

Bioclimatic design and low energy cooling systems at IER-UNAM

J Rojas*, G Huelsz, G Barrios and R Tovar

Instituto de Energías Renovables, Universidad Nacional Autónoma de México, Priv.
Xochicalco S/N Temixco Morelos, CP 62580, Mexico

*E-mail: jrm@ier.unam.mx

Abstract. This article presents some strategies of bioclimatic design for hot-subhumid climate and of low energy cooling systems and how they have been implemented at the IER-UNAM buildings since 1985. Some of the experimental and numerical simulation projects carried out by the Energy in Buildings Group (GEE) are commented. Finally, the project for a new building for undergraduate students is presented, where passive and low energy strategies as night ventilation, evaporative cooling, radiative cooling and earth tube cooling are been evaluated.

1. Introduction

The Instituto de Energías Renovables (Institute of Renewable Energies) (IER) of the Universidad Nacional Autónoma de México (UNAM) has a group of researchers in energy in buildings (Grupo de Energía en Edificaciones (GEE) [1]). This group works in collaboration with experts in Mexico such as the Bioclimatic Architecture Group of the Universidad de Sonora and of the Architecture Group of the Universidad Autónoma Metropolitana - Azcapotzalco, and with experts in other countries such as the Lawrence Berkeley National Laboratory in Berkeley California and the Universidad Nacional de Ingeniería (National Engineering University) in Lima Peru. The GEE is formed of four researchers and a significant number of postdoctoral fellows, doctoral, masters and bachelor students.

The main objective of the group is to carry out research that helps designers and builders of houses and commercial buildings to build bioclimatic houses and buildings that are thermally comfortable but with the lowest possible energy consumption by reducing or avoiding the use of mechanical air conditioning systems for space cooling and heating. As in Mexico 17.6% of electricity is consumed in buildings [2] and most of that energy is produced with fossil fuels, reducing electrical power consumption in buildings will imply a lower CO₂ emission into the atmosphere.

2. Bioclimatic design considerations

Some of the important points that should be considered for bioclimatic design are:

i) Know in detail the local conditions of the climate where the building is going to be built. You should have information on a typical year of air temperature and humidity, solar radiation, wind velocity (magnitude and direction), among others.

ii) Define the geometry and orientation of the building, according to the local weather. You have to select the most convenient location of windows in order to avoid excessive direct solar gains in hot climates or season and to promote them in cold climates or season and allows natural lighting and ventilation.

iii) Select operable windows to allow the required ventilation and with adequate glass to control the solar radiation transmission.



iv) Choose the opaque materials of the envelope according to the climate and to the mode of the building's operation, with or without air conditioning.

v) Include the use of passive systems such as solar controls, shading devices, windexchangers and double walls.

