# CASE STUDY 2-11: MBAKADOU PRIMARY SCHOOL – 3rd Classroom | SENEGAL

| GEOGRAPHICAL AND CLIMATE INFORMATION | |
|---|---|
| Location | Mbakadou village, Touba Merina rural community, Darou Mousty district, Kébémer department, Louga Region, Senegal |
| Latitude; Longitude | 15°17'30.4"N 15°56'09.8"W |
| Climate zone (Köppen–Geiger classification) | BSh: Hot semi-arid steppe |
| **BUILDING INFORMATION** | |
| Building Type | Educational |
| Project Type | New construction |
| Completion Date | 2019 |
| Number of buildings | 1 |
| Number of storeys | 1 (ground floor) |
| Total Floor Area (m² ) | Classroom: 74 |
| Net Floor Area (m² ) | Classroom: 74 |
| Thermally conditioned space area (m² ) | 0 |
| Spaces with Natural Ventilation (with or without Ceiling Fans) Only (m²) | Classroom: 74 |
| Total cost | ~15 000 € |
| Cost /m² | ~203 €/m² |
| Performance Standards or Certification | - |
| Awards | - |
| **STAKEHOLDERS** | |
| Building Owner/ Representative | Public School Darou Diop 2 |
| Architect / Designer | Architetti Senza Frontiere Italia |
| Construction manager | Touba Merina building company (construction) + GIE GANDIOL BATIMENT (thatch) |

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| Others | Mbakadou village (beneficiaries and participants in the construction), Associazione Solidarietà Dimbalente and Associazione Insieme (promoters and facilitators) |

