SENSITIVITY STUDY FOR ARCHITECTURAL DESIGN STRATEGIES OF OFFICE BUILDINGS IN CENTRAL CHILE: EFFECTIVENESS OF NOCTURNAL VENTILATION.

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ABSTRACT

Office buildings in Chile show higher cooling than heating energy demand. The climate of the country show important differences between cities by the ocean and those of interior regions, located between the coastal and the Andes range. Main cities of Central Chile, where more than 40% of buildings are constructed every year are Santiago and Valparaíso, both located at around 33° S. Santiago presents a Mediterranean climate, with a high temperature oscillation between day and night during cooling period. Valparaíso, by the coast, shows lower temperature fluctuation compared with Santiago during identical period.
In order to define design strategies for energy efficiency of office buildings in mentioned cities, a sensitivity study has been made, considering variables like size of windows (window to wall ratio), type of windows (clear and selective glazing, including low e, single and double glazing), use and type of solar protection and use of nocturnal or diurnal ventilation. In opaque facades (walls and roofs), thermal insulation is considered. In case of walls, in order to increase thermal inertia external insulation is assumed.

The sensitivity analysis is developed considering a square building containing office rooms on all four orientations. This10 story building has been specially proposed and designed for this analysis. Methodology considers an evaluation of heating and cooling demand of the building in both cities. For this purpose, a simulation software under dynamic conditions has been used (TAS of Environmental Design Solutions Limited).

The lowest cooling energy demand is reached when using the lowest window to wall ratio (20%), with solar protection in east, west and north oriented glazed areas. In fact, fully glazed facades in both cities are not recommended. Nocturnal ventilation was highly effective for decreasing cooling demand in both cities. In the case of Valparaíso, due to relatively low temperature during cooling period (maximum lower than 26°C), diurnal ventilation for cooling purposes is also effective.

KEYWORDS: Office buildings, cooling demand, energy efficiency, nocturnal ventilation

INTRODUCTION

Chile shows a wide latitudinal variation (from 17º30′ S to 56ºS), which generates high North-South climate variation. On the other hand, the presence of the Pacific Ocean and the Coastal and Andes mountains, generate important climate variation from East to West. Santiago (located in the foothills of the Andes) is the governmental capital and also the industrial and financial centre of the country. Valparaíso is the main port of the country, located at almost the same latitude of Santiago but by the coast.

Climate of Santiago is Mediterranean, showing high temperatures and solar radiation during spring and summer. Mean value of maximum temperature is 29,7°C and mean minimum is 13°C for the warmest month of the year (January). Mean temperature of coldest month (July) are: 3.9 °C (mean minimum) and 14.9 °C (mean maximum). A high temperature fluctuation is observed, especially in summer and intermediate seasons. Climate of Valparaiso is influenced by the Pacific Ocean, showing lower temperature oscillation than Santiago. Mean value of maximum temperature is 20.8°C and mean minimum is 13.5°C for the warmest month of the year (Jan.). For the coldest month (July), mean minimum is 9.2°C and mean maximum is 14.3°C[1].

In Chile, around 4.73 million of square meters of buildings of the Industry, Commerce and Financial Institutions sector were constructed during 2008 [2]. 53,2% was built in Santiago and 6,6% in Valparaíso. In the country there is no mandatory thermal behaviour requirements for office buildings and most of their design patterns are brought from developed countries, even if some architectural strategies, such as double skin, are not suitable –for example- in Central European countries due to the generation of overheating problems, especially when they are designed with fully glazed façades [3;4].

Normally office buildings show higher cooling than heating energy demand. Several studies in different countries have been done approaching the impact that different architectural strategies have over the energy demand [5]. A study performed in 2004 in London for an office building, showed benefits in energy use if windows size, solar protection, and internal profit, are optimized. During two representative weeks, one with hot temperate climate and the other with extreme hot climate, 23% and 40% of refrigeration energy reduction were respectively obtained, once previous modifications were applied. On the other hand, once nocturnal ventilation is applied to the optimized building, an additional reduction of 13% is reached [6]. A study performed in 1998 in Sweden (predominantly cold climate), shows how important are the selection of type of glazing and window to façade ratio for reducing cooling and heating energy demand. Glass use with low U values and solar transmittance may mitigate overheating problems but it does not solve it [7].

