CASE STUDY: BIO-CLIMATIC BUILDING DESIGN FOR TROPICAL CLIMATES

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Environmental design in the humid tropics requires special consideration. This chapter is based on two case studies which attempt to develop a practical approach to including key elements of bio-climatic design in tropical regions.

Location: Reunion Island
Population 840,000 inhabitants
Area: 2512km ^{2}
Geology: Volcanic island
Highest point: Mount des Neiges 3070m
Rainfall: Reunion holds all world records for precipitation between 12 hours and 15 days

Figure 1: Geographic Location of Reunion

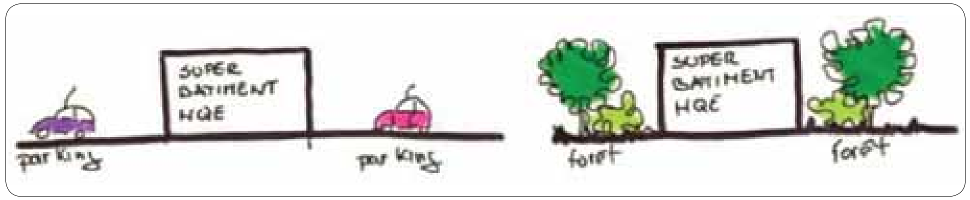
Case Study 1
Malacca Flores:
Promoter: SIDR (Semi-Public Social Housing)
Architects: Michel Reynaud / Antoine Perrau
Environmental quality department: LEU Meeting
City: Le Port
Altitude: 10 m leeward coast
Delivery: 2011
Total floor area: 8950 m^2

The Context:

The project is located in a Development Zone and the objectives include: opening the city towards the sea, to reinvigorate the city centre, create a link between the periphery and centre of the community, and to implement the principles of sustainable development through a green master plan.
The projects location and surroundings were thus crucial to its success.

The Site:

The site of a project and its concomitant micro climate is of particular importance in the tropics. Favourable conditions on site will impact the performance of buildings constructed there.



For instance the presence of trees plays a fundamental role in the areas micro-climate.

Our firm's offices are in the centre of the island, allowing us to illustrate these differences.

During February, the month with the highest temperatures in the Southern Hemisphere, a temperature differential of 7 ° C was measured between the street and the inside of the office (without air conditioning). This is achieved in part, by planting buffers of vegetation such as grass and shrubs between the street and the building. The effect of the plants is to cool the air through evapotranspiration, and reduces the albedo effect by shading the concrete and other hard surfaces.

Figure 2: Office veranda and adjacent garden shielding the building from the street

The role of plants in reducing the urban heat island effect has also been demonstrated in the city of Paris by researchers from Météo France. The diagram below illustrates the difference in temperature between the suburbs and the city center during a summer's day, which was 4 ° C.

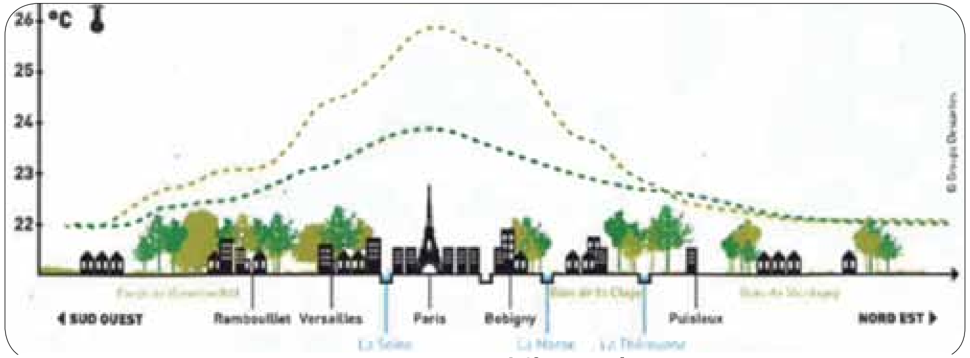


Figure 3: Temperature differentials in Paris
Source: The Journal of Research

We therefore sought a favourable site for the project, and special effort was taken to re-vegetate surrounding buildings and find space on natural land.

