Nocturnal natural ventilation for low and zero energy office buildings in Central Chile

Waldo Bustamante Gómez[1] and Elisabeth Gratia[2]

[1]School of Architecture, P. Catholic University of Chile, Santiago, Chile1*
wbustama@puc.cl
[2]Architecture et Climat, Université catholique de Louvain, Louvain la Neuve, Belgium

ABSTRACT

Office buildings in central Chile normally show higher cooling than heating energy demand. Overheating is a frequent problem in this type of buildings in cities like Valparaíso and Santiago.
Santiago (33°S) presents a Mediterranean climate, with a high thermal temperature oscillation between day and night throughout the year. Valparaíso -with a temperate climate influenced by the Pacific Ocean- shows lower temperature compared with Santiago. On the other hand, latelly, office building have been incorporating double skins facades in ofiice buildings without previous studies to determine if this is an appropriated strategy for these cities.
This paper shows the thermal performance of a multistory office building with a double skin facade in Santiago and Valparaíso, comparing it with an identical building without this type of facade. Thermal performance was studied with TAS software. Results show that double skin is not necessarily an effective strategy for energy efficiency. A non appropriate design and/or a non proper operation of double skin facades may generate over ventilation, overheating and a high cooling energy demand in office buildings in mentioned cities. Cooling nocturnal natural ventilation in office buildings (without double skin), combined with solar protection are effective strategies for energy efficiency in office buildings.

KEYWORDS

Double-skin façade; office building, natural ventilation, cooling demand.

INTRODUCTION

Office buildings in Chile have been showing foreign design strategies even if some of these remain questionable in Central Europe due to overheating problems. This is the case of double-skin façades with a completely glazed external skin (Manz, H. et al. 2005). On the other hand, some studies carried out in Belgium, show that day natural cross ventilation 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 get into the offices (mainly to those of last floors of the building) increasing risk of overheating during summer (Gratia, E. et al. 2004).

More recent studies have shoved 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 (Gratia, E. et al. 2007).

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.

In the country, in case of office buildings, cooling energy demand is generally higher than heating demand. 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/m2 year. The latter is completely glazed façade building (Bustamante W. 2006).

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 (33°30’’S) and Valparaíso (33°03’’S). A comparison with other strategies is made in order to make recommendations for achieving comfort with energy efficient use in office buildings.

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). Valparaíso -with a temperate climate influenced by the Pacific Ocean- shows lower temperatures compared with Santiago. Mean maximum during summer is 20,8°C with a mean minimum is 13,5°C (January). (Instituto Nacional de Normalización.2008).

METHODOLOGY

Simulations in order to make a thermal analysis of an office building using TAS software. Heating and cooling energy demand were estimated. Variation of internal dry bulb temperature, relative humidity and mean radiant and resultant temperature were also determined.

The Building

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. 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.

Specifications

Main thermal properties of wall and windows are the following: Roof: U= 0.47 W/m2K External walls: U=1.2 W/m2K (concrete walls with internal insulation of 20 mm of EPS). Windows: Double glazing; U=2.9 W/m2K (for building windows and for double skin). Intermediate floor: U= 2.8 W/m2K (Concrete slab). Partition walls of light construction (timber frame panels). Ground floor with no thermal insulation. Air cavity width (double skin): 1.2 m.

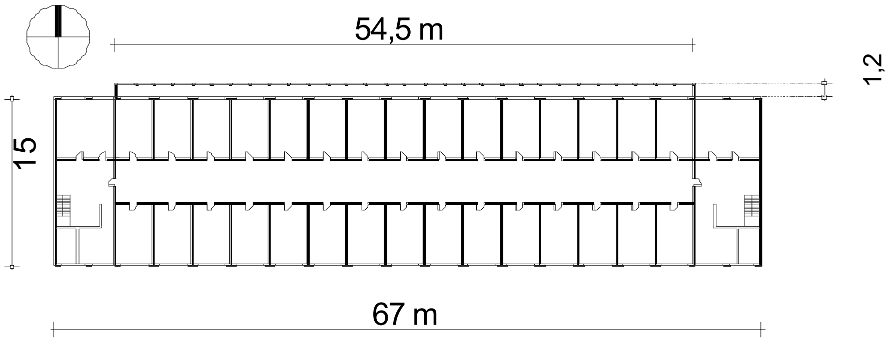

Figure 1. Plan of the building

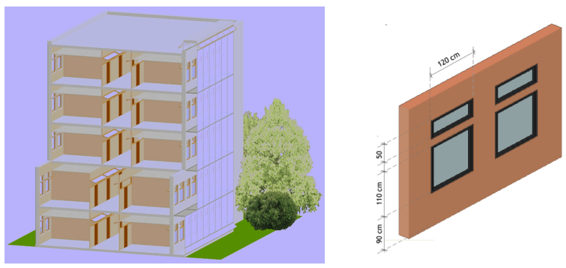

Figure 2. Perspective of the building and detail of lower and upper windows of northern and southern façade.

Internal Gains

For each office, internal walls considered are: People: 10,6 W/m2. Lighting: 20 W/m2. Equipment: 12 W/m2.

Internal Conditions

When cooling demand was estimated, the following inside office temperatures 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. Lighting gain (from 8:00 AM till 19:00): Corridors: 1,0 W/m2. Halls: 5W/m2.

