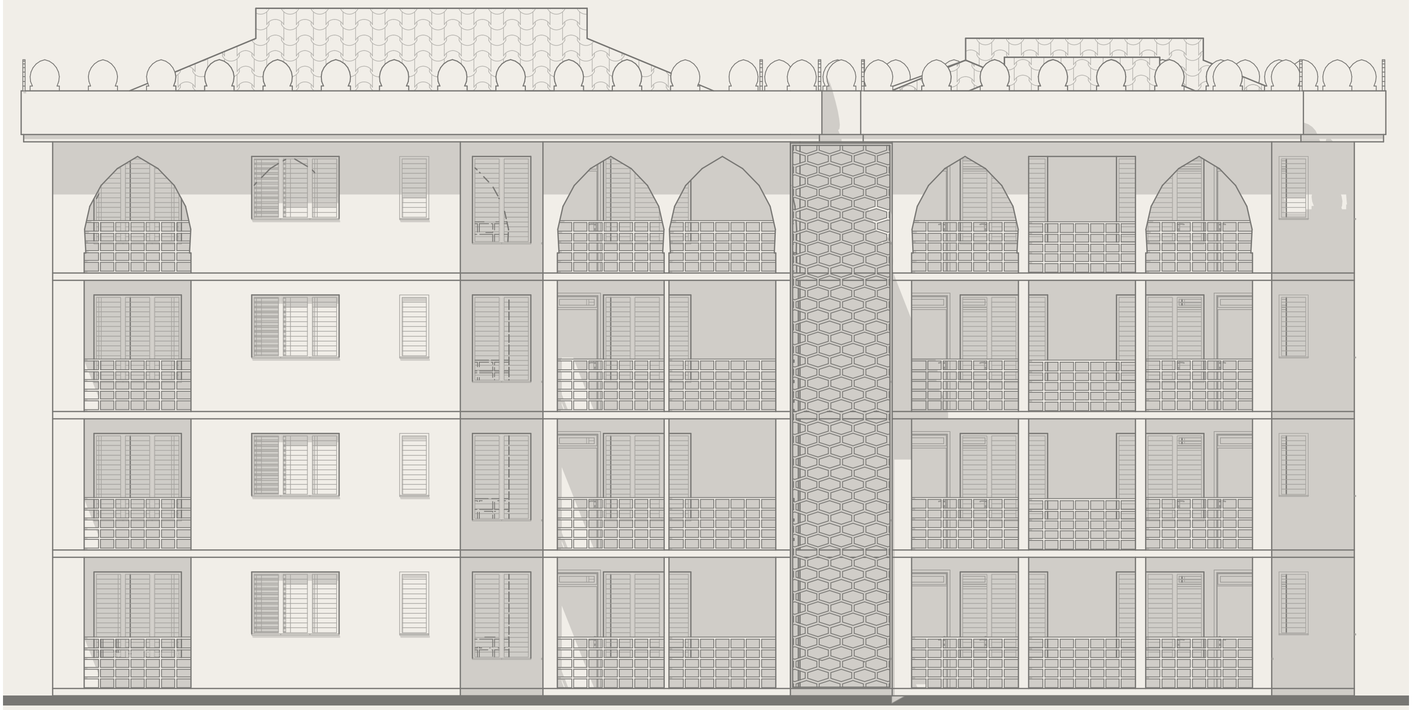
ISSUE NO. 1

The Journal of SUSTAINABLE BUILDING DESIGN

Multi-dwelling housing



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FOR A BETTER URBAN FUTURE

The Journal of Sustainable Building Design

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This publication was made possible through the financial support of the Global Environment Facility (GEF).

ACKNOWLEDGEMENTS:

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SUSTAINABLE BUILDING DESIGN

Multi-dwelling housing

UN-HABITAT

Contents

1 Introduction

Buildings have a strong potential to impact positively or negatively two important elements of everyday life: our environment and energy bills. Their contribution to climate change mitigation on greenhouse gas emission and higher or lower energy bills are directly related to the way buildings are designed in relation to the local climate and site-specific characteristics.

