

171: An urban office designed for the southern Brazilian climate

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Abstract

The climate in southern Brazil is characterised by mild winters and hot-humid summers which requires the design to be adaptable to the often conflicting summer and winter requirements. In the commercial sector, air conditioning consumption has been growing significantly along with an increase in office's profit, which emphasizes the importance of encouraging a change in construction practices [1]. The aim of the research is to design a two stories office building that combines traditional and contemporary techniques and technologies, along with a smart design, providing acceptable summer and winter thermal comfort. This was pursued by considering the advantages found in some precedents, such as, passive heating and cooling strategies that respond to the climate; and by controlling the relationships between buildings and outdoor spaces to ensure a response to the different seasons. Environmental design approach is found to go far beyond the quantification of energy consumption through the use of different materials or strategies.

Keywords: environmental design, thermal comfort, natural light, passive strategies

1. Introduction

To reduce energy consumption, the adequacy of the architectural standard is the item that requires the lowest investment and provides one of the highest energy savings.

Finding successful means of energy reduction and a solution to the environmental effects of air conditioning is a strong requirement for the future. Possible solutions include the adaptation of buildings to the specific environmental condition of cities in order to incorporate renewable energy technologies efficiently to address the radical changes and transformations of the radiative, thermal, moisture and aerodynamic characteristics of the urban environment. This involves the use of passive and hybrid cooling and heating techniques to decrease cooling and heating energy consumption and improve thermal comfort.

2. Objectives of the building

2.1 Project Brief

It is a two-story office building designed for Nostra Casa Construction and Incorporation Company. The company's desire was to have a more energy efficient office, where after the building is built, they could test passive strategies and technologies to further apply them to its new buildings. The size required is around 250 m².

The programme is composed by reception, show-room, toilets, kitchen, engineers' room, architects' room, directors' room and meeting room.

2.2 Conceptualization

According to the study of the built examples some conclusions were drawn, such as the importance of the engagement of the architecture with the environment, about rethinking the way

that people work and how the design should respond to the climate [2].

The office should be adaptable, able to be changed according to the seasons, responding at the same time to the climate and to the occupants' attitudes and expectations of comfort. In winter it should be more compact and well insulated to keep the internal and solar gains inside the office and save energy when mechanical heating is needed, but at the same time it should be able to be more permeable in the summer and be integrated with the outside.

3. Design Guidelines

3.1 Chapecó's Climate

The context of this work is the city of Chapecó, which is located in Southern Brazil, in the west of Santa Catarina State at Latitude 27°14' S, Longitude 52°37' W and Altitude 668 m.

The following description of the climate of Chapecó is based on 10 years of hourly meteorological data recorded in Chapecó's airport processed through the Software Meteororm [3].

3.1.1 Dry bulb temperature

The annual mean temperature is 19.2°C. The hottest month is January, presenting a mean temperature of 22.8°C and the coldest is June, with a mean temperature of 13.5°C. The annual mean daily range of temperature is 9.3°C. In January, the mean maximum temperature is about 28°C and the mean minimum is 16.9°C, producing a daily range of temperature of about 11.1°C. In June, the daily swing of temperature is also about 11.1°C, ranging from a minimum mean of 7.9°C to a maximum mean temperature of 19°C.

It was observed that during the winter, or even in the summer, there are periods of heat and cold, respectively.

3.1.2 Relative air humidity

The annual mean relative humidity is 73%. The months with the highest average relative humidity are May and June (around 78%) and November is the month with lowest average (around 68.6%).

3.1.3 Wind speed and direction

The annual mean wind speed is 2.5 m/s. March is the month with the weakest winds and September has the highest speeds, both average and maximum.

Wind frequency, relative to its direction, shows the north-eastwards and northwards directions as predominant throughout the year. The north-eastwards direction is predominant during summer and the northwards direction in August. The second highest frequency occurs south-eastwards in most part of the year, mainly in winter and in the months of June and September.

3.1.4 Cloudiness and Insolation

In Chapecó's climate, winter months feature lower cloudiness rates than during summer months.

Annual average cloudiness is 5.4 (part of the sky covered by clouds: from a 1 to 10 scale, that is, greater than 50%); also, cloudiness tends to increase from September to February, reaching 59% in January and February. May is the month with the lowest cloudiness rate and is the only one to fall below 50%.