Climate

The climate of Santiago and Valparaíso with hourly data of temperature, humidity, global solar radiation, diffuse solar radiation, cloud cover, dry bulb temperature, wind speed and wind direction were 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 for each city (January 31st for Santiago and Feb, 5th for

Valparaíso). In case of Santiago, this day shows a maximum temperature of 32 °C, a minimum of 9,3°C. Cloud cover is zero throughout the day so solar radiation is intense. In case of Valparaíso, this typical day show a maximum and minimum of temperature of 27 and 11 °C respectively. Cloud cover is 0,5 in the morning, until noon and after 7:00 PM. In between cloud cover is zero.

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 and lower apertures opened. Windows of offices were assumed closed.

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 .

RESULTS

Simulation 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, overheating risk in offices was observed.

Simulation 2

In case of opening the lower aperture and 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. An important overheating risk is observed in north oriented offices of the building.

Simulation 3. Unilateral ventilation

A third simulation assumed the lower and the south oriented upper aperture of the double skin façade opened during 24 hours (during cooling season). Also upper windows of each office (north and south) were assumed opened during occupancy of offices (see Fig 3). Ventilation rates reached in this case were relatively low in Santiago, with unilateral ventilation from 2.5 (ground floor) to 2.7 ach (upper floor) in northern offices and from 4.5 (ground floor) to 4.9 ach (upper floor) in south oriented offices. In double skin, ventilation rate reached values from 2.2 to 4.4 ach in Santiago and from 2,5 to 4,8 ach in Valparaíso. The main problem was inside temperature, which remains higher than confort limit in both cities.

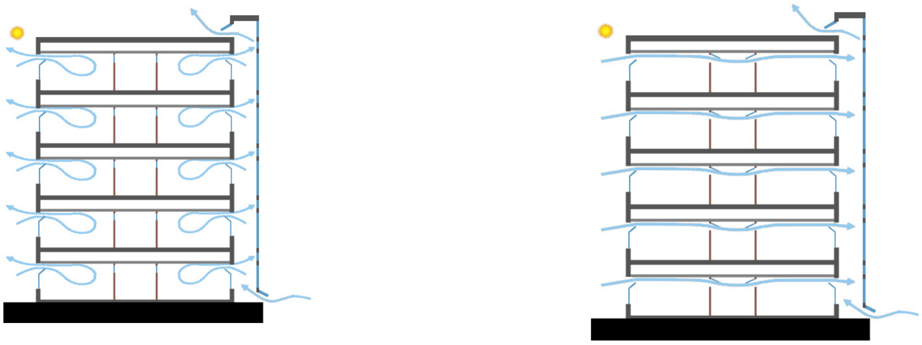

Figure 3. Offices with unilateral (left, simulation 3) and croos ventilation (right, simulation 4).

Simulation 4. Cross ventilation

Cross ventilation was studied, with upper windows of offices 100% opened during 24 hours of the day. In this case, over ventilation occurred, reaching ventilation rates from 60 to 110 ach in Santiago and up to 115 in Valparaíso, 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 hors of the day.

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). See figure 3. In this case, ventilation rates were not higher than 9.0 ach in both cities. Temperature variation in the inside of buildings shows overheating problems so artificial cooling is necessary.

Simulation 5. Building without double skin

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 originally 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 simulation 4 (nocturnal cross ventilation for building windows with 10% of opening). A lower cooling demand was obtained in this case.

In a critical day, overheating is observed in Valparaíso but this may be avoided with some diurnal ventilation.

The following table (Table 1) shows the building cooling demand considering different exposed situations.

TABLE 1: Cooling demand. Building with with and without double skin façade (case6)

Case	Santiago Cooling Demand kWh/m2 year	Valparaíso Cooling Demand kWh/m2 year
Simulation 1.All windows (Double Skin (DS) & building (B)) closed	18.2	17.7
Simulation 2. Lower and upper Double Skin windows opened. Building windows closed.	12.2	11.4
Simulation 3. DS windows opened 24h. Unilateral ventilation24h.	9.5	8.5
Simulation 4. DS windows opened 24 h. Cross nocturnal ventilation with 10% opening of B windows	7.2	5,7
Simulation 5. Building without DS façade and with solar protection for north oriented windows and nocturnal natural ventilation	5.3	3,6

CONCLUSION

A double skin façade building has been studied for two different climates of Central Chile. A non appropriated operation of the double skin façade may produce overheating and over ventilation during cooling periods of the year.

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 considered city, reaching a better natural cooling performance than double skin façades buildings. 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 Santiago. In this case internal inertia is necessary which in the studied building is given by reinforced concrete slab in different floors.

Cooling demand is significanly lower than real cases studied in Santiago. This demand is very close to cero cooning demand in Central Chile, specially in Valparaíso.

REFERENCES

[1] Manz, H. and Th. Frank, (2005). Thermal simulation of buildings with double-skin façades. Energy and Building, 37: p. 1114-1121.

[2] Gratia, E. and A. De Herde, (2004). Is day natural ventilation still possible in office buildings with a double skin façade?. Building and Environment 39 : p. 399-409.

[3] Gratia, E. and A. De Herde, (2007). Are energy consumption decreased with the addition of a double skin? Energy and Building 39 : p. 605-619.

[4] Bustamante, W. (2006). Cooling natural ventilation for office buildings in a Mediterranean climate. Proceedings of PLEA 2006. Geneva. Switzerland.

[5] Instituto Nacional de Normalización (2008). NCh 1079-2008. Arquitectura y Construcción. Zonificación climático habitacional para Chile y recomendaciones para el diseño arquitectónico. Santiago de Chile.

Paper was developed with the framework of project 1090602 of FONDECYT-Chile.