This journal calls for change in the way we build. It promotes creative ways to produce buildings which achieve optimum conditions for their inhabitants whilst making minimum demands on fossil-based energy. The first step in creating comfort and thermal delight in buildings is to understand the relationship between the local climate and our need for shelter. Buildings should vary with climate and thus with location.

The design of energy efficient buildings and homes depends on, solar path and solar radiation, rainfall, humidity, prevailing wind, and ambient temperature of a particular place among others. Design parameters of buildings and homes, therefore, vary with different climatic zones. Therefore, to achieve sustainable housing, it is important to build conssidering the prevailing climatic conditions.

Poor climatic design of buildings, all too often seen in 'modern' architecture, causes many buildings to overheat, even in temperate or cold climates where such problems were never faced before the advent of modern architecture. The influence of the sun should be understood and respected by designers of passive solar buildings in which the sun's free energy is used for natural lighting, heating and drying out but will not interfere with the occupants' comfort. Well-designed buildings with environmentally friendly solutions use less energy. They require lower maintenance compared to ordinary buildings and are more comfortable spaces to live in.

Designing an energy efficient built environment involves minimising the wastage of energy resources while maximising the use of passive design options and renewable energy sources. The green building (or sustainable building) is a result of a holistic approach. It is designed, constructed, and operated in an environmentally responsible way; it is resource efficient (land, water, energy, material, waste) throughout the building's life-cycle.

This journal acts as a guideline in providing applicable passive design principles for different climatic conditions that should be taken into consideration when designing in the different climates. These include:

- Site analysis
- Building orientation
- Natural ventilation
- Day lighting
- Solar shading
- Building materials
- Window sizes
- Window location
- Location of building services

Whereas sustainable buildings are directly related to local climate and site conditions, this journal is not intended to provide generic templates replicable in any part of the East African region. It aims to discuss examples and guide the user on how best to explore local climatic conditions.

Designing an energy efficient built environment involves minimising the wastage of energy resources while maximising the use of passive design options and renewable energy sources.

2

Sun Path Analysis

To understand the effects of the sun on the location and design of a building, we need to know its position in the sky at various times throughout the year. The position of the sun at noon will be higher or lower, according to the season (spring/summer/fall/winter). This will help to know the amount of light and heat that a given surface of the building envelope will receive to control the solar radiation that gets into the building.

Sun path diagrams are a convenient way of representing the sun's changing position in the sky throughout the year. The sun's position is represented with a coordinate system (altitude and azimuth). It can be read off directly from the diagram for any time of the day and month. This is useful in providing a summary of the solar position that should be considered when designing.

The most used systems are the polar and the cylindrical sun path diagrams.

Polar sun path diagram: The polar representation gives the image of the celestial sphere by placing itself right above the zenith (the point of the sky directly overhead) of the place under consideration.

In this type of representation, lines of equal solar altitude are spaced widely apart near the zenith of the sky, but are concentrated quite closely together near the horizon.

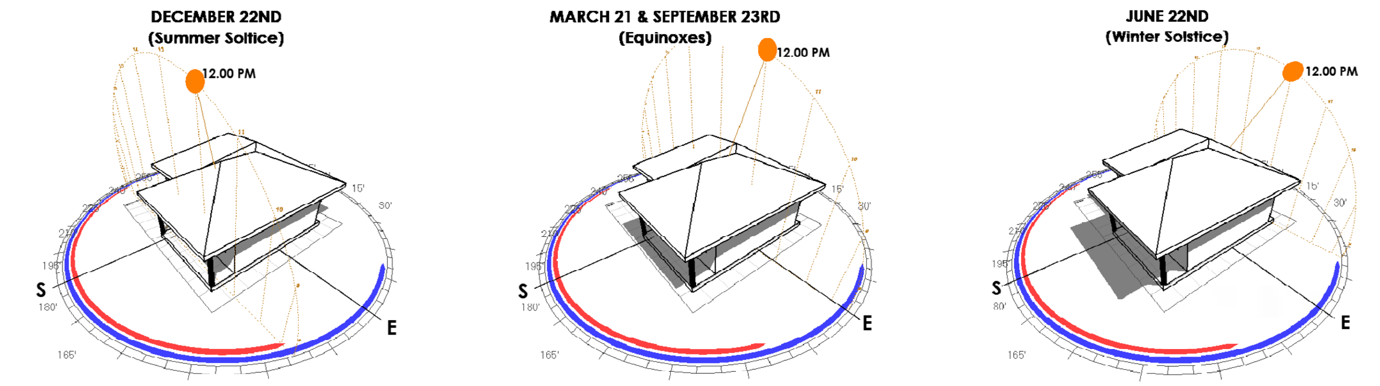
The generation of each sun-path line is done by determining the exact position of the sun as it passes through the sky (hourly) for each date. This is then projected from the sky dome onto the flat image.

