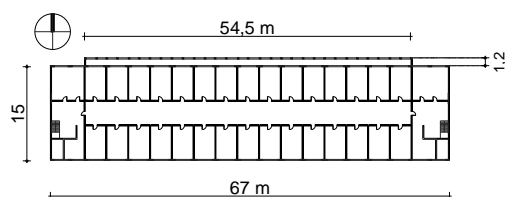


Fig 1. Plan of the building



Fig 2. Perspective of the building

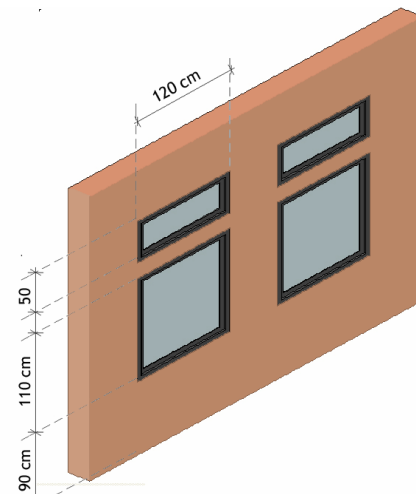


Fig 3. Window of northern and southern façade

### 2.3 Internal gains

People:  $10,6 \text{ W/m}^2$

Lighting:  $20 \text{ W/m}^2$ .

Equipment:  $12 \text{ W/m}^2$ .

Lighting gain is rather high due to non efficient artificial lighting systems used in office buildings in the country. These figures has been obtained from a study made in different office building in the country, where it was also showed that users commonly leaves artificial lights on even if this is not necessary. Simulations made with lower lighting gains shows effectiveness of introducing better artificial systems and making an adequate use of this system in office buildings [4;7].

### 2.4 Internal conditions

When cooling demand was estimated, the following temperatures in the inside of each of the 150 offices were considered:

Week days: Maximum of 26°C from 8:00 AM till 19:00 PM.

Weekend days: No temperature restrictions.

Infiltration rate: 0,3 ach.  
 Ventilation rate: 1,0 ach.  
 In corridor only a lighting gain of 1,0 W/m<sup>2</sup> was considered. In halls of each extreme of the building, a lighting gain of 5W/m<sup>2</sup> was assumed. In both cases, from 8:00 AM till 19:00 PM, the occupancy hours of the building.

### 2.5 Climate

The climate of Santiago de Chile with hourly data of temperature, humidity, global solar radiation, diffuse solar radiation, cloud cover, dry bulb temperature, wind speed and wind direction was used. For analyzing overheating and ventilation rates through openings of the building and of the double-skin façade, a typical day of summer was considered (January 31<sup>st</sup>). This day shows a maximum temperature of 32 °C, a minimum of 9,3°C, a mean value of wind speed of 10,0 m/s with SW orientation. Cloud cover is zero throughout the day so solar radiation is intense.

### 2.6 Simulations

As a first step, the inside temperature variation was observed in different offices of the building considering the double skin façade completely closed and then with one of the upper (southern oriented) and the lower apertures opened. Windows of offices were assumed closed. The study of these temperature variations were made for January 31<sup>st</sup>, as mentioned.

As a second step, openings of the double skin, in combination of different opening schedule for north and south oriented façades were considered. In these cases, the ventilation rates and internal temperature variation were estimated.

Finally, the same building, without a double skin façade was studied in order to evaluate different design strategies for reaching inside comfort during cooling period of the year. Evaluated strategies were solar protection, nocturnal ventilation and decreasing of lighting gains.

## 3. Results

### 3.1 Case 1

When assuming all windows closed, including those of the building and the upper and lower apertures of the glazed skin of the double-skin façade, a high overheating risk was observed. Temperatures in the double skin and in offices of the building reached temperatures over 43,0 °C, which makes that a closed double skin is not recommended for summer time in the city of Santiago.