In order to define architectural design strategies for reaching thermal and visual comfort with energy efficiency in office buildings of the mentioned cities -with different climates- a sensibility study has been made. Variables considered are the following: size of windows (window to wall ratio), type of windows (clear and selective glazing, including low e, single and double glazing), use and type of solar protection and use of nocturnal or diurnal ventilation. In opaque facades (walls and roofs), thermal insulation is considered. In case of walls, in order to increase thermal inertia and effectiveness of nocturnal ventilation, external insulation is assumed. This paper will mainly show results of this study related to the effect of diurnal and nocturnal ventilation on cooling energy demand.

METHODOLOGY

This study aims to analyze the thermal behaviour of an office building, for different design strategies, during a whole year. For this analysis, simulations are performed with TAS (www.edsl.net), software under dynamic conditions. The sensibility study was developed with a 10 story building, specially designed for this study. Figure 1 shows the plan (16X16) building and 3D image. Each story contains 12 offices of typical dimensions (4 m x 4 m x 2.8 m height).

The building

Main specifications of the building are the following:
Walls: Reinforced concrete 150mm with external EPS 30 mm. U=1.0 W/m2°C
Roof: Reinforced concrete 150mm with EPS 60mm. U=0.59W/m^2°C (in Valparaíso) and with 80 mm of EPS in Santiago. U= 0.40 W/m2°C.
Windows: single glazing, clear. U=5.8 W/m^2°C, Lighting transmittance: 0.90 Solar transmittance: 0.87. In the case of windows, this corresponds to the initial situation. Type of glazing is changed during the sensibility process. It is necessary to mention that it is still common to find new office buildings with single glazing in the country.

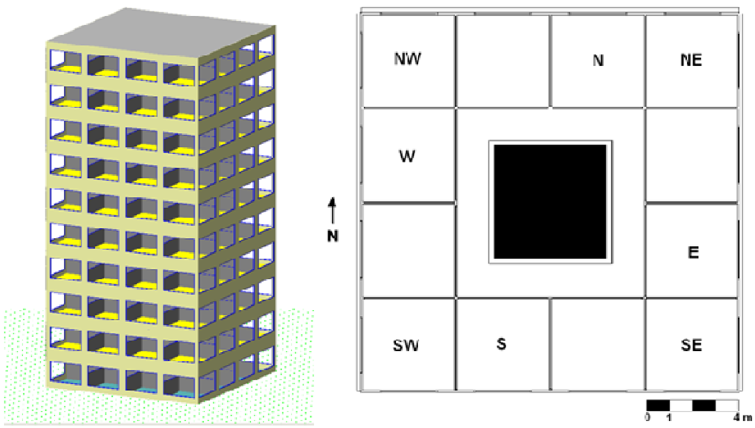

Figure 1. Plan and 3D image of the building

Internal gains and internal conditions

Internal gains of the buildings considered are the following:
People: 9.38 W/m2 (sensible) 6,88 W/m2 (latent).
Lighting: 11 W/m2.
Equipment: 11.25 W/m2.
When cooling demand was estimated, the following temperatures in the inside of each office 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 during week days from 8:00 AM till 19:00 PM.

Sensibility analysis

For defining cases to be simulated, a factorial design was adopted. This involves a given number of samples per each input parameter and consequently running the model for all combination of samples [8]. This method is based on the sampling-based approach, where the model is repeatedly executed from the combination of input parameters sampled with some probability distribution. Since the design of this sensibility analysis consists in 4 input parameters with 3, 3, 4 and 8 parameters per each one, the total combination of samples gives a complete sample of 288 cases. Table 1 presents the different input parameters considered for this study and their associated variables.