Reading the Position of the Sun (altitude and azimuth):

1. Select the chart of the correct latitude (each location has a different chart).
2. Select one date line to be analyzed.
3. Select the hour line and mark its intersection with the date line.
4. Read from the concentric circles the altitude angle (sun height from the ground also known as solar altitude).
5. Lay a straight line from the center of the chart, through the marked time point to the outer circle and read the azimuth angle (sun orientation related to the north).

To access the optimal building orientation, place the building plan in the center of the diagram, aligning it with the orientation under consideration.

Figure 1: Position of the Sun at different times of the year for Latitude 0°

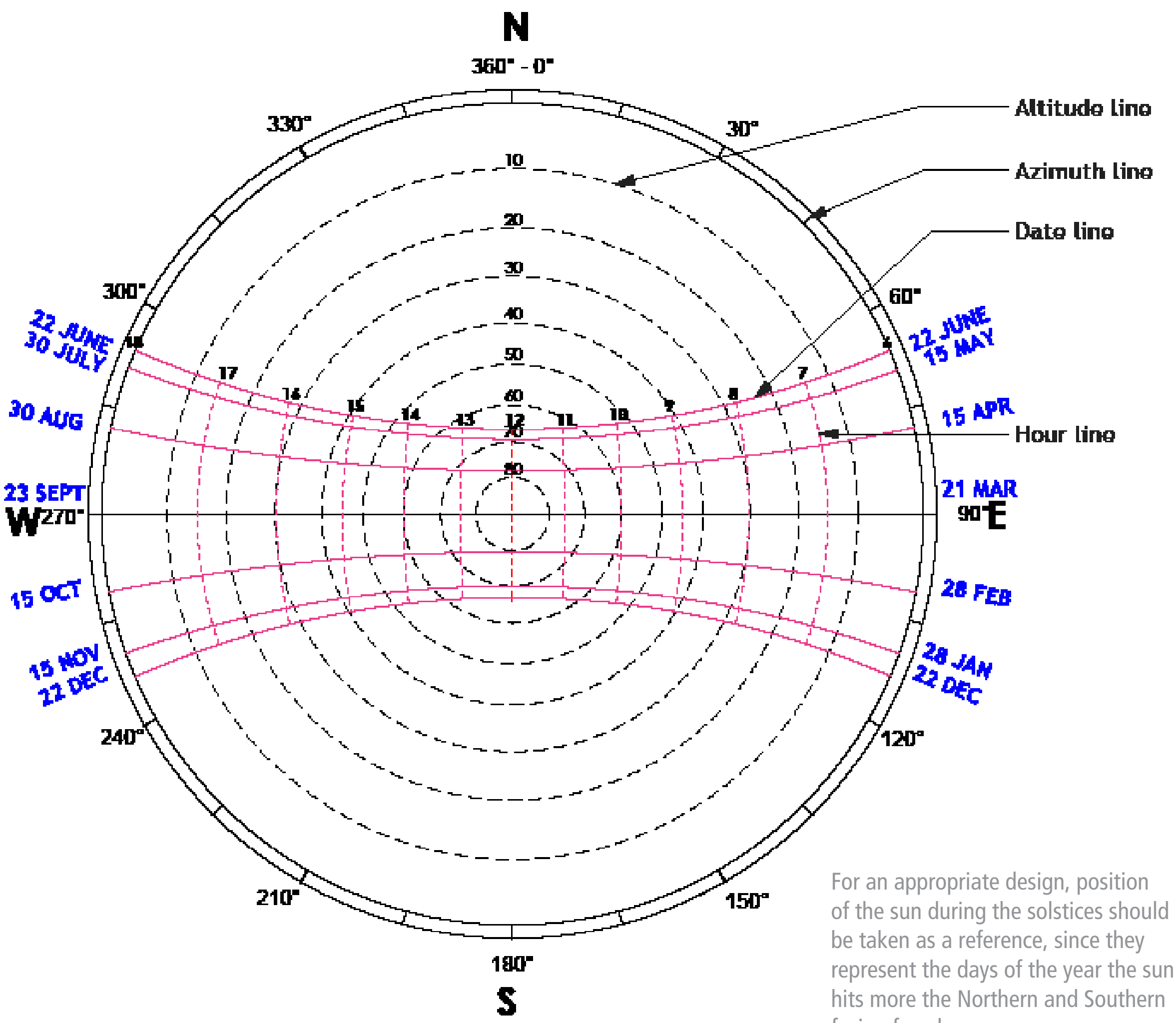


After September equinox the sun's path gradually drifts southwards. By December 22, it rises south of east and sets at the south of west.

During these dates, the sun's path follows the celestial equator and rises directly east and sets directly west.

After March equinox, the sun's path gradually drifts northward. By June 21 it rises due north of the east and sets due north of west.

Figure 2: Polar sun path diagram for Latitude 0° (E.g. Eldoret town 0°31’N 35°17’E)



For an appropriate design, position of the sun during the solstices should be taken as a reference, since they represent the days of the year the sun hits more the Northern and Southern facing facades.

3

Sun Shading

The most significant factor affecting the built environment in the East Africa region is solar radiation which impacts on it throughout the year. Buildings and space shapes have a significant impact on indoor temperatures. When designing a new building, it is very important to pay attention to the needs of its users and consider the environment they are most likely to spend most of their time in. The building should be user friendly and comfortable. Factors to be considered for adequate indoor comfort are daylight, room temperature and indoor air quality.