3.2 Passive Strategies Investigation

To obtain some building design guidelines the result obtained was analyzed by applying the program developed at LABEEE (Laboratory of Energetic Efficiency in Buildings – Federal University of Santa Catarina – Brazil), based on Watson's and LAB's method (1983), thus allowing the crosschecking of all hourly climate data on the Bioclimatic Building Plan tailored to Chapecó [4] (Fig. 1).

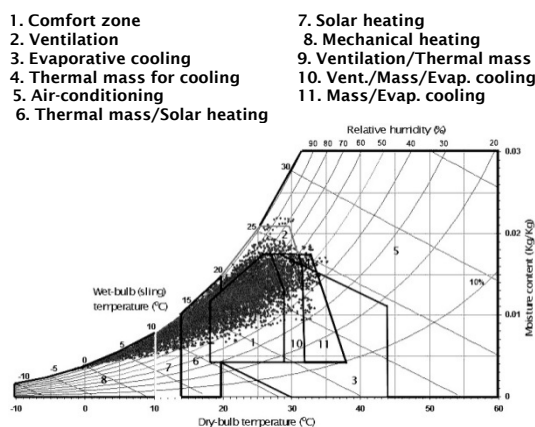


Fig 1. Chapecó's climatic year

4. Design Development

According to the local climate analysis the primary need is to increase winter heat gains and reduce summer heat gains during the day. This was attempted through a comprehensive set of actions that start on a large scale by controlling the relations between the building and the outdoor space.

4.1 Site Layout

The site is located in front of the company's storage building. The area of the site is 100 m² in total, 20 m wide and 5 m long. It is a flat plot and on its left side it should be left a 5 m wide entrance for cars and trucks, so its dimensions were reduced to 15x5 m.

The site has its street façade to the West, on the Southern façade there is a two-story building, on the Eastern there is the Company's storage building and on the Northern the 5 m wide entrance.

4.2 Design Project

The office proposed is in winter a more compact and well insulated building, to keep the internal and solar gains inside the rooms and save energy when mechanical heating is needed. In summer it is more permeable and the relationship with the outside is stronger (Fig. 2).



Fig 2. Nostra Casa's 3D model

4.3 Internal Layout

Building plan layout requires main spaces and secondary ones to be correctly located: north orientation permits to enhance passive solar gains during the winter and to easily control solar radiation during the summer. The north-eastwards and northwards directions are predominant wind frequency as well, which becomes a double advantage for the openings' orientation.

The office was designed with an internal layout so that the main rooms, such as, the architects' room and the engineers' room could face North, as they are the rooms that will be the most occupied ones at daytime and evening in the winter.

The directors' room and the meeting room, the second most occupied spaces, are facing East, and the reception, show-room, circulation, toilets and kitchen, which are occasionally occupied, are facing West (Fig. 3 and 4).

Openings are not placed at the South façade as it does not have any solar gain in winter, and in summer it gets some sun, and the South façade might require extra insulation to avoid loss of heat gain. Also, an internal garden crossing the two floors was placed to provide natural light and ventilation for the rooms which do not have enough window area and to allow cross ventilation to the others (Fig. 3 and 4).