## PROJECT DESCRIPTION

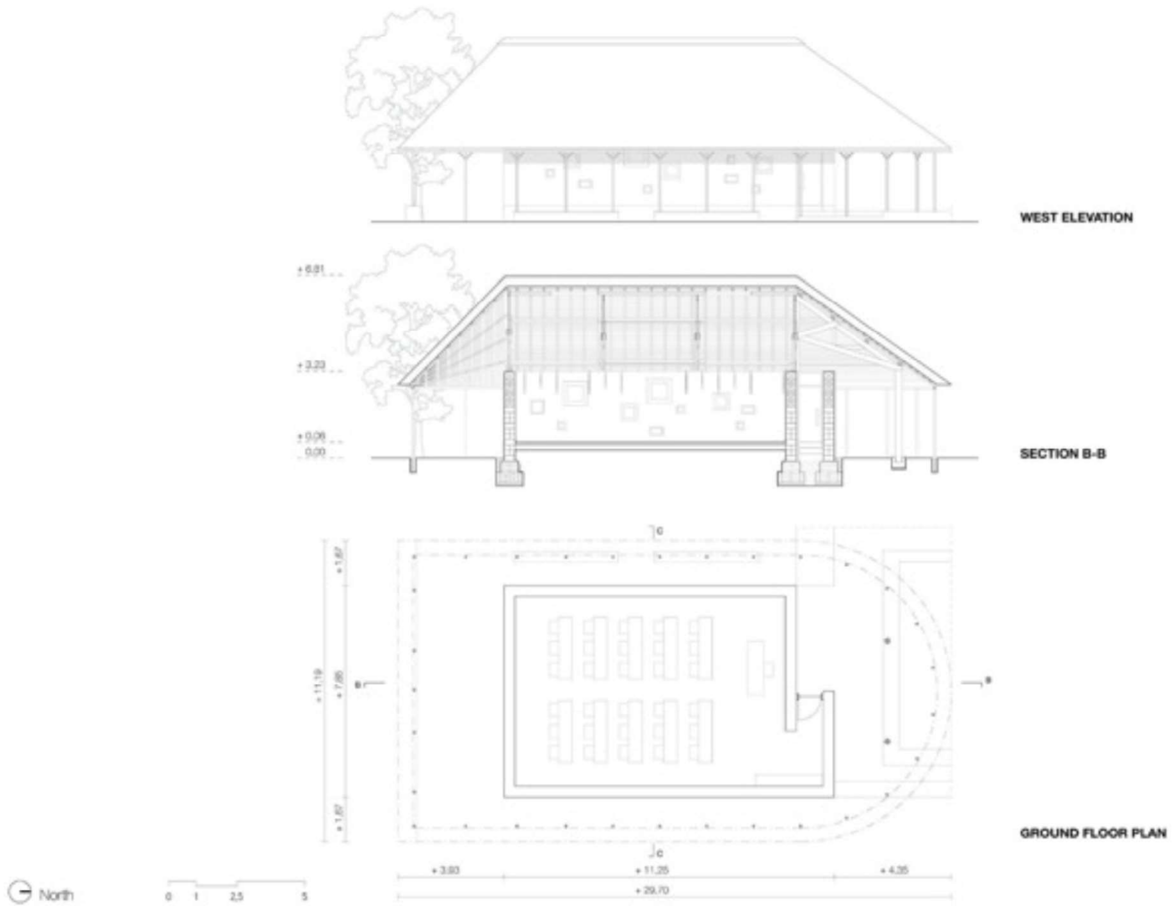


*Figure 146 West elevation, longitudinal section, and ground floor plan of the third classroom*

The Mbakadou school consists of three independent classrooms, a fence with 14 tanks for collecting rainwater, a cassava orchard, a kitchen with a bread oven, a toilet block, and an ablution area. Independent classrooms were built due to the bottom-up character of the project: a new classroom was built each time the necessary funds could be raised.

After the construction of the first classroom, Solidarietà Dimbalente, Insieme, and the community of Mbakadou called Architetti Senza Frontiere Italia to rethink and improve the general project of the school for the third classroom to come.

The new project was thus designed based on bioclimatic principles so as to enhance thermal comfort, valorise local natural materials and sustainable processes, as well as directly involve the participation of local people both in the design and building phases.

The school's newest classroom, built between 2018 and 2019, is characterised by a thatch roofing in Typha that shapes a porch all around the building and shelters the earthen walls from the rain; clusters of windows on the East, South, and West sides that allow natural free cooling; an entrance protected from winds.

The building combines low-tech technologies and local traditional knowledge:  Foundations are made of on-site quarried sandbags, walls are of mudbricks and earth plaster, the thatched roof has a structure of wooden planks and bamboo.

## SITE INTEGRATION

*Figure 147 : (a) Aerial view and (b). ground plan of the Mbakadou primary school. (source: Google Earth and ASF Italia)*

Mbakadou is a small rural village of about 600 inhabitants, located in the Louga region of Senegal, very close to the sub-Saharan area. The landscape is characterised by a mainly sandy soil dotted with baobab trees which provide shade and around which village life is concentrated during the hottest hours. The classrooms serve all the surrounding villages, which are sometimes dozens of kilometres away.

## CLIMATE ANALYSIS

Mbakadou is very close to the pre-desert region, an area that is experiencing progressive desertification. The school borders the village's eastern side; thus, it is fully exposed to the prevailing desert winds, which blow from the northeast to the southwest. The climate is hot and dry, with little rainfall even during the rainy season.