The implementation of sun shading devices is one of the passive strategies needed to improve indoor thermal conditions during sunny conditions. Appropriate and well-designed sun shading devices can dramatically affect indoor conditions by controlling indoor illumination from daylight, solar heat gains and glare while at the same time maintaining view out through windows, thus saving thermal energy, lighting and maintaining visual comfort.

To size the sun shading device a Sun Path Diagram (figure.2) should be used to find the solar altitude and azimuth angles for any given time. To do this, choose the sun path diagram with the latitude closest to the site. Find the intersection of the two curves corresponding to the month and hour of interest. From this point, read the solar altitude and azimuth angles. This is the sun's position at that month and hour.

External sun shading devices are the most effective way of controlling solar heat gain through glazed areas in buildings. These can either be devices attached to the building envelope or extensions of the envelope itself. An external sun shading system has the advantage of blocking the solar radiation before it penetrates buildings, but has the disadvantage of exposure to the climatic elements for maintenance. The size and position of these external shading elements can be calculated so as to cover all glazed areas or windows on the most problematic hours i.e. 9.00 am to 4.00 pm. This reduces energy consumption for cooling of buildings.

It is important to make sure that sun shading devices do not cause glare.

Types of external sun shading devices.

There are 3 types of sun shading devices namely:

1. Horizontal
2. Vertical
3. Eggcrate

Figure 3: Horizontal overhangs along north and south facing elevations cut out unwanted solar radiation

