Sustainable and Passive Architecture in the Tropics
The Day Care Center for the Elderly in Tabasco, Mexico

CAROLINE VERUT VON ILBERG[1], MARIA VIRGINIA PEREZ REYES, CO-AUTHOR[2]

[1 2] Itaca Proyectos Sustentables, Mexico City, Mexico

ABSTRACT: The Centro Gerontológico Tabasco is the day care centre for the elderly located in the city of Villahermosa, Tabasco in Southeastern Mexico, a region with a hot and humid climate. It is designed based on the analysis of bioclimatic variables to determine appropriate passive strategies for that climate. Buildings were oriented towards dominant winds, favouring natural cross ventilation through operable windows and a double ceiling structure that generates the stack effect. This, together with natural lighting, allows to greatly reduce energy consumption, in particular through the reduction in air conditioning, substituting it with ceiling fans and operable windows, and by eliminating most electrical lighting use during the daytime. Photovoltaic panels generate much of the Center´s energy needs and external lighting is provided through solar power. The Center is also 98% independent of external water sources through a closed circuit involving rainwater harvesting, pre-filtration, storage and potabilization for use in all fixtures, and a water treatment plant that circulates wastewater back to toilets once treated and for use in the extensive gardens. The landscape architecture is based on endemic species requiring little irrigation, creating large green spaces and horticulture plots that are shaded by the trees, for the enjoyment of the users. The design also guarantees total accessibility through a one story construction, low incline ramps linking all areas of the program and handrails that crisscross from one structure to the other.
Keywords: Mexico, tropic, passive architecture, sustainable design, day care center for the elderly

INTRODUCTION

The Centro Gerontológico Tabasco was commissioned by the Mexican federal government agency DIF (Integral Family Development) through its local chapter in the state of Tabasco. Its purpose is to provide day care and health related services for the elderly residing in the region. It is located in the city of Villahermosa, Tabasco in Southeastern Mexico, a region with a tropical wet climate. This climate, also known as tropical monsoon climate, poses particular design challenges. Located within the equatorial zone in latitude 18° N, it features monthly mean temperatures above 27°C in every month of the year, ranging from a minimum average of 22°C in winter to a maximum 33°C in spring (Fig. 1).

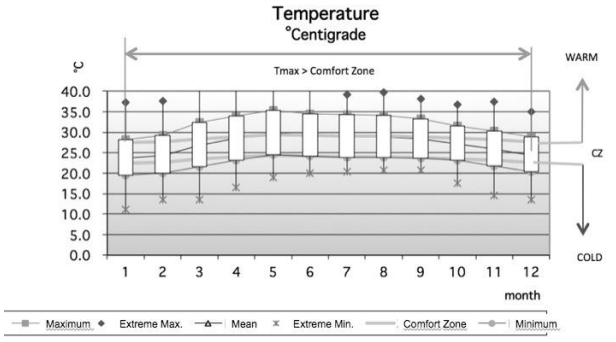


Figure 1: Temperature chart for Villahermosa, Tabasco, showing temperatures consistently above the comfort zone (CZ). Own research based on data from the SMN using the methodology of Dr. Fuentes Freixanet

Maximum temperatures can reach over 40°C in May or June [1], way above the comfort zone comprised between 23.5 °C and 28.5 °C (Fig.1). Temperature variations are relatively small, both from month to month and throughout the day.

Relative humidity reaches up to 96% to 98% during the winter months, averaging 78.8%. on an annual basis The region features wet and dry seasons, with copious amounts of rain during the wet season in the form of frequent thunderstorms, and less pronounced dry seasons, which often experience heavy rainfall as well. Average annual rainfall is close to 2,000mm. The rainy season begins in June, lasting through October, followed by a dry season with lowest precipitation in March and April. Solar radiation is direct and diffuse, depending on cloudiness, and relatively low due to high humidity levels. Prevailing winds are from the northeast with low speeds.

The main challenges when designing for this climate, are the conditions of extreme and constant heat and humidity experienced throughout the day and year, low wind speeds, and high precipitation with the consequent risk of flooding. Climate change further contributes to creating conditions that are out of the comfort zone most of the time, both within and outside buildings [2].

THE DAYCARE CENTER FOR THE ELDERLY

The Centro Gerontológico Tabasco was designed to house as many as 500 elderly (ages 65 and over) people, each day. The concept of this Center was developed by

the geriatrist Dr. Nicomedes de la Cruz, in conjunction with Ms. Karin Beer Guttler, former director of DIF Tabasco, to provide day care for the state's elderly in order to provide families with an alternative to placing their elderly in a nursing home. It features an integral program that includes six major areas. Care, Health, Strength, Recreation and Learning, in addition to the Day Care Center. The users begin their journey by receiving a full physical and psychological diagnosis, as well as an understanding of their family and social environment, through a qualified staff of geriatrists, geriatric nurses and social workers. Based on the above, the staff issues a series of recommendations to the family and the elderly person, and develops an integral care program.