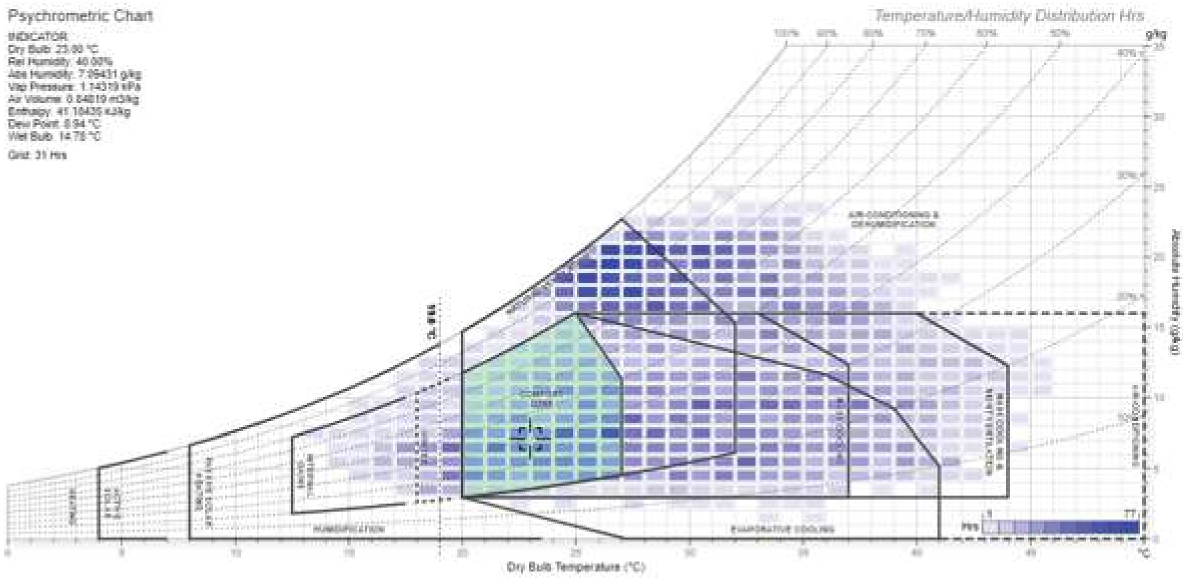


*Figure 148: Givoni Bioclimatic chart for the climate of the Louga region using Andrew Marsh online tool [2]. Weather data are extracted from the PVGIS tool of the jrc for the 2007 – 2016 period.*

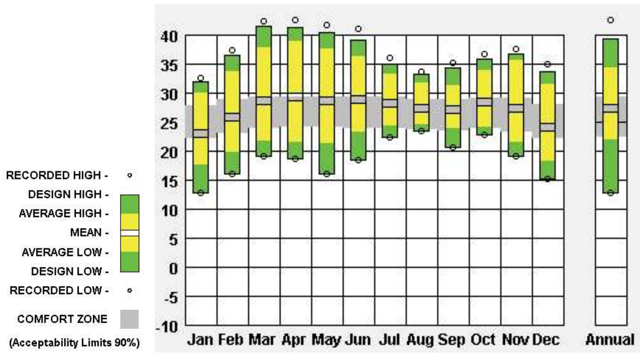


*Figure 149: Temperature range by month for the Louga region, Senegal (Source: Climate consultant – Adaptative Comfort model).*

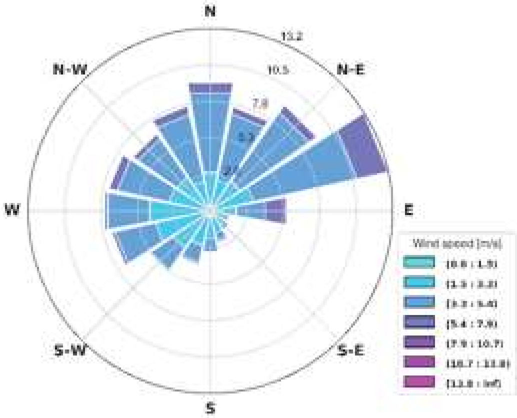


*Figure 150: Wind rose for the Louga region, Senegal*

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| Global horizontal radiation (Avg daily total) Min (month) / Max (month) | Min: **5 208** Wh/m² (Dec.)<br>Max: **7 722** Wh/m² (Apr.)<br>Mean: **6 339** Wh/m² |
| Annual Degree-Days for weather classification according to ASHRAE Standard 169-2020 | HDD 18°C: **11**<br>CDD 10°C: **6 311** |
| Annual Degree-Days for the Adaptive Comfort Base Temperature according to the ASHRAE 55-2017 | HDD: **121**<br>CDD: **390** |
| Annual Degree-Days for a static comfort temperature approach | HDD 18.6ºC: **17**<br>CDD 26º: **973** |

| KEY BIOCLIMATIC DESIGN PRINCIPLES | |
|---|---|
| Passive cooling strategy | **Comfort ventilation: Natural cross-ventilation**<br>**Nocturnal convective cooling**<br>Windows of varying sizes and heights arranged on three sides of the building bring 24h natural cross-ventilation. The free space between the walls and the roof structure also contributes to cross-ventilation.<br>Thick walls and thatch roofing provide high thermal inertia. |
| Passive heating strategy | High thermal mass of the walls. |
| Solar protection | The Typha roof overhang protrudes the building on all sides, shading windows and walls. |
| Building orientation | The main facades of the building are oriented East/West. . |
| Insulation | Thermal insulation is provided by the materials and thicknesses of the roof (Typha, 35cm) and walls (Mudbricks, 40cm), which give the building great thermal inertia. |
| Vegetation | Shrubs and trees have recently been planted close to the building. Indeed, between 2021 and 2022, the entire school area was planted with shrubs and trees, creating a cassava garden, and bougainvillaea has been installed along the fence. The aim is to cool the air temperature, counteract the action of the winds, and improve the environment quality. |