### 3.2 Case 2

In case of opening the lower aperture and the upper south oriented window in the double skin façade (remaining all rest of windows of the building closed), temperature in double skin is a little higher than in the outside ambient, reaching a maximum temperature of 33.0 °C. An important overheating risk is observed in the inside of the building, where in north oriented offices, temperature reached values over 35.0 °C. See Fig. 4

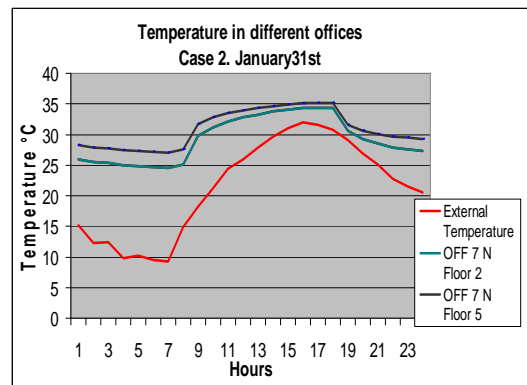


Fig 4. Temperature variation in some offices of the building. Case 2.

### 3.3 Case 3

A third simulation assumed the lower aperture and south oriented upper aperture of the double skin façade opened during 24 hours. Also upper windows of each office (north and south) were assumed opened during 24 hours (see Fig 5). Ventilation rates reached in this case were relatively low, with unilateral ventilation (see figure 5) from 2.5 (ground floor) to 2.8 ach (upper floor) in northern offices and from 4.2 (ground floor) to 6.5 ach (upper floor) in south oriented offices. In double skin, ventilation rate reaches values from 2.2 to 4.4 ach. The main problem was inside temperature, which remains higher than 32.0°C, mainly due to day ventilation rates. In this case, the higher ventilation on south oriented offices than in north oriented offices may be explained by the SW west direction of wind coming directly –during night and day – to the upper window of the double-skin façade and to windows of this south oriented façade.

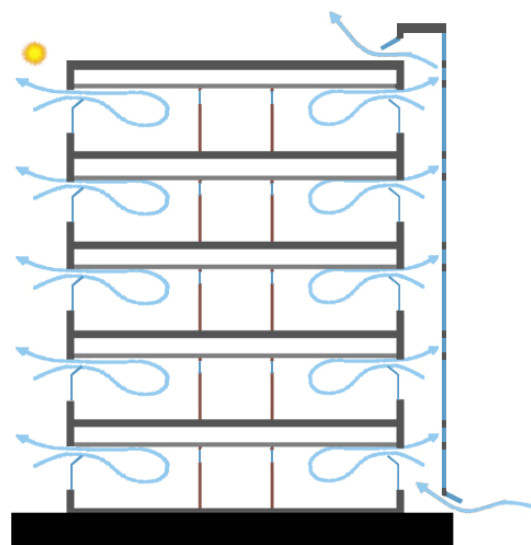


Fig 5. Offices unilateral ventilation

### 3.4 Case 4

The next step considered window opened as showed in figure 5 during 24 hours of the day.

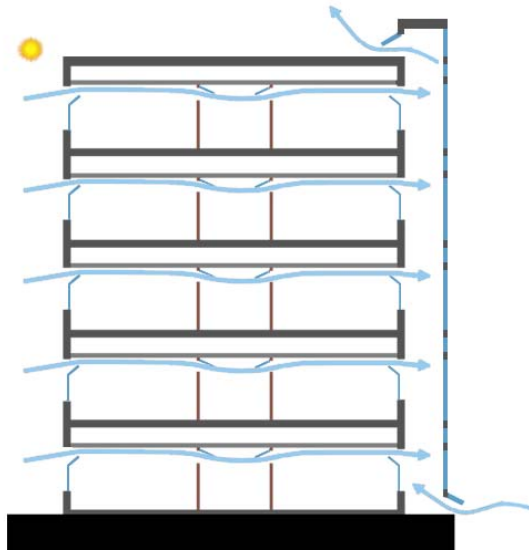


Fig 5. Offices cross ventilation

In this case, over ventilation occurred, reaching ventilation rates from 60 to 110 ach, which is not recommended even during the night when the building is not used. In this case, due to high ventilation, inside temperature follows external temperature during the 24 hours of the day.

### 3.5 Case 5

When opening only a 10% of the above windows of each façade (windows to double-skin in north oriented facade) and remaining completely opened windows to corridors for 24 hours of the day, ventilation rate was lower than the latter case, reaching values from 15,9 ach (in ground floor) to 19,5 ach in upper floors. In this case, the higher inside temperature in all north oriented offices are a little lower than external temperature, but still over comfort. In this case, the double skin façade windows that remain opened during 24 hours are the south oriented ones.

