Cooling natural ventilation for office buildings in a Mediterranean climate

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ABSTRACT: Office buildings in Santiago of Chile show a high cooling energy demand during summer. Most of these buildings are based on design patterns of developed countries and they do not consider the local climate and elemental design strategies for improving their thermal behavior in cooling periods of the year. Due to this, office buildings show overheating problems and a high cooling energy demand. For two buildings of Santiago, preliminary studies through simulations made with TRNSYS, allowed to conclude that some free cooling design strategies -such as nocturnal natural ventilation- are highly effective. Through TRNSYS, it is not possible to study the effect of wind on natural ventilation of buildings, nor can either quantify the effect caused by the opening of windows in ventilation. In this work we have used TAS, software that allows the indicated studies. This paper shows the feasibility of reaching the necessary ventilation through windows, for an efficient cooling of two buildings already constructed in Santiago. It is observed that using this strategy, energy saving is possible to be obtained. More than 50% of energy saving respecting to the two studied buildings of Santiago, may be reached when using this effective design strategy.

Keywords: cooling, natural ventilation

1. INTRODUCTION

In Chile, important steps have been done in order to define a regulation for thermal behavior of residential buildings. Since March 2000, a maximum U value for ceilings of new residential buildings is been applied. On the other hand; the Ministry of Dwellings and Urbanism has recently decided to apply a second step of this regulation that consider thermal requirements for walls, windows and floor of residential buildings.

In order to regulate the thermal behavior of office buildings, there is no mandatory requirement and excepting some cases, most of tertiary buildings of the country do not show any criteria for achieving inside comfort with energy efficiency. In Chile, a mean of 2.69 millions m^2 of tertiary buildings were constructed each year between 1996 and 2000 [1].

The Ministry of Publics Works of Chile has been developing some initiatives in order to promote design strategies for energy efficiency in public buildings in different climates of the country [2].

These strategies have been considered in the design of some recent projects for buildings like a state building in the city of La Serena (29° 54´ S°), north of Santiago.

Climate of Santiago show high temperatures during spring and summer. Due to this and the fact that normally no bioclimatic design strategy is considered for office buildings in the country, they reach high cooling energy consumption.

On the other hand, different studies have been made in order to show efficiency of using natural nocturnal ventilation for cooling office buildings in different climates [3;4].

This paper shows the high impact in heating and cooling energy demand that some types of buildings show in the city of Santiago, the main city of the country. The paper will also show that when assuming some bioclimatic architecture strategies, energy demand to achieve thermal comfort in the inside ambient of buildings, significantly decreases in this type of buildings.

Preliminary simulations for estimating cooling energy demand were made using TRNSYS. Strategies using solar protection for windows and natural nocturnal ventilation were considered. Application of these strategies has been effective to reduce cooling energy demand but using this software it was not possible to verify if nocturnal ventilation was possible with opening windows during the night [5]. .

In order to evaluate feasibility and how effective could be nocturnal natural ventilation through window opening of the buildings, simulations were made for two buildings of the city of Santiago. Simulations were made using TAS software.

2. METHODOLOGY

Two office buildings constructed within the last 15 years in Santiago (capital of Chile; 33º 30¨S) were selected: Building Las Industrias and building Pedro de Valdivia, both with very different architectural styles as it will shown later.

To analyze the thermal behavior of these buildings, simulations using TAS software were made. These simulations considered the architectural design, the internal gains and comfort conditions to be achieved. Internal gains were estimated according to data obtained from buildings' administrators.

Internal gains for present situation of buildings were the following: Light: 40 W/m2; occupancy: 7.5 W/m2; equipment: 12 W/m2.

Comfort conditions in the inside of buildings are the following: Day (8:00AM to 20:00 PM): 20 – 24 °C during winter and 20 to 26°C in summer. Rest of the day: free variation of temperature. Ventilation for hygienic purposes: 2.0 ach in throughout the year.

The climate of Santiago is Mediterranean. The city is located between the coastal range and the Andes Cordillera. Mean value of maximum and minimum temperatures are 14.9°C and 3.9 °C for coldest month of the year (July). From September to March, mean value of minimum temperature is between 8,5 to 13,0 °C. Mean value of maximum temperature in identical period is between 20,0 to 29,7°. Prevalent wind direction for January is SW with mean speed of 8.6 km/h. Prevalent wind direction for July is also SW with mean speed of 4.9 km/h [6].

The first step of simulations considered the buildings as they are being used at the moment (present situation), without considering any improvement in the architectural design. Cooling demand was so estimated.

Improvements in the design of buildings were assumed. Improvements considered were: Solar protection in windows (overhangs for north orientation and vertical protection for west and east orientation) and nocturnal ventilation (from January to April and from September to December) through openings. Due to high lighting internal gains, a decrease on these gains was also assumed. Cooling demand was estimated through simulations after each improvement. Also combinations of these improvements were considered.