Figure 4: Project Location

Shading:
The second step was to determine the most favourable orientation of the shading devices through computer simulations of sunscreen designs.

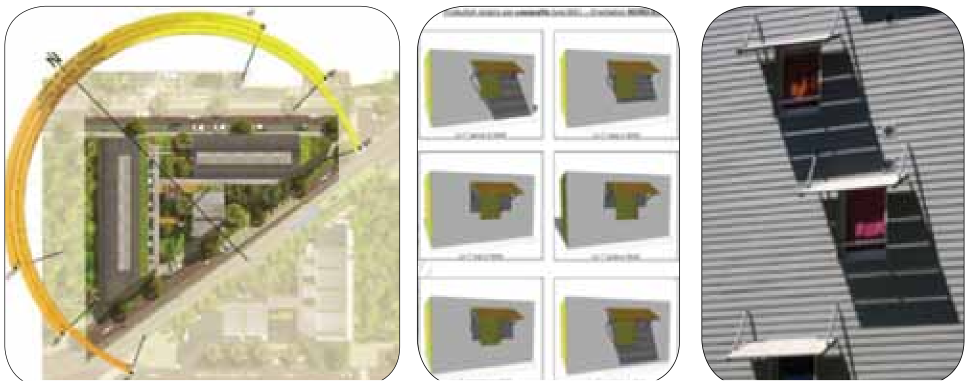


Figure 5: Modeling Efficacy of Sun Shading Devices

Parallel to this reflection, we verified the thermal comfort. It should be noted that the concept of comfort temperature is different from the temperature measured with a thermometer and is not absolute but depends on several parameters: humidity, air velocity, air temperature, the radiation temperature of the walls, metabolism and clothing.

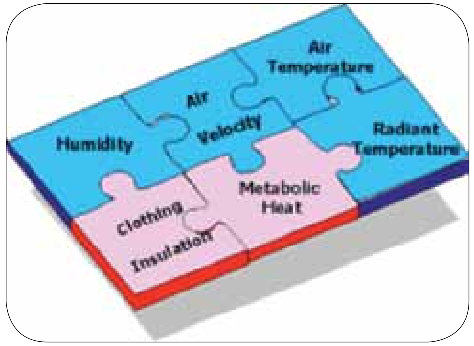
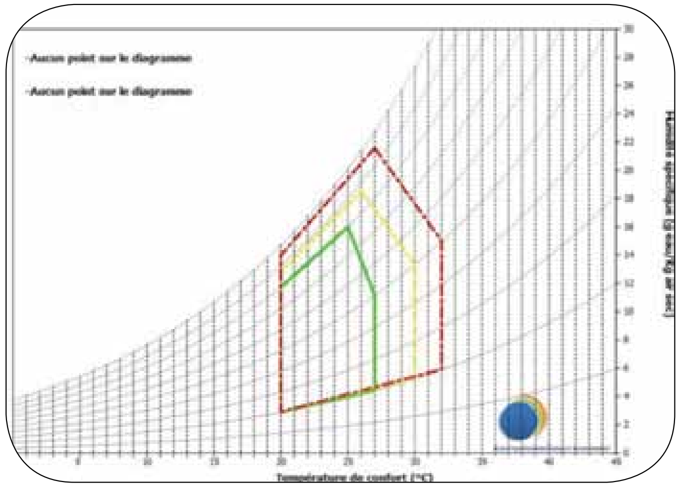


Figure 6; Factors Influencing Thermal Comfort

One can evaluate the effect on internal comfort of a building as influenced by the first four factors mentioned above using the comfort graph developed by Givonni:



Red air velocity of 1m / s
Yellow air velocity of 0.5 m / s
Green air velocity of 0m / s

Figure 7: Givonni Chart

The graph demonstrates how essential it is to ensure natural ventilation, which is achieved through the porosity of the facades, and in this latitude, there should be a minimum porosity of 20% between two opposite facades.

Effective implementation of these interventions allows urban and architectural buildings to reduce their energy consumption by between 28 and 41 kWh / m^2 / year. In fact spaces designed in this way provide thermal comfort without the need for air conditioning, even in the tropics.