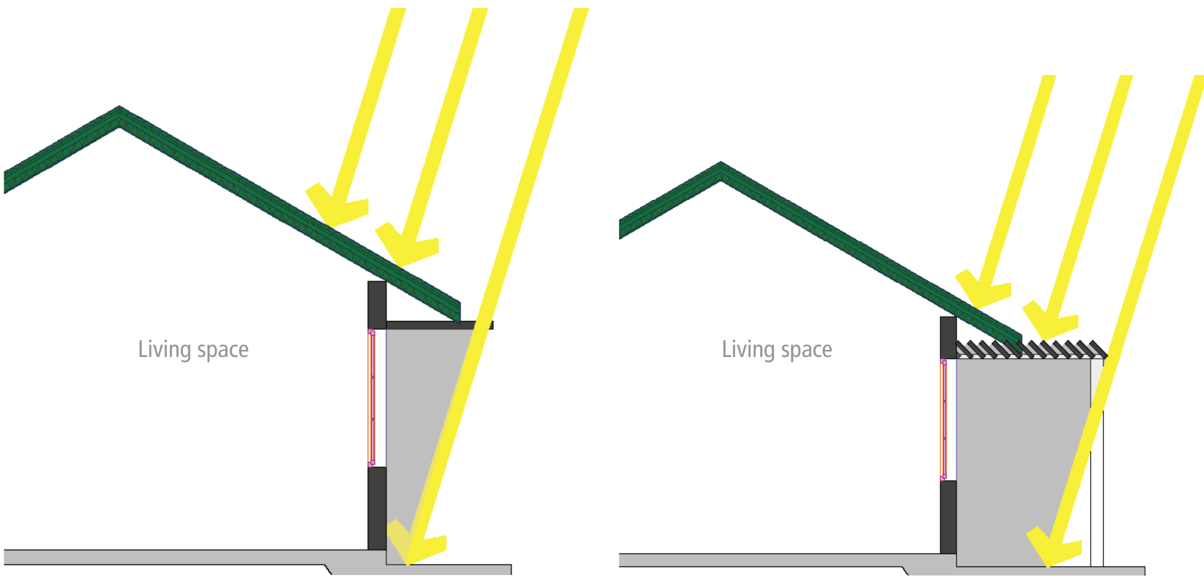
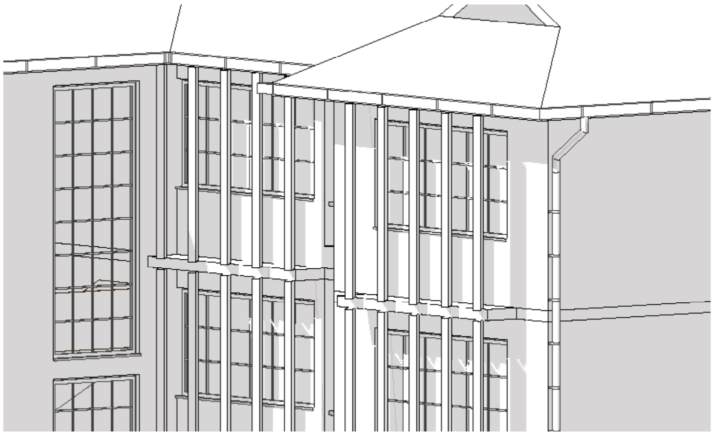


Figure 4: Vertical sun shading devices are more effective along east and west orientations

Shading elements on the east and west should be vertical. These are best against the low morning and afternoon sun respectively.



1. **Horizontal:**
These include

a) **Roof Overhangs:** The most natural type of sun shading is roof overhangs, which is also one of the traditional sun shading ways that has been standardised by time. Roof overhangs provide effective shading for walls directly under the eave when the sun is high in the sky.

b) **Overhang shading device:** This shading device is simply a solid horizontal projection located at the top exterior of a window or row of windows. It performs just like the roof overhang in that it provides shade against the high sun to the wall surfaces directly under the overhang. This type of overhang is best suited where the roof overhangs' shade does not reach far enough or is impractical like in the case of multi storey buildings.

c) **Shading devices in front of windows:** In some cases, placing shading devices in front of windows is more efficient than using overhangs. Usually, these devices are placed in front of the glazing. If placed correctly, they act as sun blockers and reflectors of solar radiation if the materials used are made of reflective materials.

d) **Balconies:** These have the same effect as horizontal overhangs. They are deep enough to provide significant shading even if they do not face in a northerly or southerly direction. In addition to providing shade, they also provide major additional value as usable space and as an ambiance feature.

2. **Vertical shading:** Vertical fins serve well toward the near east and near west orientations. They are essential to stop the low angled sun heating the walls i.e. early morning and evening sun and penetrating inside the home and therefore significantly reducing the amount of heat absorbed by the building.