For simulations, two types of windows were considered. Each window of 1.0 meter wide has two types of apertures. One of these windows has a lower aperture of 0,6 m and a higher aperture of 1,2 m height . The other window has a lower aperture of 1,2m height and a higher aperture of 0,6 m height (see Figure 1).

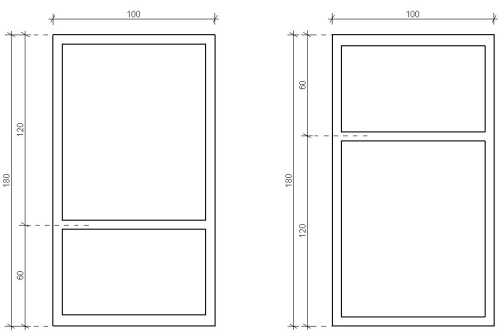

Figure 1: Type of windows.

3. BUILDINGS DESCRIPTIONS AND RESULTS

3.1 Description of the building Las Industrias. Santiago. Chile.

Office building of 33 floors, 51838 m2, with 3 underground floors and completely double glazed facades, representing a common style of office building adopted during the last decades in Chile (see Figure 2)

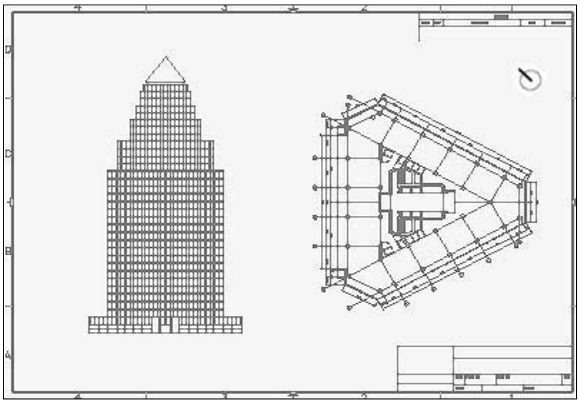

Figure 2: Building Las Industrias. Santiago, Chile.

Approximately 80 persons work every weekday in each floor. Around 80 % of these occupants use a computer. Artificial lighting is used throughout the day during all weekdays.

3.2 Results of simulations.

The graph of figure 3 shows results of simulations for cooling energy demand. Simulations and data collected from the administration of the building showed that cooling demand in this building was higher than heating demand.

Simulations were made for different floors of the building. Opening of the higher and lower big apertures of windows were assumed. Results for the floor 10 are showed.

The graph shows that the higher cooling demand is the one of the present situation. When applying a nocturnal ventilation strategy in cooling period (from October to March, both included), the total cooling energy saving compared to the present situation is 33%. Nocturnal ventilation was obtained through opening of windows and according to TAS ventilation reached between 6 to 8 air changes per hour. Only unilateral ventilation was assumed and this was enough for obtaining cooling. Cross ventilation was higher than unilateral ventilation (over 25 ach) without obtaining a significant saving of cooling demand.

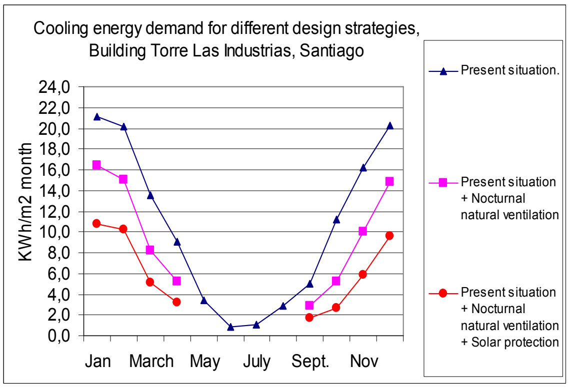

Figure 3: Cooling energy demand for building Las Industrias. Santiago. Chile.

When assuming a combination of the nocturnal summer ventilation strategy with solar protection in windows, total cooling demand decreased in a 58% respecting to the present situation.

Even if nocturnal ventilation is effective for reducing cooling energy demand, due to the fact that the building is completely glazed, it is difficult to reach energy efficiency in his performance, being this a good example of an unsustainable building.

3.3 Description of the building Pedro de Valdivia. Santiago. Chile.

Building's area is 6938 m2, with 11 floors and 2 underground floors.

The building is constructed with reinforced concrete external walls with ceramic recovering and reinforced concrete slabs. Window (with single glazing) to floor ratio is 15 %.

Approximately 50 persons work in each floor. The building shows a high internal gain due to persons, computers (almost one for each occupant) and lighting used throughout the day. The building was constructed in 1997. See figures 3;4 and 5.

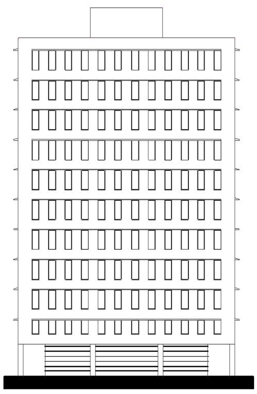

Figure 3: Main façade for building Pedro de Valdivia. Santiago. Chile.