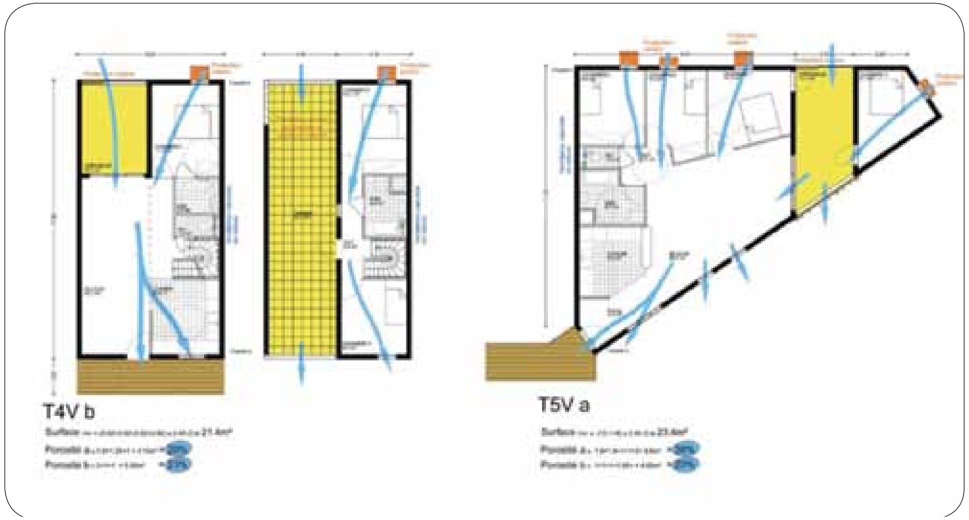


Figure 8: Cross Ventilation

Additional features:

Beyond these provisions, the specification proposes a number of other environmental features:

Implementation of solar hot water panels and photovoltaic roof panels

These panels are also used to shield the roof from high levels of solar radiation. 70% of the heat input comes through the roof, and so this element of the design should be treated with the utmost consideration and care.

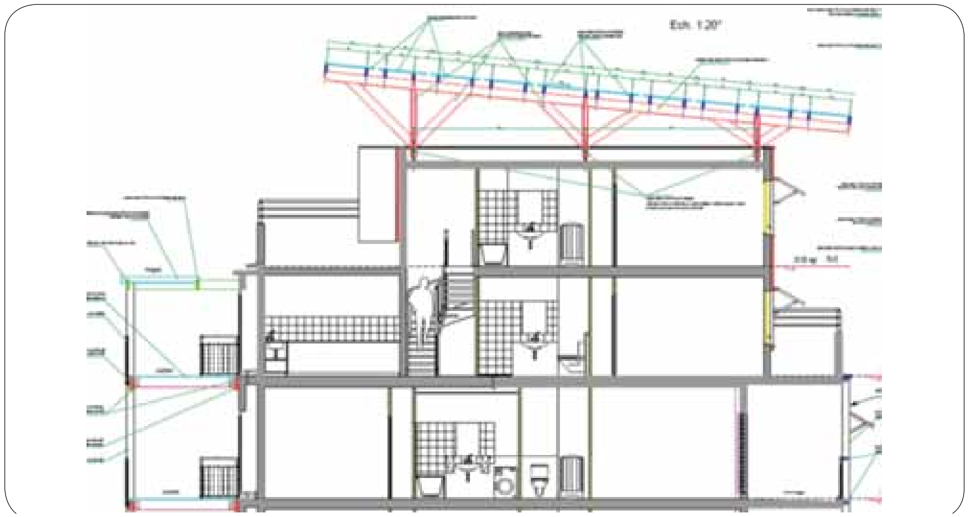


Figure 9: Using Photovoltaic Panels as a Roof

This dual purpose of the solar devices can increase their efficiency and reduce overall cost.

Increased use of wood to reduce the carbon footprint of the project

Wood was specified for the structure of corridors, sidings, sunscreens and pergolas.

Figure 10: Timber Material Choice

Grey water recycling

We used a filtration system with a settling tank and a filter zeolite vertical which provided regular contributions of water for irrigation.