Input parameters	**Number of variables**	**Description of variables**
Glazing ratio*	3	20% 50% 100%
Types of solar protection devices	3	Without solar protection Overhang in N orientation and blinds for E and W orientations Blinds in N, E and W orientations
Types of glazing	4	Single glazing, clear Single glazing, selective Double glazing, clear Double glazing, selective
Orientations	8	All orientations (N, NE, E, SE, S, SW, W, NW)

(*) Ratio of the glazed area with respect to the total area of

Table 1: Input parameters for sensibility analysis

The 8 orientations correspond to different office rooms showed in figure 1 (N, NE, E, SE, S, SW, W and NW). For each one of these office rooms of 6th floor, the cooling and heating demand was estimated according to variation of type of glazing, types of solar protection and glazing ratio (see Table1).

Simulations considered the following type of glazing: Clear single glazing clear (CS, 4mm) selective single glazing (SS, 6mm), clear double glazing (DGC) and selective double glazing (DGS). Properties of these types of glazing are shown in Table 2. LT: Light transmission, ST: Solar transmission

	CS	SS	DGC	DGS
LT	0,90	0,60	0,82	0,54
ST	0,82	0,50	0,68	0,41
U (W/m2°C)	5,80	5,70	2,78	2,76

Table 2: Properties of different types of glazing.

After obtaining energy demand results and selecting cases with lower heating and cooling demand, simulations considering low e glazing were made. They showed a non significant impact in lowering heating demand in both climates. As it will be observed, heating demand is significantly lower than cooling demand in office buildings in Chile.

Also, for a selective number of cases, after obtaining the 288 mentioned results, ventilation strategies (diurnal and nocturnal) were studied, in order to observe their impact on reducing cooling demand in the building.

RESULTS

First of all, we have confirmed that heating energy demand for office buildings is significantly lower than cooling demand. In the case of Valparaíso, with only diurnal ventilation for maintaining quality of air in different offices, the lower energy demand was reached with selective double glazing, a WWR of 20% and solar protection (Overhang in N orientation and blinds for E and W orientations). In this case annual cooling demand is 16.3 kWh/m2 year and heating demand reaches 3.2 kWh/m2 year. These values represent the energy demand of all 16 offices of the 6th floor of the building. In the case of Santiago, cooling demand for identical case is 31.8 kWh/m2 year and 4.5 kWh/m2 year as heating demand. When using selective and double glazing with low e, cooling demand increases in a 15% in the case of Valparaíso and around 1% in the case of Santiago (both with identical solar protection).

Sensibility analysis

Regarding the sensibility study and due to high output variability (cooling energy demand for each office) -as consequence of the input variability- the energy performance of office buildings is highly impacted by their façade glazing ratio. Differences on annual cooling demand according to window to wall ratio are significant. See figure 2 for the case of Valparaíso. Identical results were obtained for the case of Santiago. See figure 3.

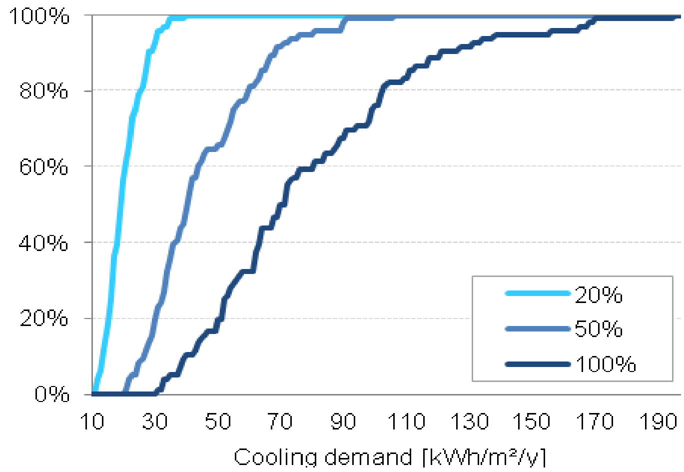

Figure 2. Cumulative frequency (%) for cooling demand with respect to glazing ratio in the case of Valparaiso.

