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An experience on integrating monitoring and simulation tools in the design of energy-saving buildings

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Abstract

In this paper we describe the design and thermal behaviour of a bioclimatic Auditorium at the National University of La Pampa, used for teaching activities in Santa Rosa, La Pampa (Argentina). The building was monitored in winter and simulated with *SIMEDIF for Windows*, a code developed at the Non Conventional Energy Research Institute (INENCO, Argentina). Then, a new project of a similar building was proposed for General Pico city, and the obtained physical model was used to simulate the building under the summer temperatures of the new city. The building was redesigned and passive solar strategies were applied to reduce heating and cooling loads. The final layout and the monitored thermal behaviour of the new building in winter and summer are described. Without additional costc, the new building savings were 50% in heating requirements respect to the conventional layout, and 70% in the requirements of conventional energy for cooling.

Keywords: Energy-efficient buildings; Passive solar design; Energy-saving; Thermal simulation

1. Introduction

The challenge of reducing the emission of greenhouse gases at local and global levels requires behavioural changes in life styles and energy consumption patterns in people, and the use of more energy efficient production, processing and distribution technologies. The improvement of building techniques is an alternative way to increase the energy efficiency and reduce gas emissions. Passive solar design exploits the building's orientation, shape, materials, windows, and external landscape, in combination with other energy efficiency strategies, to create a pleasant environment which is less dependent on fossil fuel-based energy. It has been extensively shown that it is possible to build passive houses with very low energy use and to normal costs. Important energy-savings as high as 60% compared to conventional houses have been found in cold [1], tropical [2], Mediterranean [3] and hot summer/cold winter climates [4]. Some successful applications of passive design are social housing [2,5] and office buildings [6,7], where the energy demand for air conditioning can be significantly reduced.

In this context, simulation programs have become important tools to improve building designs and energy consumption. These programs can calculate the thermal behaviour of buildings and change different variables, as the climatic conditions, geometry, materials, etc., to evaluate their thermal response. Thus, a feedback is carried out until an adequate final project is achieved [8]. If experimental data validates the physical model used in the simulation, a deeper insight of the building physics and good energy performance can be achieved, as shown in many research works [3,6]. Nowadays, a wide variety of simulation programs is available, of different complexity levels going from steady-state situation to very sophisticate CFD simulation [9]: TRNSYS [7], ESP-r [10,11], DOE-2, BLAST, Energy Plus [12], TAS [5], FLUENT [13], DEROB-LTH [14] between other common programs, can be mentioned. Methodologies for validation of building energy simulation programs have also been developed [11].

In Argentina, a lot of effort was directed since 1984 to develop a code for the simulation of transient thermal behaviour of passive *multiroom* buildings. *SIMEDIF* model and program was made by researchers of INENCO (Non Conventional Energy Research Institute), Argentina. The first version was

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developed for DOS by Casermeiro and Saravia [15] in 1984 and the code has been largely validated since then throughout years of experimental work in Argentina. Numerous groups continuously used it for research [16], design, and simulation of the thermal behaviour of lightweight [17,18] and massive [19] buildings from the desert climate of the Puna (North of Argentina) to La Pampa. Since 2000 the code was adapted for Windows environment [20] and two modules for passive cooling systems were added: a module to calculate earth-to-air heat exchangers and a module for evaporative cooling systems. These models were validated with monitored data on existing buildings with buried pipes [21] and a greenhouse with evaporative panels [22]. This software was used in this paper, so a brief description of the thermal model was included in the related section.

As mentioned, the growing demand for air-conditioned buildings and the resultant demand for electrical energy has prompted research into passive cooling, such as the European Union funded PASCOOL programme [23] and recommendations, guidelines and laws for energy-saving in buildings [24]. In Argentina, the local laws are not deeply concerned with lowering energy consumption of buildings. Local building designers have largely ignored passive design strategies, which can effectively reduce the building energy consumption. Only isolated exceptions can be mentioned ([25–27]), mainly architects and researchers of universities, who tried to change this situation and whose efforts are becoming clear since the last years. In La Pampa, the situation is even worse, because there is a lack of non-traditional materials and qualified workmanship. It is very difficult to convince the local authorities that energy conservation devices, passive solar heating, and bioclimatic design are beneficial and can be used without additional cost. On the other hand, designers still lack confidence to apply these techniques in absence of information about the performance of existing bioclimatic buildings in Argentina. In the last years, some effort was made to change this idea, by building energy-saving apartments for low-income students [28], a solar school with buried pipes for earth-to-air heat exchange [29], and a College of Agronomic Sciences (National University of La Pampa) [21], whose design combines different passive solar strategies to reduce up to 50% the natural gas consumption, when compared with conventional buildings. This paper trends to fill these holes and to bring some confidence to designers and construction workers of developing countries.

In this context, socio-economic, educational and environmental reasons have driven the design of two Auditoriums with reduced energy consumption, for the National University of La Pampa. The local government insisted that the economic costs were similar to that of a conventional building, which due to local economic reasons is in general low. A big effort was made in the building design in order to accomplish this requirement. Both buildings are located in the center of La Pampa province, in Santa Rosa and General Pico cities, in a temperate semi-arid agricultural region of central Argentina (Fig. 1). The climatic data for summer and winter are summarized in Table 1 for both cities. According to the Olgyay's bio-climogram, people could take advantage of solar radiation and reach the comfort area in 60% of the annual period. Passive solar systems, thermal inertia, natural ventilation, thermal insulation, external shading, building orientation and a compact design can be used to improve the thermal comfort along the year.

Fig. 1. Location of Santa Rosa (36.57°S, 64.45W, 189 m over sea level) and General Pico (35°7′S, 63°8′W, 141 m over sea level).

The first building was designed and built between 1998 and 2000 in Santa Rosa city, where the climate is cold-temperate. It was monitored and simulated during a winter period to evaluate its thermal behaviour and to obtain a physical model of the building. Then, the possibility of a new similar project in General Pico city arose, where the winter conditions are more temperate (1204 vs. 1545 heating degrees days) but the cooling loads in summer are higher than in Santa Rosa (473 vs. 128 cooling degrees days), as shown in Table 1. The previous experience on Santa Rosa's building was used and the simulation of the building under the summer temperatures of the new city was done. When overheating was confirmed, the redesign of the building was afforded in order to load the heating and cooling energy requirements. In the first part of this

Table 1
Meteorological data for Santa Rosa and General Pico, La Pampa, Argentina (provided by the National Meteorological Service)

	Winter				Summer			
	Temperatures (°C) (June)			Heating degrees days base 18 °C	Temperatures (°C) (December)			Cooling degrees days base 23 °C
	Mean minimum	Mean	Swing		Mean maximum	Mean	Swing	
Santa Rosa	1.8	8.2	11.9	1545	30.3	22.3	14.9	128
General Pico	2.7	8.9	6.6	1204	30.9	23.4	14.6	473