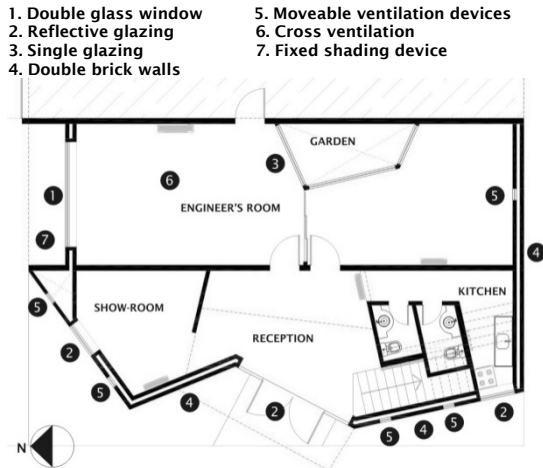


Fig 3. First Floor Plan

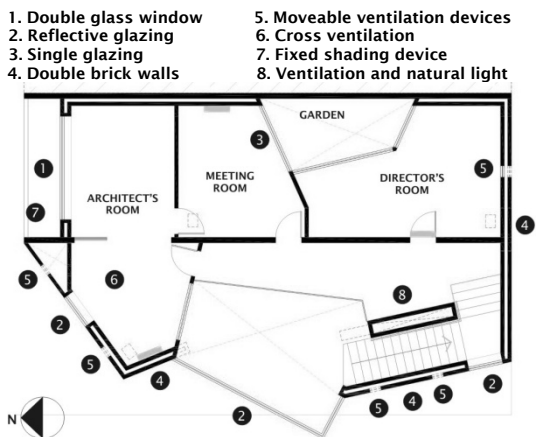


Fig 4. Second Floor Plan

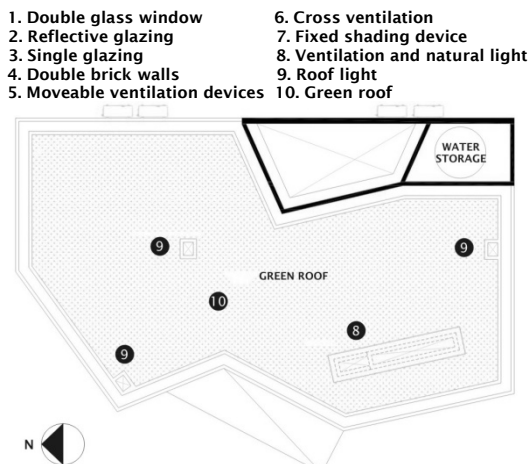


Fig 5. Roof Plan

4.3.1 Thermal Mass

Thermal mass was applied through the brick walls, concrete ceilings and floors. It is a strategy suitable for summer, decreasing the peak of cooling loads and releasing, with a delay, the heat to indoors. In winter, the solar diurnal gain can be stored in the thermal mass and transferred into the building at night.

The office's envelope heavily influences thermal gains and losses. Thus, to increase thermal weakening, to delay internal temperatures and to reduce internal thermal amplitudes the office was built with double walls composed by six holes bricks 12 cm thick. It was also left a 10 cm cavity between the walls (Fig. 6).



Fig 6. Double brick walls with cavity

To ensure a greater thermal weakening in summer, moveable ventilation devices were placed at the West and Northwest façades to release the hot air inside the cavity and delay the heat transfer (Fig. 7). They are going to remain opened in summer and closed in winter.

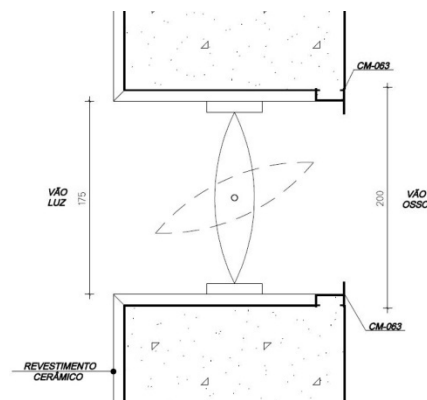


Fig 7. Moveable ventilation device

Double glass windows also were specified to ensure thermal insulation in the rooms (Fig. 8).

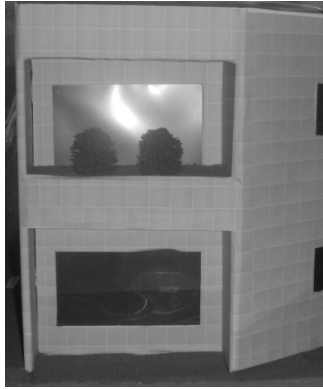


Fig 8. Double glass and fixed shading devices – physical model

4.3.2 Natural Light and Ventilation

Positive aspects can be detected in the use of the natural light as the illumination of the interior space and its integration with the exterior.

The rooms on the Western façade have small windows, necessary just for lighting and ventilation, apart from the reception which is all with reflective glass for design purposes. The most occupied rooms have double glazed windows with vertical and horizontal shading devices (Fig. 2).

Roof lights were placed in the rooms of the second floor and in the toilets to ensure a better distribution of natural light and decrease, they were also placed on the other side of the garden (Fig. 5 and 9).