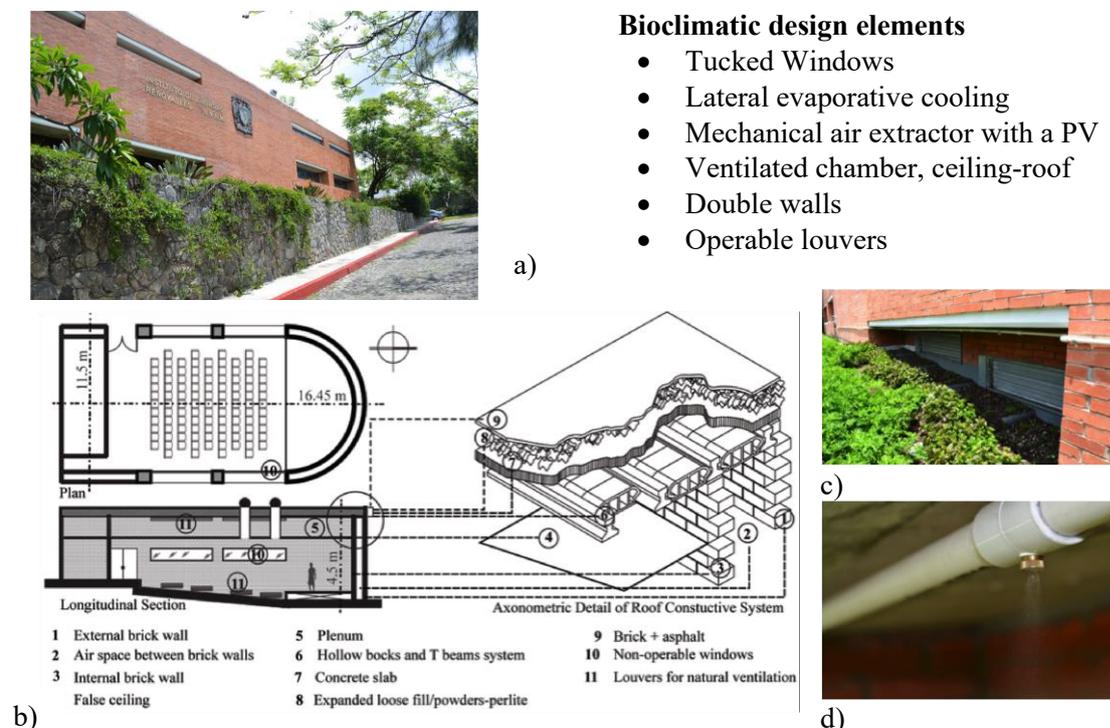
vi) Integrate low energy cooling systems such as evaporative cooling, radiative cooling or earth tube cooling.

3. Bioclimatic design at IER-UNAM

The IER-UNAM is located in the city of Temixco in the state of Morelos approximately 80km south of Mexico City. The climate is hot-subhumid with pronounced dry and raining seasons. During the months from March to June the weather is hot and dry with maximum air temperatures of 37 °C and minimum of 20 °C.

3.1 Tonatiuh Auditorium

There is a great tradition of bioclimatic design in this Institute. The construction of the first buildings, dating from 1985, have important bioclimatic strategies. For example, the Tonatiuh Auditorium, Figure 1, has high thermal-mass double-walls of brick with a separation of 0.6 m between them. The roof is made of 5 layers, from inside to outside, hollow blocks, expanded loose fill, powders-perlite, brick, and asphalt. The auditorium includes a false ceiling hanging 1.5 m from the roof forming a ventilated plenum. The east and west walls present each one two non-operable tucked windows on top of the wall to provide daylighting. Natural ventilation is given by controlled louvers located on the bottom of east and west walls. When they are opened air enters through them and exits through ducts at the ceiling. Louvers are opened at night and keep closed during the day to promote night ventilation. To increase ventilation and improve thermal comfort at the hours of use during the hot season, mechanical air extractors installed in the ceiling ducts, energized by a photovoltaic panel (PVP), and an evaporative cooling system are operated [3].



3.2 IER offices

The office buildings also have bioclimatic design. They have rectangular base, with the long façades oriented North and South. These façades have operable windows to allow natural cross ventilation (Figure 2 a). The short East and West façades do not have windows. The roof has a slope with the lower part to the South that extends as a shading element. This roof is made of hollow blocks that form internal channels opened at both sides, allowing ventilation promoted by wind, from South during daytime, and by thermal buoyancy from the lower to the upper openings. The offices are thermally comfortable most of the time during the year, but in the hottest season there are some discomfort hours. One strategy that is being tested is the use of a radiative cooling ceiling as shown in Figure 2b.



Figure 2. a) South facade of an office building with manually operable windows and ventilated roof, b) radiative cooling ceiling installed in an office.

3.3 Laboratory building

In year 2012 a new building was built to house new laboratories. Unfortunately, the available land has a steep slope and was not possible to build it with the long façades to the North and South, which is recommended for hot climates. Instead, the long façades were oriented Northeast and Southwest. This last façade has the most unfavorable orientation since it receives solar radiation from noon until the sun set. The main strategies for this building were double ventilated façades, shading elements in the windows and white painted external walls and roof [4]. See Figure 3.



