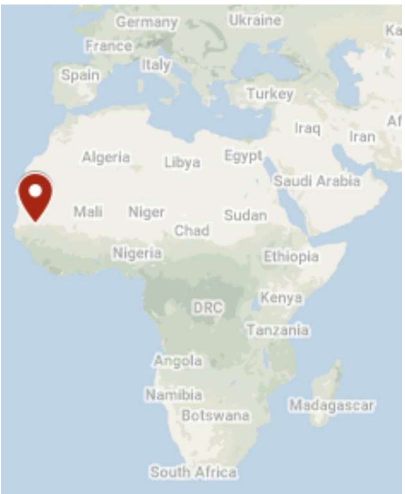
CASE STUDY 2-09: LYCEE JEAN MERMOZ | SENEGAL



GEOGRAPHICAL AND CLIMATE INFORMATION	
Location	Avenue Cheikh Anta Diop - BP 3222 - Dakar, SÉNÉGAL
Latitude; Longitude	14.718193231710131, -17.484476683878636
Climate zone (Köppen–Geiger classification)	BSh: Hot semi-arid steppe
BUILDING INFORMATION	
Building Type	Educational (Kindergarten, primary, high school, CDI, administrative centre and sports platform)
Project Type	New construction
Completion Date	2010: Classrooms 2012: Sports infrastructure
Number of buildings	19
Number of storeys	2 for the kindergarten and primary school 3 for the high school
Total Floor Area (m²)	Unknown
Net Floor Area (m²)	17 000m²
Thermally conditioned space area (m²)	Unknown
Spaces with Natural Ventilation (with or without Ceiling Fans) Only (m²)	Unknown
Total cost (€)	15,7 M€ excluding taxes (10 102 MFCFA)
Cost /m² (€/m²)	923,5
Performance Standards or Certification	None
Awards	Winner of the 2012 AFEX Grand Prize Nominated for the Aga Khan Award for Architecture 2013
STAKEHOLDERS	
Building Owner/ Representative	A.E.F.E (The Agency for French Education Abroad), Paris / The embassy of France in Dakar
Assistance to the contracting authority	SCO Afrique (Société de Coordination et d'Ordonnancement)

Architect / Designer	TERRENEUVE architects (lead architect), Adam Yedid Architect (associate architect), Architecture and Climate (Architects and Construction Economics)
Building control expert	SCAT Internationale
Construction Manager	POLYPROGRAMME
Mechanical engineering and environmental consultancy	ALTO Ingenierie
Structural Engineer, Civil Engineer	SATOBA Ingenierie
Acoustical consultant	AYDA Yves Dekeyrel
Landscape design	Armelle Claude
Others	GETRAP, GENERALE D'ENTREPRISES (GE), Miquel Mont

PROJECT DESCRIPTION [1][2]

Figure 123 : Exterior view of the building. ©Daniel Rousselot

The "Lycée Schorge" is a completely modern and state-of-the-art building, using innovative passive solutions so as to ensure thermal comfort. This project is based on the local knowledge, enhancing a great economy of technical means and limiting the importation of manufactured products. The layout of the buildings in narrow strips, whose in-betweens form shaded tree-lined interior islands, optimizes natural cross ventilation. The building typology of each entity offers several "passive" solutions for cooling and solar protection: exterior corridors, ventilated double walls, solar shading devices and high inertia of the roofs. All of these features ensure thermal comfort during most of the school year and reduce the period of air conditioning use to one or two months per year. The facility includes a school complex that welcomes students from kindergarten to high school. It also includes an administrative centre and common facilities such as a school restaurant, a multi-purpose room and sports' infrastructures.

