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Experimental monitoring and post-occupancy evaluation of a non-domestic solar building in the central region of Argentina

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ABSTRACT

Previous experience in designing and monitoring bioclimatic buildings in central Argentina suggests that their thermal behavior is a matter of concern and that further research is needed. Thus, the objectives of this work are: to describe the design and the post-occupancy evaluation of a new non-domestic solar building in a continental semiarid region of central Argentina (37°38′ latitude S, 63°34′ longitude, 175 m above sea level), to analyze the building's hygrothermal and energy performance, and to estimate the PMV and PPD. The design guidelines were: to minimize the consumption of conventional energy in thermal-lighting conditioning, to use traditional technology, to maximize the thermal comfort, and to reach an extra-cost lower than 10%. The post-occupancy monitoring of the building was performed along one complete year (August 9th 2011–August 18th 2012). Data-loggers were installed in each functional area to sense the indoor temperature and relative humidity at time steps of 10 min. A meteorological station was installed near the building. The experimental results showed that during winter the average temperature in the areas of permanent use was 20.3 °C (average outdoor temperature: 10.1 °C) and the heating energy consumption was around 73.5 kW h/m^2. During summer the average indoor temperature in the building was 26.9 °C, 1.7 °C below the outdoor temperature average (28.6 °C); cooling systems were turned on when the indoor temperature reached 28 °C, at approximately 11:30 AM, when the outdoor air temperature exceeded 30 °C. Mechanical cooling consumed around 59% of the daily electricity consumption. The PDD results obtained for winter and summer representative days meet the requirements of ISO Norm 7730. Heating and cooling energy saving was around 63% and 76.5% respectively. The monitoring showed that the thermal behavior and energy performance met the expectations of both designers and users, and it is considered satisfactory and promising for low-energy consumption buildings.

1. Introduction

In most countries, buildings account for 40% of primary energy consumption and are also a significant source of CO_2 emissions [1]. The International Energy Agency (IEA) identified the building sector as one of the most cost-effective sectors to reduce the energy consumption. Moreover, reducing the overall energy demand can significantly reduce CO_2 emissions from the building sector. In this context, energy efficient buildings are the main protagonists. The IEA produced policy recommendations based on best practices: governments requiring the implementation of building energy codes – for both new and existing buildings – and setting overall minimum energy performance standards and mandatory renovation rates to capture the savings' potential of the building sector [2]. The definition of low energy-building is not unique. Sartori and Hestness [3] affirm that low-energy buildings are those built with special design criteria aimed at minimizing the buildings' operating energy. According to Feist [4], a low-energy building (LEH standard) can be defined as one having an annual heating requirement below 70 kW h/m^2 year. In Switzerland, the Minergie Standard for buildings establishes a limit value of 42 kW h/m^2, while the German Passive-house Standard establishes an annual heating requirement below 15 kW h/m^2 [5].

Many non-domestic buildings are major energy-wasters. New buildings are not necessarily better, with energy use often proving to be much higher than their designers anticipated [6]. Norford et al. [7] found that the most important sources of discrepancy between

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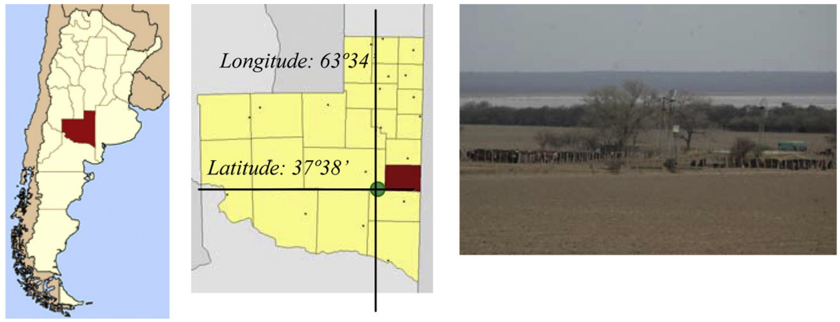

Fig. 1. Location of the province of La Pampa and city of Guatraché in Argentina. Right: typical landscape of the study area.

the actual energy consumption and the one predicted by simulation are those related to users' behavior. As shown, careful decisions made in relation to the building design and operation may improve significantly its thermal performance, and, as a result, reduce its energy consumption. The impact of those decisions on the building's thermal behavior will decrease along the different stages of that building's life. Effective and well-thought decisions made at the project's early stage would mean a future decrease in energy consumption in terms of operation and maintenance.