Figure 2: Location map of the Centro Gerontológico Tabasco

The Care area (green) (Fig. 2) includes administrative offices, medical offices for valuation, and additional services including legal advice, job offers and meeting rooms.

The Health area (red) features preventive medicine for the elderly including geriatrics, ophthalmology, audiology, nutrition, psychology, dental care and specialized clinics for sleep, diabetes, medication review, pain, wounds and memory, in addition to an emergency room.

The Strength area (blue) is designed to provide rehabilitation and physical therapy to help the elderly regain their strength and flexibility. The Center provides a pool used for walking and water exercises to strengthen lower limbs in addition to two Jacuzzis, plus a physical and mechanical therapy room and various cubicles for electrotherapy, massage and acupuncture.

The Recreation area (violet) includes sports (volley and basketball, boules or "*pétanque*", a gym for yoga, gymnastics and specialized equipment for the elderly), as well as spaces for a variety of workshops: music, drawing, ceramics, knitting, embroidery, beauty salon, kitchen for cooking classes, electricity and carpentry, as well as an orchard for urban agriculture. A chapel is also a key element to the Center and a dance and play room.

The Learning area (pink) includes a library, computer room, two training rooms and an auditorium.

Finally, the Day Care Center (orange) itself was designed to house the elderly that need constant care and provides a safe environment where they are received from 8am to 3pm to follow occupational and cognitive therapy, receive health care and rehabilitation and eat a healthy meal.

SUSTAINABLE DESIGN

The first step in the design process was to thoroughly understand the needs of the elderly, their limitations and requirements, and to work closely with Dr. de la Cruz and Ms. Beer in understanding their day care program. We also visited various day care centers and nursing homes in Mexico to assess their strengths and weaknesses, through all of which we determined the architectural program. The executive project was developed through a systemic design process involving professionals from many disciplines: architects, mechanical, structural, hydraulic and electric engineers, landscape architects, biologists, and other specialists, led by Arq. María Virginia Pérez Reyes, Director General of Itaca Proyectos Sustentables, sustainable architectural firm located in Mexico. The guiding principles throughout the design process were based on the in-depth bioclimatic analysis and the passive design strategies derived from this, which basically involved conserving existing trees for shading, maximizing natural ventilation through structural measures and conditions, such as the dispersion of buildings, orientation towards prevailing winds and cross ventilation. Accessibility was also a fundamental guiding principle given the population that would be housed in these buildings.

This project follows the guidelines of leading certifications for sustainable buildings, such as LEED (Leadership in Energy and Environmental Design) [3] and The Living Building Challenge [4], in conjunction with guidelines for passive architecture in the tropics [5, 6, 7, 8, 9, 10, 11]. The methodology used is based on the (unpublished) thesis for master in bioclimatic architecture of Arq. María Virginia Pérez Reyes entitled Design Guide for Sustainable and Bioclimatic Low Income Housing Developments in Tropical Climates. This project will be analyzed based on the following major subsections.

Site

The centre for the elderly is centrally located within the inner city limits of Villahermosa, capital of the state of Tabasco. It is well served by public transportation and surrounded by a variety of services including hospitals, supermarket, department store, schools, as well as a variety of stores and restaurants. The site covers a total of 8,000m^2, which were previously impacted by two existing buildings that were no longer used and had to

be torn down. Particular care was given to protecting the 94 mature trees located on site during the demolition process, as well as to adequately handling and recycling demolition waste. To support increased connectivity, a public transportation hub was placed outside the gates of the center, vehicle access is resolved through a motor lobby that allows quick and easy loading and unloading, and a bicycle station offers parking for bike riders. Parking spaces were reduced to a minimum in order to provide increased room for gardens and green areas that cover 38% of the site.

Nature

After visiting the site, we decided to keep all of the trees located on site. Through topographic mapping we determined the exact location of all 94 mature trees and with the local biologist and the landscape architect identified their species and determined the health and viability of each tree. We decided to keep and heal 56, transplant 21, mostly palms, and had to fell 17 that were not viable, of little botanical value or sick. The location of the trees determined the final design of the center. We conducted a full landscape architecture project around the existing trees, planted additional species and created gardens with local endemic plants providing shading, fresh air along wind corridors, beautiful surroundings and opportunity for occupational gardening (Fig. 3). Plants and flowers also contribute to the color coding of the center into its six main areas (see Fig. 2).