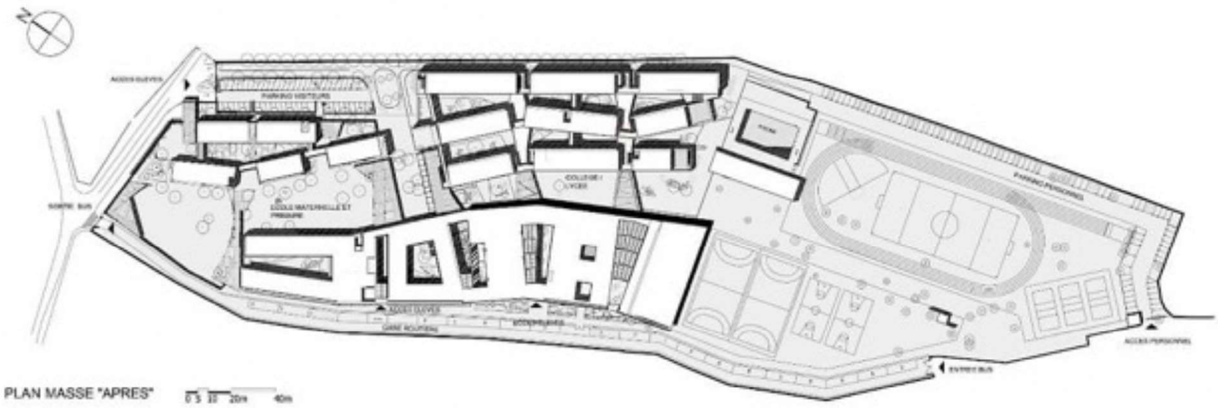


Figure 2: Site plan of the "Lycée Mermoz" ©TERRENEUVE

SITE INTEGRATION

(a) (b)

Figure 124 : Aerial views of the building in its surrounding environment. (Source: (a) Google Map and (b) ©Daniel Rousselot)

The Mermoz high school is located in the densely built-up Ouakam district, along the western coastline of the Dakar peninsula. The new buildings replace the old high school built temporarily in 1994 and made up of prefabricated modular constructions but benefiting from a very appreciated vegetal environment. The French high school has a special relationship with the surrounding neighbourhood, since the configuration of the site offers only two points of contact with the city. Almost totally enclosed, the lycée is hardly visible from the urban space. The project tends to minimize its impact on the immediate environment, and in particular on the existing urban networks. The traffic and parking of school buses and private vehicles has been taken care of within the plot, as well as all water treatment.

CLIMATE ANALYSIS

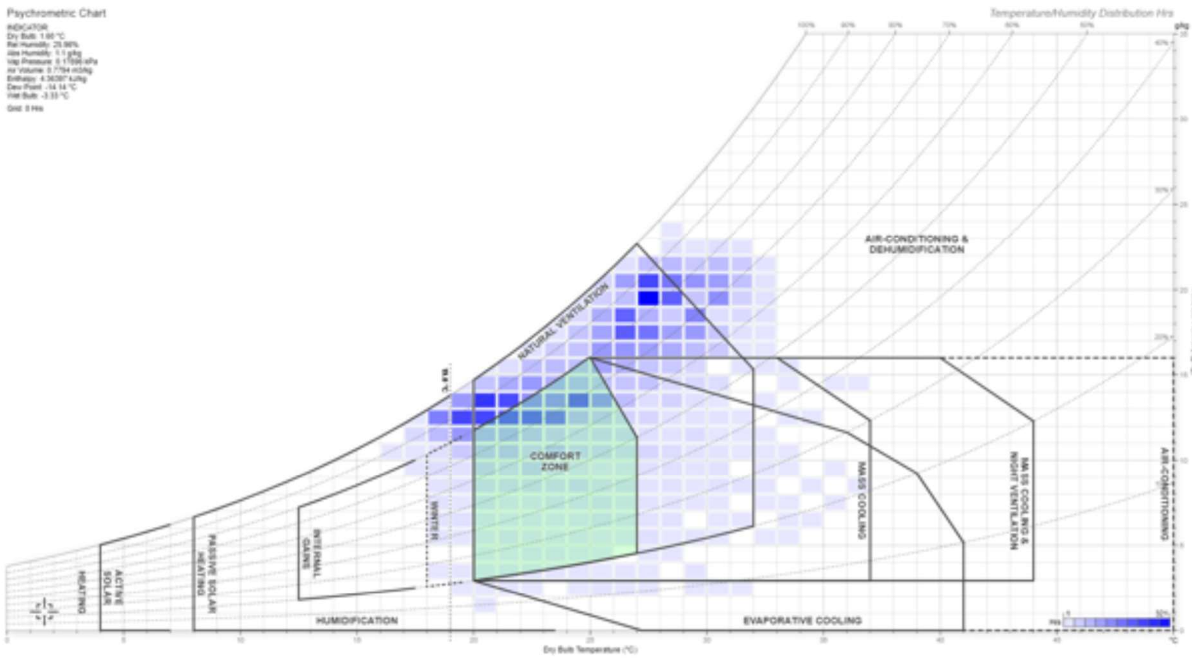


Figure 125: Givoni Bioclimatic chart for the climate of Dakar, Senegal using Andrew Marsh online tool [2]. Climate data are extracted from the database of the climate.onebuilding.org website.