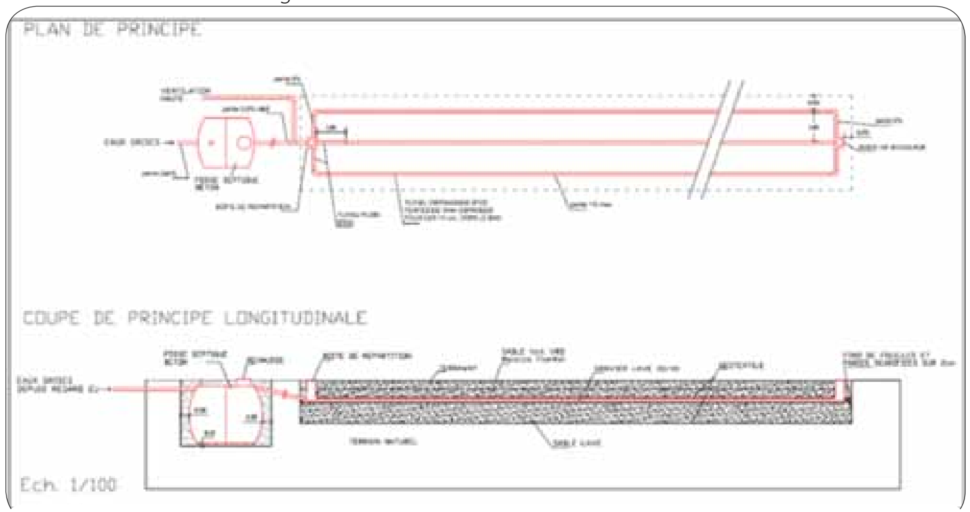


Figure 11: Filtration System

Figure 12: Aeral View of Completed Project

Case Study 2
National park House of Réunion

Figure 13: Images of Proposed Development

Promoter: National Park Meeting
Architects: Michel Reynaud / Antoine Perrau
City: The Plain Palm
Altitude: 1050 m
Delivery: 2013
Work in progress

The context:
The context here is very different from the first project as the site is located in the centre of the island, a mountainous area at an altitude of 1000m. The challenge therefore was to achieve conditions of human comfort in respect of both heating and cooling as the area can get very cold in winter.

Figure 14: Site Plan

This region is characterized by heavy rainfall, prevailing winds from opposite directions and a high quality bio sphere with many endemic species.

A key objective was to organise the buildings in a manner that least affected the surrounding, and this was achieved in part by building on narrow stilts. The effect is to preserve flora at the forest floor and allow for the movement of animals and insects, and at the same time creating opportunities for natural ventilation.

The position of the site within the surrounding environment is highly favourable due to the existence of plants and trees, and the objective here was to preserve and thus take advantage of the micro climate and its characteristic albedo and thermal regulation.

The Building

The environmental strategy was focused primarily on the following topics: thermal comfort in summer and winter, optimised natural lighting, optimisation of one unit energy consumption, water treatment, storage of CO_2 with the use of wood and ecological restoration of the site.

Thermal comfort

As mentioned above the altitude of the location has led us to consider two strategies utilising two thermal and different operating modes to achieve comfort in summer and winter.

Moreover, given the non-permanent occupation of the premises (offices and exhibition) we focused on comfort during periods of occupancy and have implemented climate zoning to optimise shading and natural ventilation devices to optimise different thermal comforts.

The strategies employed are:

Workspace: Control of hygrothermal conditions (Controlled Mechanical Ventilation dehumidification)
Circulation: Buffer space (cold in winter - warm in summer)
Large volume space: passive functioning + wood stove
Technical / Sanitary spaces: ventilation + humidity control

Figure 15: Building Configuration

Summer comfort:

The founding principles here are similar to those mentioned in the previous project: input controls such as shading on the building and effective ventilation to maintain a comfortable temperature.

To obtain satisfactory results we have taken the following steps:
-Dry construction to limit thermal storage in the walls
-Good thermal insulation of the roof (remember 70% of heat gain through the roof)
-Good porosity of the facades, to optimize the ventilation
-Buffer thermal circulations positioned to the North

A Trombe wall consisting of polycarbonate tubes filled with water acting as sun protection and cold tank thermal inertia was also used.