### 3.6 Case 6

Lower ventilation rates were reached when upper façade windows (south oriented ones) and windows to corridors are opened only a 10% during the night (nocturnal ventilation). In this case, ventilation rates reached values from 7.2 ach (ground floor) to 8.7 ach in upper floor. Temperature variation in the inside of buildings shows overheating problems so artificial cooling is necessary. Following graph (figure 6) shows inside temperature of identical offices showed in figure 4. Inside maximum temperature has decreased in around 5°C respecting to case 2.

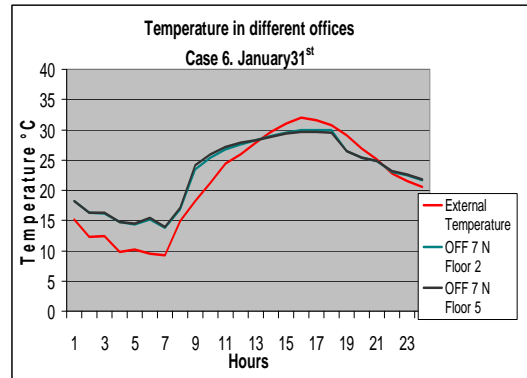


Fig 6. Temperature variation in some offices of the building. Case 6.

### 3.7 Case 7

The building without a double skin façade was evaluated, estimating cooling demand. In this case, opaque external solar protection was considered for north oriented windows (windows that were oriented to the double façade). Internal gains and internal conditions were identical to those of the double-skin façade building. Windows remained opened as described case 6 (nocturnal ventilation for building windows with 10% of opening).

Following figure (figure 7) shows lower temperatures in identical spaces of the building of case 6. This explains the lower cooling demand obtained in this case compared to the rest of situations.

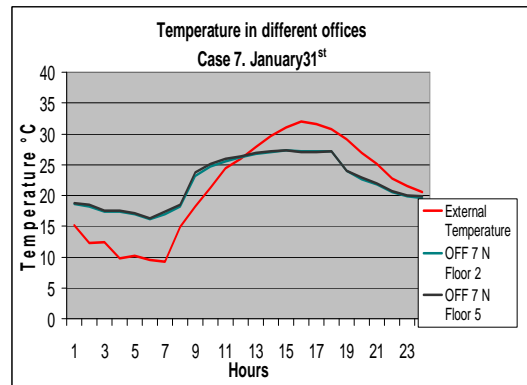


Fig 7. Temperature variation in some offices of the building. Case 7.

The following table (Table 1) shows cooling demand of this building (without double skin façade) and heating –in same cases– and cooling demand of different situations considered for the double skin façade building.

North oriented windows correspond to those where double skin façade is assumed in other cases.

Table 1: Heating and cooling demand of the building with double skin façade and a building without it (case7)

Case	Heating Demand kWh/m <sup>2</sup> year	Cooling Demand kWh/m <sup>2</sup> year
Case1. All windows (Double Skin (DS) & building (B)) closed	17.0	18.2
Case2. Lower and upper DS windows opened. B windows closed	18.2	12.2
Case3. DS windows opened 24h. Unilateral ventilation 24h.	---	9.5
Case6. DS windows opened 24 h. Cross nocturnal ventilation with 10% opening of B windows	---	7.2
Case 7. Building without double skin façade and solar protection for north oriented windows and nocturnal natural ventilation	---	5.3

#### 4. Conclusion

A double skin façade building has been studied for a Mediterranean climate, with high temperatures and solar radiation during summer. It has been able to observe that a non appropriated operation of the double skin façade may produce overheating and over ventilation during cooling periods of the year.

We may also conclude that heating demand is low when openings of the double skin remain closed during 24 hours of a winter day. This heating demand may decrease if we consider a lower thermal transmittance on walls.

When using other architectural design strategies, like solar protection on north oriented windows combined with nocturnal ventilation we may achieve energy efficiency in office buildings in the city of Santiago de Chile, reaching a better natural cooling performance than double skin façades. Due to temperature variation between day and night in cooling periods of the year, nocturnal ventilation has showed to be effective for office building energy efficiency in the mentioned city. In this case internal inertia is necessary which in the studied building is given by reinforced concrete slab in different floors.

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