Figure 3. Southwest façade of the laboratory building with double ventilated facades, shading elements in the windows and external walls and roof painted white.

4. Experimental and numerical simulations

The GEE has extensive experience in experimental studies of fluid dynamics and heat transfer applied to buildings. Currently, fluid dynamics studies are carried out using scale models of a room in an open water channel for the design of windexchangers, that are small structures on the roof to enhance natural ventilation (see Figure 4). Stereoscopic particle image velocimetry technique is used to obtain velocity fields of the flow outside and inside the scale model room, that includes a window and a windexchanger.

Other experimental studies of the GEE are those related to the time dependent heat transfer through construction systems of the building envelope. For this, the GEE has designed and constructed a laboratory (Figure 5), that has a climatic chamber, a habitable chamber and a thermal guard. The air in the climatic chamber can be set to follow the conditions of a typical day of a month, for the city of interest. The construction system under study is placed between the climatic chamber and the habitable chamber. The thermal performance of this construction system can be evaluated in two room conditions, with and without air-conditioning system. For the without air-conditioning system condition, the temperature of the thermal guard is controlled in such a way to ensure that the change of temperature in the room is only due to the heat transferred through the construction system of interest.

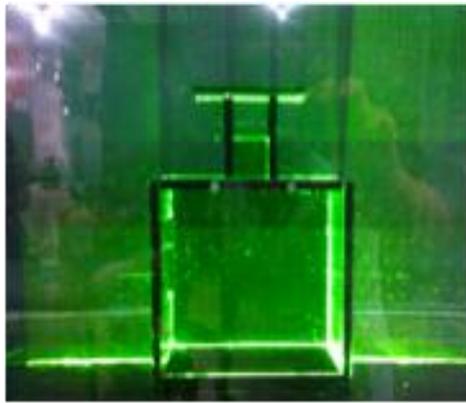


Figure 4. Scale model of a room with a window and a windexchanger immersed in an open water channel.

Figure 5. Laboratory to study the time dependent heat transfer through construction systems of the building envelope



The GEE also has experience in numerical simulations applied to building studies. The GEE has developed the Ener-Habitat program that evaluates the thermal performance of the building envelope construction systems considering non air conditioning or air conditioning situations (Figure 6). Ener-Habitat can evaluate the thermal performance of the constructive systems in more than 80 cities in Mexico. Ener-Habitat has more than 4000 users and performs more than 5000 evaluations per month. For construction systems with homogeneous layers the program numerically solves the time dependent

heat transfer equation in one dimension and for cases with construction systems with one non-homogeneous layer, it solves the time dependent heat transfer equation in two dimensions. Work is being done to implement in Ener-Habitat the model of equivalent homogeneous layers of Huelsz *et al* [5]