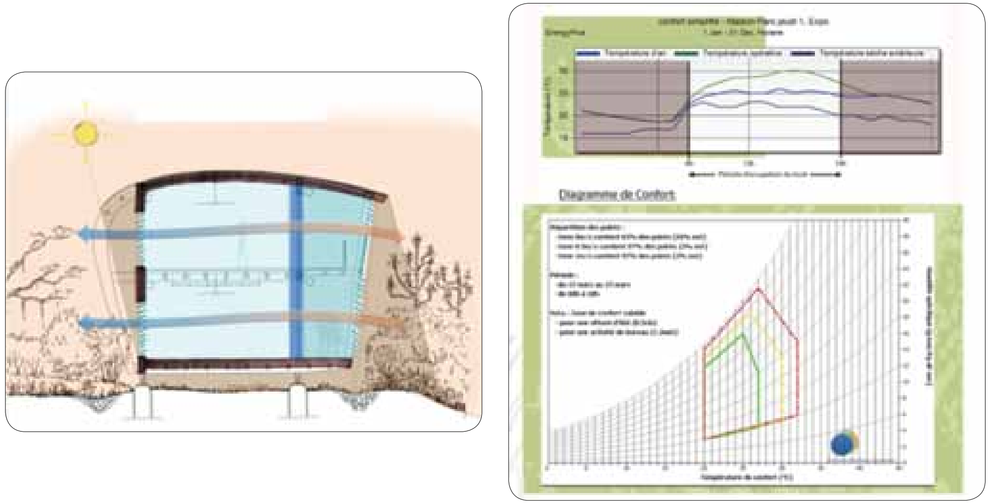


Figure 16: Summer Comfort Strategies

Winter comfort

A major goal here was not to have to mechanically regulate heating and to minimise the high humidity discomfort factor.
To obtain satisfactory results we have taken the following steps:

- Dry structure to limit cold wall effect
- Good insulation to walls
- Fenestration: all closed but may be opened for localised temperature
- North passageway bioclimatic greenhouse to optimize solar radiation
- Trombe wall water Heat diffusion, thermal inertia tank
- Double flow CMV with dehumidification and air preheating new

Trombe wall

The sun warms the tubes filled with water in the morning, through solar radiation, and heat in the water is distributed throughout the height of the tubes by convection which then returns the heat to the air. In Reunion clouds very often appear in the afternoon which assists this process.

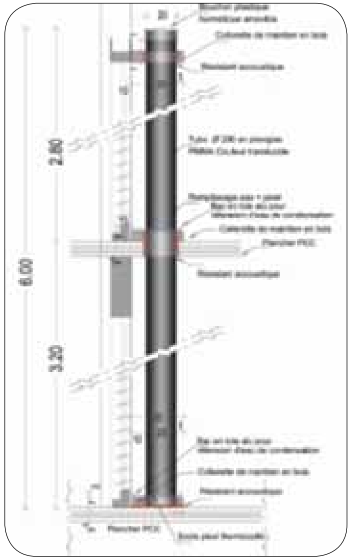
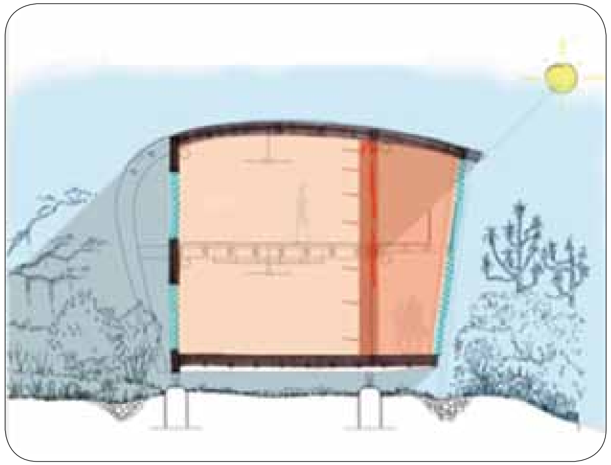
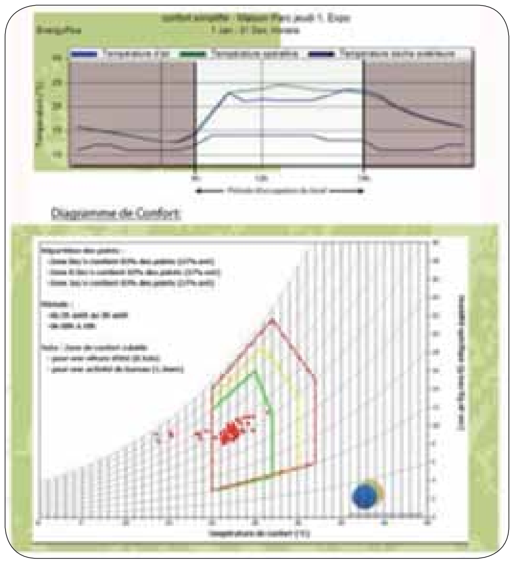