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| Natural daylighting | Natural daylighting is generous and partially shielded by the roof overhang. |
| Use of local and embedded materials | The clay used for the bricks, plaster and floor was quarried about 100 metres from the school. The foundations are made with sand excavated from the same foundation pit. The Typha for the roof was collected about 90 km from the village. |
| Water saving | -. |
| Waste management | -. |

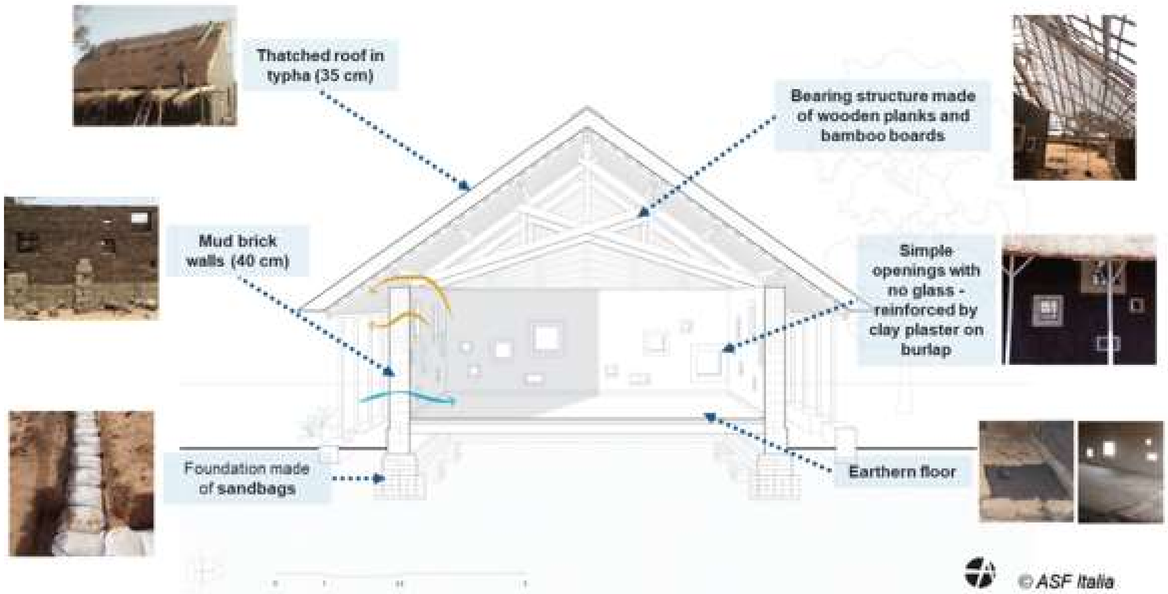


*Figure 151: Cross section of the bioclimatic strategies implemented in the classroom. The main strategies include natural cross ventilation, high thermal mass of the walls and roofs, solar shading with the large roof overhangs and the use of local materials (mudbricks and Typha).*

| 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): **No**<br>*The school well accepts it, but there is no particular indication/promotion.* |
| Protected bike parking and showers | **No**<br>Ratio with number of users: 0 |
| 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: **No** |
| Space and facilities for line drying clothes (especially important in residences, hotels, sport facilities…) | In every room, even those conditioned: **No** |
| Book of instruction for correct use of the passive features (windows, solar protections, water | Available through leaflets and posters at relevant places, online, etc.: **Yes.** |

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| savings) and active (lighting…) in order to promote sufficiency and efficiency actions | *An illustrated manual for the use and maintenance of the school (classrooms, kitchen, open spaces) will be completed in 2022.* |

Figure 152 : Construction materials. Top, from left to right: bonded sandbags foundations, mudbrick walls, wooden plank truss. Bottom, from left to right: earth plaster, earth floor and Typha thatched roof.

| BUILDING FABRIC AND MATERIALS | |
|---|---|
| Roof | ▪ Thatched roof in typha [0.35m]<br>▪ Bearing structure made of wooden planks and bamboo boards |
| Windows | ▪ Unglazed windows - simple openings with no glass nor brise-soleil.<br>▪ Each window frame is reinforced by clay plaster on burlap (clay is more water-resistant than earth plaster). |
| Walls | The **walls** are composed of (from outside to inside):<br>▪ Earth plaster [0.03 – 0.04m]<br>▪ Mudbrick [0.40m]<br>▪ Earth plaster [0.03 – 0.04m]<br>The first courses of bricks (those closest to the foundations) are improved with approximately 8% cement for better water resistance (following CRAterre guidelines and on-site tests). |
| Basement floor | Earthen floor |