Figure 3: Landscape architecture designed around existing trees is an integral part of the project

Water

Through a closed water system (Fig. 4), the center can independently supply 98% of its water needs. Villahermosa has a high level of annual precipitation, which allows for very efficient rainwater harvesting from the close to 5,000m^2 buildings' roofs. Water is pre-filtered and conducted to two 100m^3 water storage containers. Water is treated online through a system of carbon filters, UV and ozone and taken to showers, sinks and pools. All grey and black waters are streamlined towards the water treatment plant and treated water is used for toilets and irrigation. The wastewater from the showers is treated through a wetland that also acts as visual curtain around the hydrotherapy area. In order to avoid chlorine that could damage the system, salts are used for the disinfection of pools. Stormwater management is also crucial in this climate and is designed to avoid any risks of flooding and to recharge the aquifer.

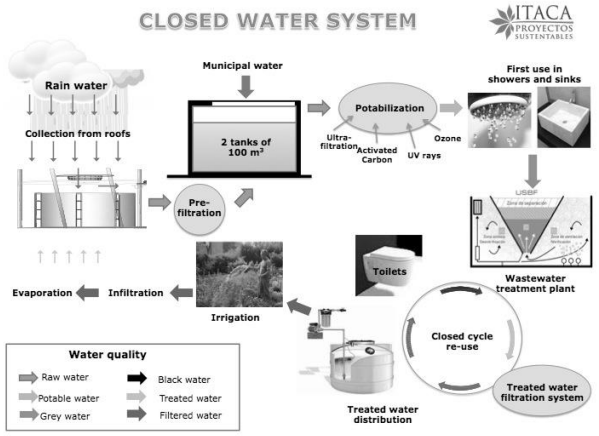
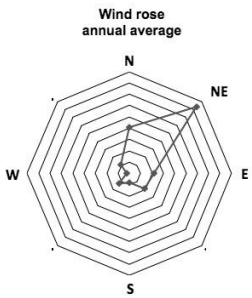


Figure 4: Closed water system of the Centro Gerontológico Tabasco involving rainwater harvesting, potabilization and wastewater treatment for reuse in toilets and irrigation.

Energy

The design is based on an in depth analysis of bioclimatic variables, including, temperature, solar radiation, humidity, precipitation, evaporation, wind direction and speed, as well as of cultural, social and economic variables to determine appropriate passive strategies for that climate and identify solutions of vernacular architecture to the climate challenges.



The most important challenge in this climate is achieving thermal comfort throughout the day at a low energy cost. Natural ventilation is the key strategy for hot humid climates and determines the distribution of buildings and the design of inner and outer spaces.

Figure 5: Wind rose for Villahermosa, Tabasco showing predominant winds coming from the Northeast

The disperse placement and the angle of orientation of the different building structures, that can be observed schematically in Fig. 2, responds to the direction of dominant winds, blowing predominantly from the

Northeast. As shown in Fig.5, all structures are placed at an angle that maximizes the area exposed to the winds, with corresponding windows downwind. This allows for maximum cross ventilation within each space. The dispersion of buildings generates eolic corridors between structures that allows the wind to reach all buildings.

Every area of the center has operable sash windows on both sides (leeward and windward) that were specially designed to maximize the entry of fresh air at the chest and diaphragm level to improve thermal comfort without creating uncomfortable air currents (Fig. 6).

Figure 6: Sash windows, double roofing and shade maximize natural ventilation and lighting

To increase the suction of warm air, all enclosed areas such as offices and workshops, include a plenum space created by a system of two roofs, one over each individual area with an opening in the ceiling, and a large overreaching roof that covers a group of rooms or areas (Fig. 7).

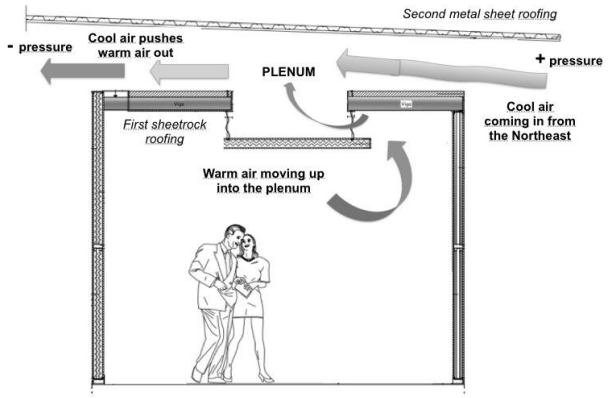


Figure 7: Illustration of plenum space ventilation through a double roofing system

Fresh air flows through the plenum space and passively eliminates heat generated in the space below through the Venturi effect. This system produces a significant reduction in temperature and humidity through natural ventilation. Open spaces are additionally fitted with ceiling fans while individual, minimum tonnage, air conditioning units were limited to administrative and medical office, thereby greatly reducing energy consumption and expenses.