Saving an average 50% in space heating energy use has already been demonstrated by projects built and operated in the UK: the best of these examples achieved impressive savings in the order of 60–75% [8]. In the case of Argentina, in spite of the fact that energy is highly subsidized and it is dependent on importation from other countries, mandatory regulations tending to improve energy efficiency of buildings do not exist. In particular, thermal insulation is not used at all. There are just some non-mandatory recommendations regarding the habitability of buildings. Unlike other developed countries, there is a very important lack of national laws regarding efficiency. Notwithstanding this, researchers made a major effort to promote the challenge of designing efficient buildings, a practice which is not only uncommon but not even recognized in its entire importance.

In this context, the National Institute of Agricultural Technology of Argentina (INTA La Pampa-San Luis Regional Centre) endorsed and supported the construction of a bioclimatic building in the central region of Argentina. The design of this building was committed to the authors in 2006, who applied their previous 10-year experience (1995–2005) in designing and monitoring solar bioclimatic buildings in Argentina to the design of this new building. The analysis of thermal performance and gas consumption suggested that, while their design and construction achievements are already well-suited to face the winter period, the summer time still represents a challenge to be overcome. Thus, further research is needed to improve the energy performance of buildings under summer conditions (Filippín and Beascochea [9] Filippín and Beascochea [10]; Filippín et al., [11]; Filippín [12]).

On the basis of the previous experience, the new bioclimatic INTA building was designed in order to obtain comfort conditions both in winter and summer periods, with energy consumption rates lower than those of a conventional building. Bioclimatic strategies and solar passive heating were included in the building design. The design guidelines were: to minimize the consumption of conventional energy in thermal-lighting conditioning, to use traditional technology, to maximize thermal comfort, and to reach an extra-cost lower than 10%. In 2011, the construction of the building was completed and a one-year post-occupancy monitoring was performed between August 2011 and August 2012. Therefore, the objectives of these work are: (I) to describe the design and the post-occupancy evaluation of a new non-domestic solar building in a continental semiarid region of central Argentina, (II) to analyze the building's higrothermal and energy performance, (III) to estimate both the PMV (Predicted Mean Vote) and PPD (Predicted Percentage of Dissatisfied).

2. Building design and location

The city of Guatraché is located in the SE of the province of La Pampa, Argentina (37°38′S, 63°34′W, 175 m above sea level). The building site is located in an area of low houses and low density of construction. This dry region is characterized by plateaus, valleys, hills and crop plains, low grazing lands and open forests (Fig. 1). The climate (Table 1) is classified as a *transition temperate-cold* climate (bio-environmental zone IV) by the Argentinean IRAM Norm [15], which recommends for such a region to use thermal insulation in the whole envelope, to avoid thermal bridges, and to minimize the risk of condensation in walls and roofs. Also, a NW-N-NE-E orientation of the building and cross-ventilation are recommended.

The design of this building prioritized natural conditioning of spaces, low-cost operation and maintenance, and clear zoning of the different functional areas. The strategies were:

- Orientation of the spaces according to their use (offices and administration facing north, services facing south).
- Minimization of the air temperature difference (thermal zoning) between areas with and without direct solar gains.
- Passive solar heating and energy conservation in winter: direct solar gain through North glazing and an insulated envelope to minimize heat losses.
- Passive cooling in summer: use of natural cross ventilation, thermal mass storage, shading and devices for solar control.
- Reduction of the electricity consumption for lighting (through day lighting and energy efficient luminaries).
- Design of the outdoor spaces: use of trees and plants according to the orientation.

The building layout is shown in Fig. 2. To the east, there is a green space with native species from the pampas forest near the building entrance and the pedestrian circulation path, which is a continuation of the sidewalk area. The entrance to the building is defined as an independent area with a double door from which the functional areas are distributed along an E–W axis. The offices face north and they have clear glazing for direct solar gain in winter, with protection eaves and pergolas for summer. The multipurpose room is destined to training-entertainment and socializing activities and it is located on the N–W side and facing north. This area is connected with the rest of the building's areas (management – extension – research) through an east-west circulation. It is also used as garage. The director's office is located in the southern side, with small windows that help visual expansion and assure indirect natural lighting coming from the circulation area and the plenum. The service sector is located to the west of this office.