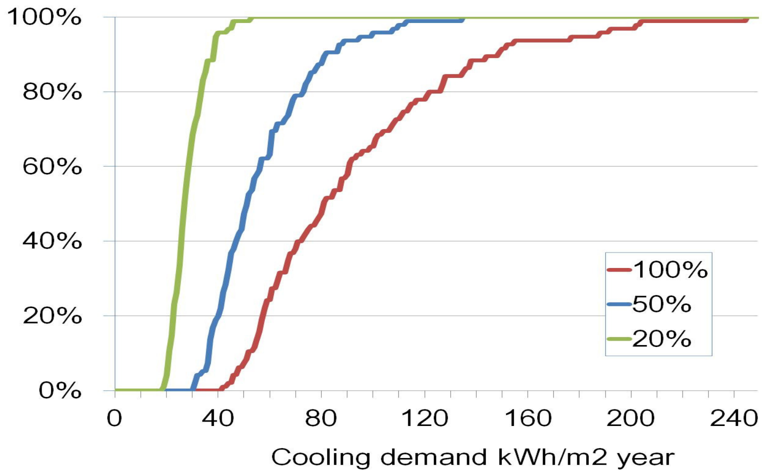

Figure 3. Cumulative frequency (%) for cooling demand with respect to glazing ratio in the case of Santiago.

On the contrary, Figure 4 shows as the variability of the output results per orientation is reduced, which is even more critical with regard to the range of low cooling demands (cases with low window to wall ratio). Figure 4 shows variability on energy demand for all office rooms of 6th floor of the building. Very similar results were observer also in the case of Santiago. According to these results, it is clear that any design strategy proposed for new office developments in Valparaiso and Santiago, the ratio of the glazed area with respect to the exposed façade should be prioritized with respect to orientation.

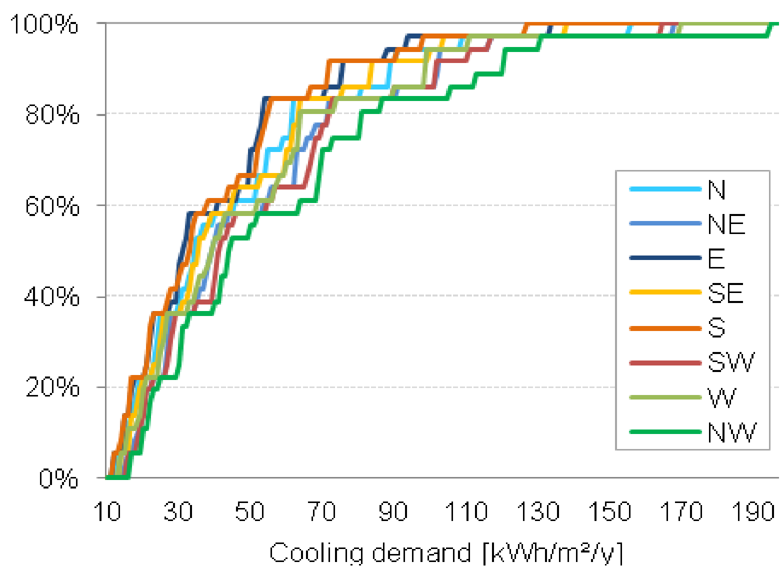

Figure 4: Cumulative frequency (%) for cooling demand with respect to orientations in the case of Valparaiso

Ventilation strategies.

As mentioned, in order to decrease cooling energy demand on office buildings in cities of Santiago and Valparaíso, strategies of ventilation were studied. In the case of Santiago, where we may observe high diurnal temperatures during spring and summer (higher than 26°C) but relatively low nocturnal temperatures (around 15°C), night ventilation was studied. In the case of Valparaíso, where higher temperatures on spring and summer are commonly lower than 26°C, diurnal ventilation for cooling was also studied.

Figure 5 shows the effect of nocturnal ventilation in cooling demand of office buildins in Santiago, when using 20% of window to wall ratio with or without solar protection (SP). Types of glazing are: Single glazing (SG), double glazing selective (DGS). It may be seen that nocturnal ventilation is very effective for getting energy efficiency in office buildings in Santiago. As we have already mentioned, envelope wall of the building is externally insulated, providing it higher thermal inertia. 8 to 10 air changes per hour for nocturnal ventilation may be recommended.