The buildings' envelope consists of light prefabricated panels (DensGlass) with a 3.5" layer of fiber glass insulation between the two panels on the south and west facing walls. The second roof also consists of two white coloured metal sheets with a layer of polyurethane based insulating material.

Every space in the project has strategically placed operable windows or skylights to maximize airflow and natural lighting. The Center's schedule of activities begins at 8am and ends at 4pm, which practically eliminates the need for artificial lighting within the buildings. All fixtures use LED lighting systems to provide energy efficiency and computers, air conditioning units and other mechanical equipment were selected based on their energy efficiency. External lighting is resolved through the use of solar powered lamps. Photovoltaic panels placed on the roof generate electricity through a system of interconnection with a bidirectional meter to the grid of the local power company (Fig. 8). This is the first such meter installed in the state of Tabasco. All of these measures greatly reduce energy and operational costs to the DIF.

Figure 8: Photovoltaic panels on roofs generate energy on site

The water used in the pools of the hydrotherapy area as well as the showers is heated through a solar thermal system, eliminating the use of LP gas and/or electricity for this purpose. Additionally, the pools are covered with a Thermo-tex lining to prevent evaporation when not in use.

Materials

The materials specified were chosen to eliminate or at least greatly reduce toxicity. We used the red list published by the Living Building Challenge [4] to eliminate all products from this list in the project. In particular, we substituted PVC with thermoformed polypropylene and high density polyethylene in hydraulic and wastewater tubing. All air conditioning

units were requested to be CFC free in addition to energy efficient. Wood was not used due to the difficulty in sourcing certified products in Mexico, substituting it with steel and recycled plastic products, such as the deck floors used for exterior plazas.
In an effort to reduce the project's carbon footprint, we made an effort at sourcing materials locally or regionally in order to minimize transportation, which in Mexico relies heavily on trucks powered by fossil fuels. Permeable pavements were used in the parking lots to allow water to flow back into the aquifers and to reduce the heat island effect.

Health

In order to maximize the wellbeing and the physical and psychological health of the Center's users, all spaces were designed to insure indoor air quality through natural ventilation and lighting. The large trees and gardens provide shading and beautiful spaces to see, sit, rest or contemplate, while also providing added oxygen. Throughout the Center, paths undulate between gardens to provide a safe way to reach buildings and to allow the elderly to comfortably walk along shaded walkways without any obstacles, ramps or stairs.
An orchard creates a space for urban agriculture that is both an occupational therapy as well as a source of organic and local foods, including tomatoes, peppers, chillies, lettuce and a variety of herbs that are used in the kitchen to prepare healthy meals (Fig. 8). Many of the trees found on site also give fruit, like lemons, oranges, mangoes, bananas and starfruit, in addition to almonds.

Figure 8: Orchard with local produce sown by the elderly

Waste

The waste generated during the demolition and construction process was adequately handled, making sure that construction waste was properly covered when exiting the site to be sent to municipally approved recycling centers or to areas that needed to be filled. Waste generated by the contractor's workers was separated and delivered to the waste collection trucks, where it is further separated. What can be recycled is sold to processors in order to reduce waste sent to landfills.
A waste management system was introduced for the operation of the center, providing for a waste disposal area and separated bins for organic and inorganic waste, the latter being further separated in the storage area. Organic waste is processed in a composting area to generate rich soil to be used in gardens and the orchard.

Accessibility

Making the whole project accessible to people with disabilities was a key design prerogative. Given the fact that the users of the Center are mostly elderly people who can have impaired motor skills, vision, hearing, or memory loss and cognitive limitations, to name a few, providing a safe environment was fundamental to insure wellbeing and personal safety. All pathways are flat, with ramps that have a maximum inclination of 6^{o} that can barely be felt (Fig. 9). Obstacles, such as stairs, were eliminated and railing provided all along the paths. Benches are strategically located, as well as bathrooms, to reduce walking distances and create resting spots.

Figure 9: Ramps and railings that lead to the garden of the Day Care Center.