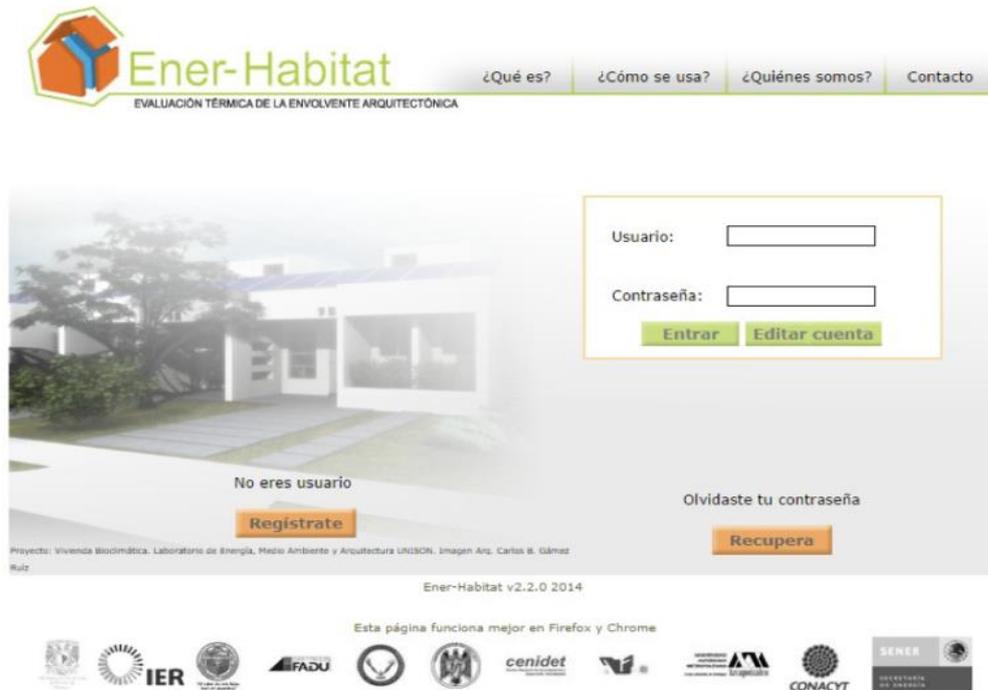


Figure 6. Ener-Habitat program initial page (<http://www.enerhabitat.unam.mx/>).

To analyze the thermal performance of whole buildings, the GEE uses the program EnergyPlus. This is an open-source software developed by the United States Department of Energy (DOE). This program had been used to evaluate the thermal behavior of the Tonatiuh auditorium in the original design and with a series of modifications. Those modifications that proved to have a significant contribution to enhance the auditorium thermal performance have been implemented on it [6]. Also, the GEE has developed a model to simulate hollow blocks in EnergyPlus, which is not possible by default [7].

5. Final comments

The GEE is currently using both programs (Ener-Habitat and EnergyPlus) to analyze the thermal performance of a new building that will be built at the IER-UNAM campus. The building will be used for undergraduate students. It will have four floors with classrooms, laboratories, computer room, cafeteria and an administration area, see Figure 7. The use of controlled louvers for night ventilation and evaporative cooling in classrooms, as well as radiative cooling and earth tubes in a computer room are being evaluated.

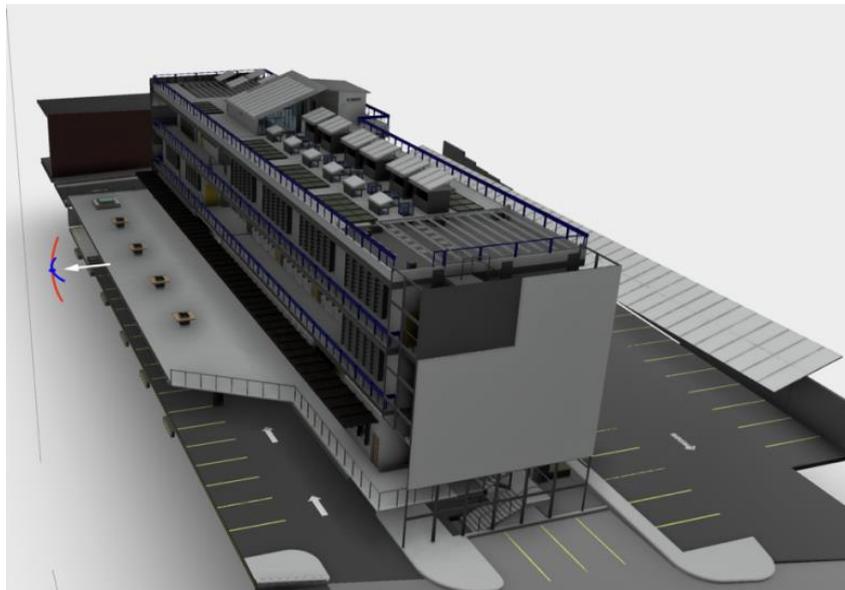


Figure 7. 3D projection of the new building for undergraduate students.

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