Ventilation happens through the openings located at the occupant's level, providing comfort ventilation and through the openings on the roof at the reception and toilets proving a stack effect. The indoor garden has windows located at a higher level helping to release the hot air above occupants' height; also tilted ceiling was applied to accelerate air movement.



Fig 9. Roof lights

4.3.3 Solar Heating and Thermal Mass

Solar Heating was applied at the design stage as storage element exposed to store excess solar energy during the sunny hours and release it back during the night. This strategy was applied through the mass of the building fabric itself, floor, in the internal layers of external walls,

internal partitions and in the furniture surface area.

4.3.4 Shading devices

The shading devices applied in the design are located at the engineers' and architects' room (Fig. 3, 4 and 8).

According to insolation studies on the 21st June the sun heats the northern windows from 8.15 am until the sunset (Fig. 10 and 11). On the 21st December the sun does not heat the northern windows, as it was placed a 1 m wide fixed shading device – horizontal and vertical - to ensure shade during the summer period (Fig. 12 and 13). They also help to reduce heat loss to the external environment, especially to the sky during winter nights and help to control daylight levels.

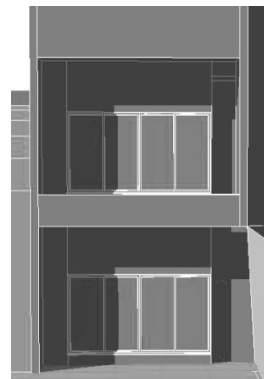


Fig 10. Shading studies-21st June 9 am

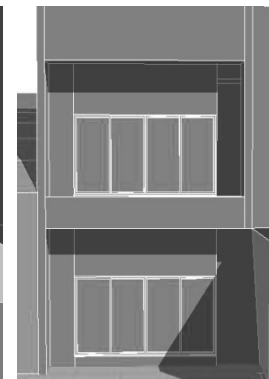


Fig 11. Shading studies-21st June 3 pm

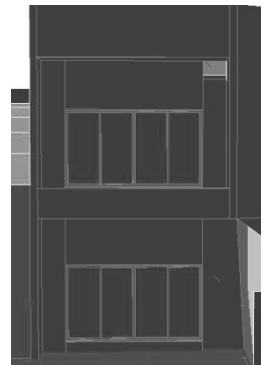


Fig 12. Shading studies-21st Dec 9 am

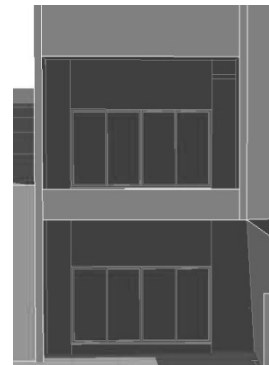


Fig 13. Shading studies-21st Dec 3 pm

4.3.5 Garden

The roof is the building element which receives the most amount of sun, especially in summer, and that is more exposed to nocturnal cooling by radiation. Vegetation protects the roof from direct solar radiation and enhances its thermal behaviour providing a cooling effect in summer as green surfaces reflect sun radiation and storage heat causing a cooling effect. In winter it can be used for its thermal insulation effect through the air cushion within the vegetation and the fact that the cold wind does not hit the earth surface consequently protecting the surface below. Thus, an intensive green roof was applied on all the extension of the roof and it was composed by a 20 cm earth layer with special drainage system.

(Fig. 14). This system required a reinforced concrete slab structure.



Fig 14. Green roof

5. Conclusion

The design of more enjoyable spaces and their interrelation in a more interesting way was pursued at the same level as the outside penetration/interference at the inside spaces, and, on its occupants interaction with the building's envelope and features.

It was found that environmental design combining passive strategies and the intention of achieving a quality design might be more efficient in the overall environmental design picture. The occupant's thermal and psychological comforts were placed as the main issues to be addressed and not energy savings, as the latter is a consequence of the two former considerations.

The relationship between architecture and environment design is infinite and many solutions for energy savings can be found and applied.

When the construction is finished, the temperature of the rooms are going to be monitored through temperature sensors installed in all the rooms to check if the passive strategies are working, so the design can be improved in further buildings.

6. References

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