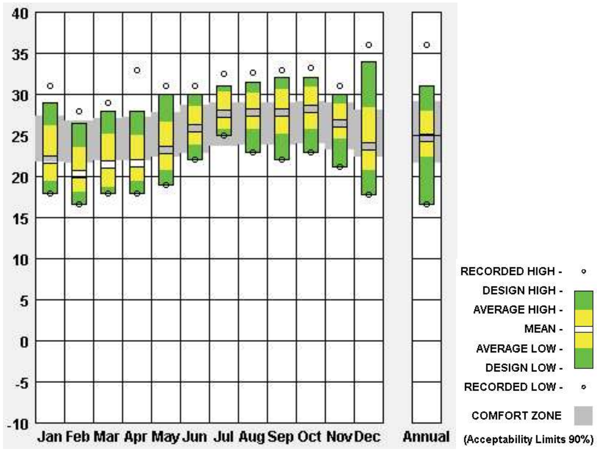


Figure 126: Temperature range by month for Dakar, Senegal (Source: Climate consultant – Adaptative Comfort model).

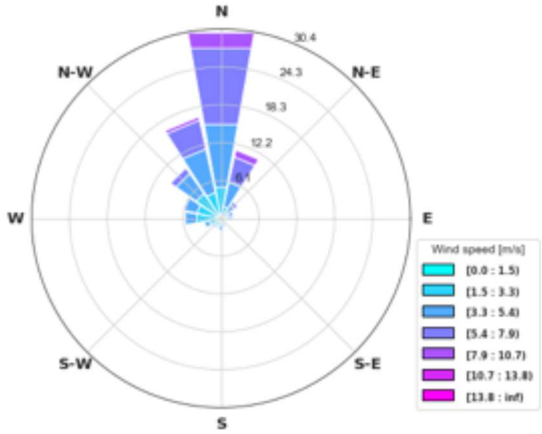


Figure 127: Wind rose for Dakar, Senegal (Beaufort wind scale).

Global horizontal radiation (Avg daily total) Min (month) / Max (month)	Min: **5 243** Wh/m² (Dec.) Max: **6 937** Wh/m² (May) Mean: **5 964** Wh/m²
Annual Degree-Days for weather classification according to ASHRAE Standard 169-2020	HDD 18°C: **0** CDD 10°C: **5 364**
Annual Degree-Days for the Adaptive Comfort Base Temperature according to the ASHRAE 55-2017	HDD: **97** CDD: **20**
Annual Degree-Days for a static comfort temperature approach	HDD 18.6ºC: **5** CDD 26º: **321**

KEY BIOCLIMATIC DESIGN PRINCIPLES	
Passive cooling strategy	**Comfort ventilation** (natural cross ventilation) The arrangement of the buildings in relation to each other generates micro-climates in the patios that enhance the natural cooling of the interior spaces. The trade winds, which benefit the oceanic climate of Dakar, justify the linear and tight organization of the buildings which amplifies the effect of the air movements and increases the impression of freshness. The rooms are equipped with French windows in the double-walled facades and louvers on the corridor side, which can be used for night-time cooling and also act as an anti-intrusion strategy. High thermal mass of the roofs and ventilated double walls
Passive heating strategy	
Solar protection	The shading provided by the arrangement of the buildings allows to limit not only the heating of the walls but also of the exterior ground. On the front facade of the teaching spaces, galleries and awnings prevent the sun from impacting the facades during the hottest hours. On the rear facade, ventilated double walls