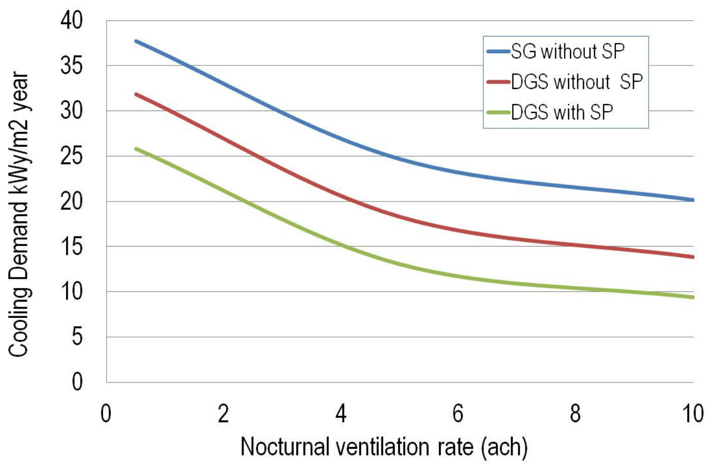

Figure 5: Cooling demand of office buildings with respect to nocturnal ventilation rate.

Figure 6 shows the case of Valparaíso, where identical cases than Santiago were studied. Nocturnal ventilation is also effective bur in this case diurnal ventilation may be recommended. Opening windows when external temperature is lower than 26°C allow reaching a cooling demand 6.9 kWh/m2 year, which decreases to 3.0 kWh/m2 year when using diurnal and nocturnal ventilation. Both cases suppose windows with double glazing selective, solar protection and envelope walls with external insulation.

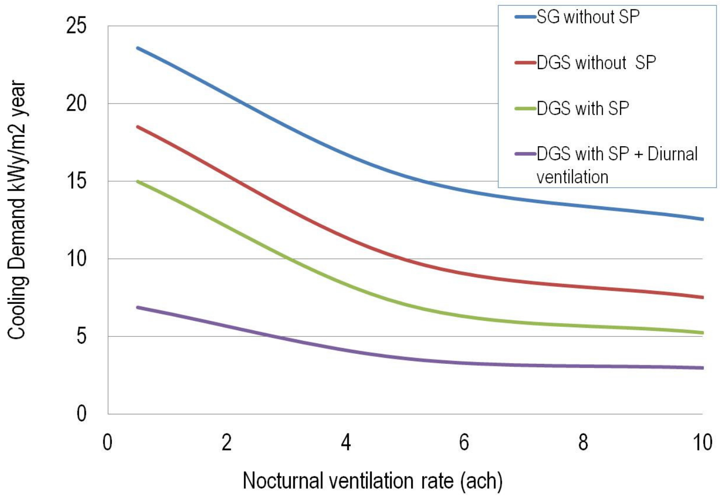

Figure 6: Cooling demand of office buildings with respect to nocturnal ventilation rate.

CONCLUSION

First of all, cooling energy demand in office buildings of Santiago and Valparaíso is significantly higher than heating energy demand. Attention on architectural design strategies for decreasing cooling demand is highly recommended. For lowering cooling demand, solar protection, size and type of windows and solar protection have been studied.

Double glazing selective may be recommended for reaching low cooling demand in both cities. Double glazing clear may also be recommended when using effective solar protection.

It has been showed that there is a high dependence between size of façade glazing area ann the cooling energy demand on office buildings in both studied cities. The lower the window to wall ratio is, a better energy performance of the building is reached. On the contrary, orientation of offices is less relevant for reaching low cooling energy demand, wich is more noticeable for lower window to wall ratio.

Finally, nocturnal ventilation is highly effective for reaching low cooling energy demand in the city of Santiago (with a Mediterranean climate). This strategy is less effective in the case of Valparaíso (with a climate influenced by the ocean). For energy efficiency in office buildings, in the case of Valparaíso, diurnal ventilation may also be applied. Nocturnal and diurnal ventilation may be combined with solar protection on windows and the lower window to floor ratio that may possible to be used.

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