Figure 17: Trombe Wall





Energy Efficiency

A careful selection of technical equipment and lighting allowed us to obtain the following energy balance as set out in the Table below:

USAGES	ENERGETIC REQUEST		
	Units	Electricity	Combustible : wood
Woodstove (recreation and exposition rooms)	kWh/year		2000 (1 stere)
Air treatment in assembly room (10 days /year)	kWh/year	400	
Heat recovery ventilation in office	kWh/year	870	
Dehumidification fresh air in office (winter + days of high precipitation)	kWh/year	8 052	-
Reheating fresh air in office (winter morning)	kWh/year	2 236	-
Additional heating (punctually in winter)	kWh/year	1 690	
Solar domestic hot water	kWh/year	2 381	
Illumination	kWh/year	3 137	-
Auxiliary	kWh/year	3 248	-
Office automation	kWh/year	32 869	-
Elevators	kWh/year	9	-
TOTAL FINAL ENERGY	kWh/year	**54 892**	
TOTAL FINAL ENERGY	$kWh/m^2_{SDO.year}$	**34**	1.2

Table 1: Technical Equipment and Lighting

HYPOTHESIS	
Opening	8h - 18 h during 253 days /years
Illumination : power installed	8276 W
Illumination : power installed	$5 W/m^2_{SDO}$
Illumination : Coefficient of expansion	0.60
Autonomy of natural illumination	75 %
Natural illumination	632 h /an
Office ventilation : ventilator power	0.5 kW nominal, 1 kW maxi (reheating)

Office ventilation : functioning heat recovery ventilation	11 hours/day during130 day/year (winter) + 50 hours/year (very high precipitation) = 1480 hours/year
Office ventilation : power ATU (maxi)	8.6 kW
Office ventilation : power ATU (nominal)	6.6 kW
Office ventilation : functioning dehumidification	9 hours/j, 130 days/year (winter) + 5 days/year(very high precipitation) = 1220 hours/year
Office ventilation : functioning reheating	2 hours/day (morning) during 130 days/year = 260 h
Office ventilation : power ATU for reheating	8.6 kW
Elevator	Functioning cumulated : 1 hour/year
Office automation	Average density de power : 8 W/m²
Auxiliary	Average density de power : 2 w/m²

This table also highlights the importance of verifying assumptions and therefore the need to monitor the building to ensure compliance with the assumptions.

Construction system

The construction system has introduced a dual use of the building facade so that the structure minimises the carbon footprint of the project while reducing the impact of building on the site by taking it off the ground and thus preserving the transparency and hydraulic corridors and embracing the surrounding ecological environment as well as mimicking the surroundings.

Figure 18: Section and Elevation

Ecological restoration:

This project also provided an ambitious ecological restoration of the site with the preservation and planting of endemic species which constitute the World Heritage of UNESCO that is Reunion.

Conclusion

The two case studies demonstrate how designing with the bioclimatic conditions of a site can enhance the performance of the building while simultaneously enhancing the ecological value of the site. It is a clear indication that it is possible to undertake developments while supporting ecosystem resilience.