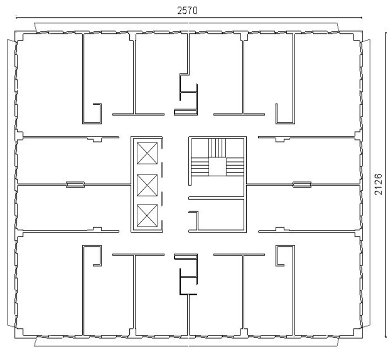

Figure 4: Plan for building Pedro de Valdivia.

Figure 5: Building Pedro de Valdivia. East oriented entrance.

3.4 Results of simulations.

The graph of figure 6 shows results of simulations for cooling energy demand. As the case of building Las Industrias, cooling demand in this building was higher than heating demand.

The graph shows that the higher cooling demand corresponds to the present situation (which considers 40W/m2 as lighting internal gain). In this case, if nocturnal ventilation is simultaneously applied with solar protection, cooling demand decreases in around 44%. A similar result is obtaining when reducing the lighting gain from 40 W/m^2 to 20 W/m^2, without applying any other strategy.

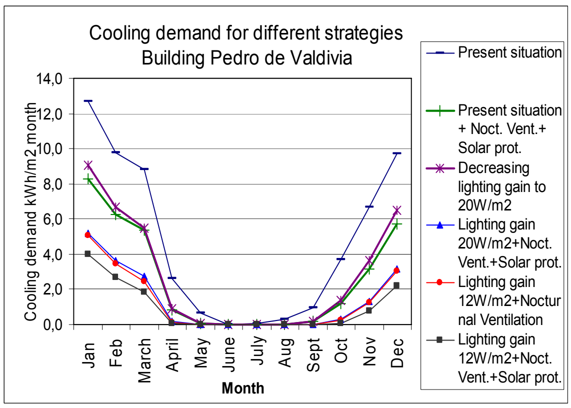

Figure 6: Cooling energy demand for building Pedro de Valdivia. Santiago. Chile.

When assuming lighting internal gain of 12 W/m^2 with nocturnal ventilation, a reduction of around 70% in the cooling energy demand is observed. A similar result is obtained when assuming 20W/m^2 of lighting internal gain with nocturnal ventilation and solar protection (See figure 6).

The higher reduction in cooling demand was obtained when supposing lighting gain of 12 W/m^2 combined with solar protection and nocturnal ventilation. In this case a decrease of a 79% respecting to present situation was estimated.

Table 1 shows the cooling energy demand for the cooling period for different design strategies applied to the building. Since the building have not included effective systems for solar protection of windows (see figure 5), the first simulations made considered external vertical solar protection for west and east facades and a more effective overhang for north oriented façade.

After assuming effective solar protection, for different lighting gain cases, nocturnal ventilation implied a significant decrease of cooling energy demand, being 31 % for 40W/m2 of lighting gain, 36% for 20 W/m2 and 41 % for 12W/m2 of lighting gain,

Respecting to openings and impact in air change per hours, simulations assumed that lower and higher little apertures were opened during the night. Simulations showed that for floor 3, during months of January and February, the hottest of the year, air changes per hour obtained through openings of mentioned windows were between 3 and 8 ach for south façade, between 2 and 3 ach in north façade and 1 to 3 in east and west façades .

These air changes per hour were enough for reaching a lower cooling energy demand, without being necessary to open the bigger apertures of the windows.

Table 1: Cooling energy demand for building Pedro de Valdivia for different design strategies.

Design strategy	Cooling demand kWh/m^2 year
Present situation	55,9
Present situation + Solar prot.	45,0
Present situation + Noct. vent.	37,4
Present situation+ Solar prot. +Noct.Vent	31,2
Reducing lighting gain to 20W/m2	33,9
Lighting gain 20 W/m2 + Solar protection	25,7
Light. gain 20 W/m2 + Noct. ventilation	21,0
Light. gain 20W/m2.+S. prot. +Noct.Vent	16,4
Reducing lighting gain to 12 W/m2	26,7
Lighting gain 12 W/m2 + Solar protection	19,5
Lighting gain 12W/m2+Noct. Ventilation	15,7
Ligh. gain 12W/m^2+Sol. prot. +Noct.Vent	11,6

In this building, single side ventilation showed to be enough for cooling the building. In corner offices of the building, simulations were made assuming small panes of windows opened in adjacent walls. Results of these simulations showed air changes per hour higher of 25 h^{-1} in the third floor, without showing a significant saving in cooling demand.

4. CONCLUSIONS

Nocturnal ventilation is possible to be applied for cooling inside ambient of office buildings in Santiago de Chile. Since external temperatures decreases to a mean values between 8,5 to 13,0°C, during cooling period of the year, nocturnal ventilation is effective for energy efficiency of buildings in this period. Reasonable nocturnal air change per hour permits this performance.

Before applying this strategy in buildings, it is highly recommended to consider others bioclimatic design strategies, such as solar protection or orientation of the building and the use of energy efficient lighting systems. Even if these strategies are applied, nocturnal ventilation is recommended for office buildings in this city.

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