Beauty and Spirit

Sustainable projects need to be beautiful, in addition to efficient and comfortable, in order to provide quality of life. In the case of this project, we used the tools of Biomimicry to ask nature how life continues in an endless evolutionary process. We discovered that plants have the capacity to live indefinitely. Their morphology is always based on the proportions of the golden section, and their parts interrelate endlessly based on this geometry. This relationship defines the infinite potential of life as well as the interconnection between the whole and its parts. All elements of the project were designed using the Fibonacci series and the golden section to provide harmony. The building that houses the enclosed

Day Care Center was designed based on the inspiration of the Fibonacci spiral (Fig 10). This form responds perfectly to the need for special attention of the dependent elderly who use this space. The curved form brings all rooms nearer to the center, allowing for visibility and a constant return to the nucleus.

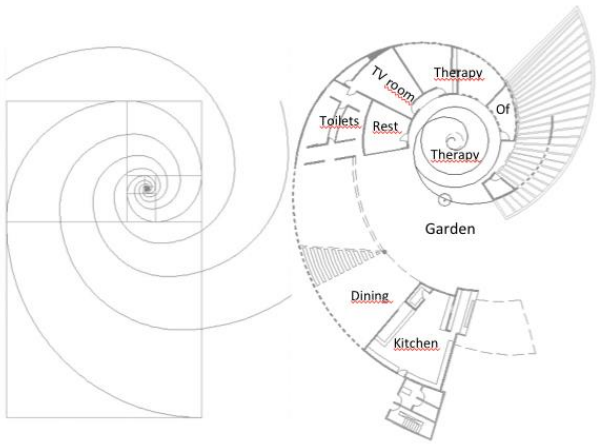


Figure 10: The Fibonacci series, the golden rectangle and the spiral as inspiration for the design of the Day Care Center

The dance and playroom was designed to visually create a dialogue with the Day Care Center and the chapel by using a series of columns and tablets that are the same in length as the windows or the same width as the walls. By following a rhythm, they allow air to flow through, visibility, light and provide a sense of order and playfulness at the same time.

Figure 11: The four elements are present within the form of the Vesica Piscis in the ecumenical chapel.

The ecumenical chapel is based on a holistic design that incorporates the Vesica Piscis and the golden section to express how God manifests in different forms and spirituality can be lived through many paths. The presence of the four natural elements of soil, water, air and fire seek to reflect the simplest essential parts and principles of life, in order to contribute to deep prayer and meditation (ether) (Fig. 11).

CONCLUSION

The day Care Center for the elderly in Tabasco celebrates transformation and change through a design that follows the trees, the wind and natural geometry to create spaces for reflection and peace, for movement and health, for learning and play, where life can be celebrated and honoured and change can be accepted. This is a gift for all of our ancestors who have given us life and now are entitled to inhabit a place where they can age with dignity, happiness and love, surrounded by beautiful spaces.

His step was beautiful: neither short nor long.
The hills were contained in his eyes
and the whole landscape in his arms.
Carlos Pellicer

ACKNOWLEDGEMENTS

Special thanks are due to my colleague, partner and fabulous architect, María Virginia Pérez Reyes, who created the design of this Center as a legacy to her community.

REFERENCES

1. Own research based on data provided by the National Metheorological System from station 767433 (MMVA).
2. Givoni, B. (1976). Man, Climate and Architecture, London, UK: Applied Science Publishers, LTD.
3. U.S. Green Building Council (2007). New Construction and Major Renovation, Reference Guide. USA: USGBC
4. International Living Future Institute (2012). The Living Building Challenge 2.1, [Online], Available: http://living-future.org/sites/default/files/LBC/LBC_Documents/LBC%202_1%2012-0501.pdf
5. Australian Government (2011). Your Home, Tecnhical Manual. [Online], Available: http://www.yourhome.gov.au/technical/
6. Fuentes, V. (2004). Clima y arquitectura. México D.F., México: Editorial Universidad Autónoma Metropolitana
7. Fuentes, V., Figueroa, A., Schjetnan, M., Pérez, J. y Sandoval, J. (1989). Criterios de adecuación bioclimática en la arquitectura. México, D.F. : IMSS
8. Fuentes, V, y Viqueira, M.(2004). Ventilación Natural, cálculos básicos para arquitectura. México D.F., Mexico: Editorial Universidad Autónoma Metropolitana
9. Olgyay, V. (2008). Arquitectura y Clima. Manual de diseño bioclimático para arquitectos y urbanistas. España: G. Gili.
10. Rodríguez, R. (1963). Arquitectura ambiental en el trópico húmedo. Santiago de Chile: Ediciones Lafargue.
11. Ugarte, J. (NA) Guía bioclimática : Construir con el Clima. Costa Rica: Instituto de Arquitectura Tropical de Costa Rica, [Online], Available: http://www.arquitecturatropical.org/EDITORIAL/documents/GUIA%20BIOCLIMATICA%20CONSTRUIR%20CLIMA.pdf