	prevent the interior walls from heating up, and form thick walls and window panels that limit direct sunlight. All exterior corridors and common pathways are at the same time places of life, architectural walks, and solar protection. Pergolas planted with Bougainvillea and other tropical species also provide shaded spaces.
Building orientation	The main facades of the different buildings are facing the North-East / South-West.
Insulation	Ventilated double walls
Vegetation	The different buildings are surrounded by vegetation (shrubs, trees and flowers). The planted patios create a comfortable microclimate around the buildings and also bring conviviality. Pergolas are covered with Bougainvillea and other tropical species.
Natural daylighting	Large openings on opposite facades allow natural light to enter in the rooms in relation to the constraints of solar protection, also favoured by high ceilings.
Use of local and embedded materials	Unknow
Water saving and flood management	Particular attention was paid to the rainwater management including the infiltration of a large part of the rainwater to limit the discharge to urban networks that are undersized and inefficient. The roofs are designed to allow for delayed runoff during heavy winter rains, with a flow limitation system allowing for temporary storage on the terraces. At the foot of the buildings, the water is channelled into large open vertical gutters and discharged into drainage basins made of several layers of basalt and laterite aggregates associated with drains.
Waste management	An autonomous wastewater treatment plant has been set up to recycle all wastewater. The recycled water is used for watering the green spaces. The plants were chosen from local species that consume little water, so that it is not necessary to use additional water resource.
Others features	-

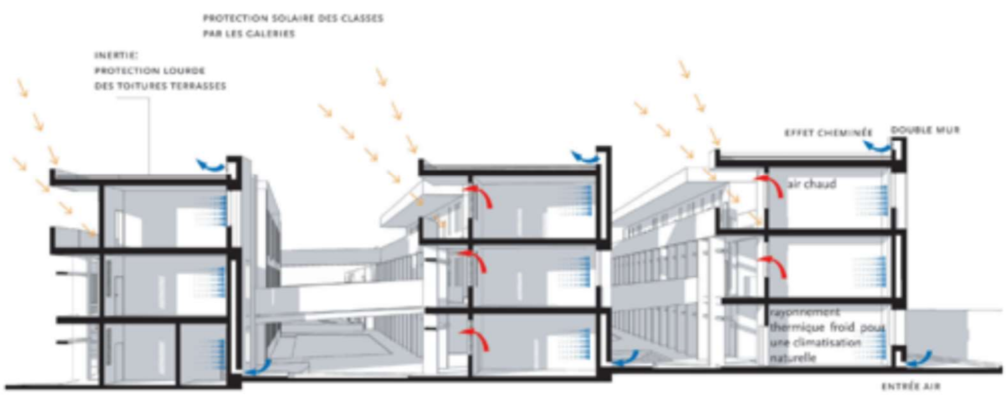


Figure 128: Cross section of the passive solutions set up for the high school buildings. ©TERRENEUVE.

Figure 129: The buildings are connected by exterior corridors. ©Daniel Rousselot

Figure 130: Different solar protection solutions have been set up, such as canopies. ©Daniel Rousselot

Figure 131 : Solar protection strategies also include vertical blade sunshades and pergolas recovered by climbing plants. ©Daniel Rousselot

Figure 132: The planted courtyards create a comfortable microclimate around the buildings and also bring conviviality ©Daniel Rousselot

INFRASTRUCTURES and REGULATIONS to enable SUFFICIENCY ACTION	
Dressing code	Informal dressing, adapted to the season, is welcome and promoted (e.g. short trousers and short leaves in hot periods): **Unknown**
Protected bike parking and showers	**Unknown** If yes, Ratio with number of users: **??**
Ceiling fans	In every room, even those conditioned: **No**
Lighting system fractioned to allow using light only in zones occupied and where daylighting insufficient	In every room, even those conditioned: **N/A**
Space and facilities for line drying clothes (especially important in residences, hotels, sport facilities…)	In every room, even those conditioned: **N/A**
Book of instruction for correct use of the passive features (windows, solar protections, water savings) and active (lighting…) in order to promote sufficiency and efficiency actions	Available through leaflets and posters at relevant places, online, etc.: **No**

BUILDING FABRIC AND MATERIALS	
Roof	**Unknown**

Windows	Type of materials: clear glass
Walls	The **Exterior double walls** are composed of (from outside to inside): ▪ Plaster and paint (1 cm) ▪ Concrete blocks (20cm) ▪ Air gap (35cm) ▪ Concrete blocks (20cm)
	The **Interior Walls** composition is unknown