*Figure 153 : Exterior view of the East façade of the classroom during the rainy season.*

| ENERGY EFFICIENT BUILDING SYSTEMS | |
|---|---|
| Low-energy cooling systems | None |
| Low-energy heating systems | None |
| Ceiling fans | None |
| Mechanical ventilation / air renewal | None |
| Domestic Hot Water | None |
| Artificial lighting | None<br>The school operates during daylight hours, so no artificial lighting is needed.<br>As the village sometimes uses the classrooms in the evening as a meeting place, (a few) light bulbs were installed in the classrooms in February 2022, powered by the photovoltaic panel in the school kitchen. |
| Control and energy management | None |

| RENEWABLE ENERGY | |
|---|---|
| PV | No PV systems for this classroom. |
| Solar thermal | None |
| Wind | None |
| Geothermal | None |
| Biomass | None |

(a) (b) (c)

*Figure 154 : Views of the bearing structure of the thatched roof under construction (a)(b) and interior view of the classroom with the Typha roof (c).*

| BUILDING ANALYSIS AND KEY PERFORMANCE INDICATORS | |
|---|---|
| Thermal comfort indicators | 2. 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: **Building 1: 47.4 %** **Building 2: 48.6 %** |
| | 6. Percentage of time inside the Givoni comfort zone of 0m/s: **Building 1: 31.0 %** **Building 2: 33.4 %** |
| | 7. Number of hours within a certain temperature range: |

| **Warm period: 15th Nov. 2022 to 10th March 2023 Occupation time: 8:00am to 4:00pm** | Building 1 – M1 | | Building 2 – M2 | |
|---|---|---|---|---|
| Range | Nb of Hours | Frequency | Nb of Hours | Frequency |
| Ta<20°C | 28 | 3,7% | 24 | 3,1% |
| 20°C≤Ta<22°C | 36 | 4,7% | 64 | 8,3% |
| 22°C≤Ta<24°C | 82 | 10,7% | 89 | 11,6% |
| 24°C≤Ta<26°C | 102 | 13,3% | 122 | 15,9% |
| 26°C≤Ta<28°C | 125 | 16,3% | 142 | 18,5% |
| 28°C≤Ta<30°C | 139 | 18,1% | 139 | 18,1% |
| 30°C≤Ta<32°C | 126 | 16,4% | 114 | 14,9% |
| 32°C≤Ta<34°C | 89 | 11,6% | 61 | 8,0% |
| 34°C≤Ta<36°C | 21 | 2,7% | 12 | 1,6% |
| Ta≥36°C | 19 | 0,7% | 0 | 0,0% |

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| Energy performance indicators | 11. Energy needs for heating (kWh/y/m2) |
| | 12. Energy needs for cooling (kWh/y/m2) |
| | 13. Energy use for lighting (kWh/y/m2) |
| | 14. Energy needs for Sanitary Hot water (kWh/y/m2) |
| | 15. Total Primary energy use (kWh/y/m2) |
| | 16. Renewable Primary energy generated on-site = **0** [kWh/m$^2$/year] |
| | 17. Renewable Primary energy generated on-site and self-consumed = **0** [kWh/m$^2$/year] |
| | 18. Renewable Primary energy exported to the grid = **0** [kWh/m$^2$/year] |
| | 19. Ratio of renewable primary energy over the total primary energy use (with and without compensation) = **0 %** |
| | 20. Delivered energy (from electricity bills) = 0 [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) |

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| | 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 | - |

## LESSONS LEARNED AND RECOMMENDATIONS

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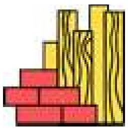
|---|---|
| Lessons learned | - |
| Recommendations | - |

## BUILDING STRENGTHS AND WEAKNESSES

*Strengths*

**Passive Design**



**Local Materials**

**Replicability**

**Affordability**

The Mbakadou primary school was designed with bioclimatic considerations in terms of cooling, ventilation and use of locally available materials.

*Weaknesses*

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## REFERENCES

1. https://www.asfitalia.org/primary-school-mbakadou-senegal