ENERGY EFFICIENT BUILDING SYSTEMS	
Low-energy cooling systems	**The building is air-conditioned.**
Low-energy heating systems	None
Ceiling fans	**No ceiling fans**
Mechanical ventilation / air renewal	**Unknown**
Domestic Hot Water	Solar thermal
Artificial lighting	**Unknown**
Control and energy management	None

RENEWABLE ENERGY	
PV	**Unknown**
Solar thermal	**Unknown**
Wind	None
Geothermal	None
Biomass	None

BUILDING ANALYSIS AND KEY PERFORMANCE INDICATORS	
Thermal comfort indicators	1. Percentage of time outside an operative temperature range (Adaptive)
	2. Percentage of time outside an operative temperature range (Fanger)
	3. Degree-hours (Adaptive)
	4. Degree-hours (Fanger)
	5. Percentage of time inside the Givoni comfort zone of 1m/s
	6. Percentage of time inside the Givoni comfort zone of 0m/s
	7. Number of hours within a certain temperature range
Energy performance indicators	1. Energy needs for heating (kWh/y/m2)
	2. Energy needs for cooling (kWh/y/m2)
	3. Energy use for lighting (kWh/y/m2)
	4. Energy needs for Sanitary Hot water (kWh/y/m2)
	5. Total Primary energy use (kWh/y/m2)
	6. Renewable Primary energy generated on-site (kWh/y/m2)
	7. Renewable Primary energy generated on-site and self-consumed (kWh/y/m2)
	8. Renewable Primary energy exported to the grid (kWh/y/m2)

	9. Ratio of renewable primary energy over the total primary energy use (with and without compensation) (%)
	10. Delivered energy (kWh/y/m2) (from electricity bills) : **64 kWh/m^2.year**
Acoustic comfort indicators	1. Airborne sound insulation
	2. Equivalent continuous sound Level
	3. HVAC noise level
	4. Reverberation time
	5. Masking/barriers
Visual comfort indicators	1. Light level (illuminance)
	2. Useful Daylight Illuminance (UDI)
	3. Glare control
	4. Quality view
	5. Zoning control
Indoor Air Quality indicators	1. Organic compound
	2. VOCs
	3. Inorganic gases
	4. Particulates (filtration)
	5. Minimum outdoor air provision
	6. Moisture (humidity, leaks)
	7. Hazard material
Users' feedback	Green spaces are appreciated a lot by the users.

LESSONS LEARNED AND RECOMMENDATIONS	
Lessons learned	This first monitoring campaign points out that the building does not work well in terms of thermal and energy performance. Despite favourable outdoor conditions, the indoor air temperature remains above the outdoor conditions is all the monitored saeces. All the spaces are air conditioned. The lack of ceiling fans does not allow to use them to balance the hot conditions or to reduce the period of air-conditioning. The electric density in terms of consumption is equal to 64 kWh/m^2/year, which is surprisingly high for a building that is supposed to be bioclimatic. The electric density is 3 times more higher compare to a conventional high school. It is reported that there is not an energy management strategy. Users and staff are not concerned and trained to demand side management. Air conditioning and artificial lighting are used all day long with sometimes the doors opened to the outside.
Recommendations	- Information and training of the staff and the users to demand side management; - Install ceiling fans in all the working spaces (1 CF/10 m^2); - Carry out an in-depth analysis of the electric consumption; - Launch a new measurement campaign and a POE; - Hire an energy manager.

BUILDING STRENGTHS AND WEAKNESSES

Strengths

Passive Design

Weaknesses

The building consumes too much energy due to the use of air-conditioning and the lack of energy management strategy

We are doubtful about the efficiency of the double wall used for night time cooling. Due to the weather conditions that are closed to a tropical climate, this passive solution may not work properly. Also, the position of the different buildings parallel to each other does not facilitate natural cross ventilation. The window to wall ratio seems to be not sufficient for an effective natural cross ventilation.

REFERENCES

1. https://www.terreneuve.fr/projets/lycee-mermoz-dakar/

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