- **Egg crates:** Egg crate types are combination of horizontal and vertical shading devices. They are the most effective shading devices in hot climates. They are usually in the form of grill blocks or decorative screens.

Figure 5: Horizontal louvres on vertical plane

4

Case Studies

Appropriate and well-designed sun shading devices can dramatically affect indoor conditions such as indoor illumination from daylight, solar heat gains and glare.

CASE STUDY 1

CLIMATIC ZONE 1:
Hot and Humid climate

Multi dwelling housing

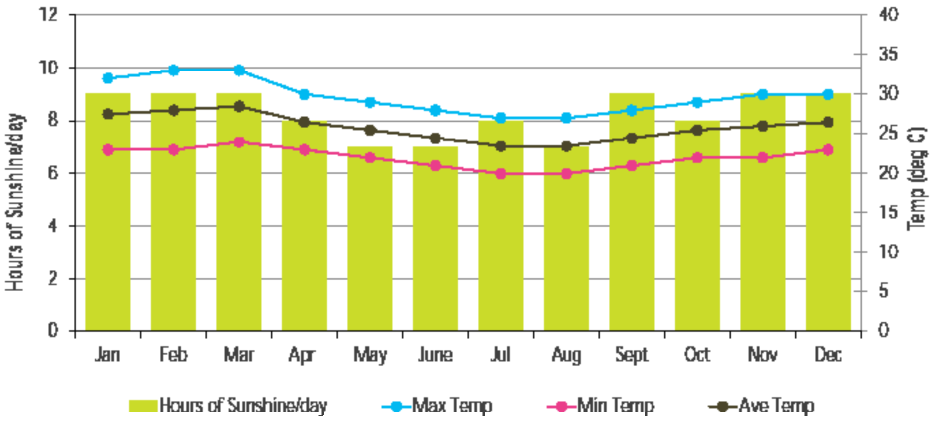
Climatic Zone 1: Hot and Humid climate

Location	Mombasa, Kenya
Latitude	4°03’S
Longitude	39°40’E
Altitude	55 m above sea level
Temperature	Min average temp 26.3°C; Max average temp 33°C
Annual Rainfall	Average 1083.2 mm
Humidity	Average relative humidity is 77.6%
Prevalent Wind Direction	South and East prevailing winds

Both day and night temperatures in this zone are high.

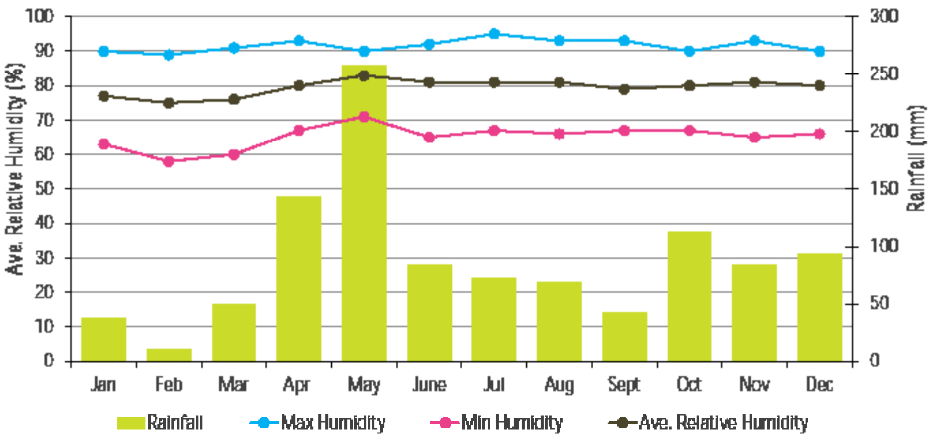
The annual mean maximum temperature is 32.6 °C and an annual mean minimum of 21.8 °C.

Figure 6: MOMBASA (Hours of Sunshine / Temperature)



The humidity levels are equally high throughout the year.

Figure 7: MOMBASA (Relative Humidity / Rainfall)



The principal wind direction is from the east direction during the North East monsoon period (December - February) and from the south during the South East monsoon period (April - October).

The wind direction and speed are very important for natural ventilation for cooling.

Figure 8: Prevailing wind direction

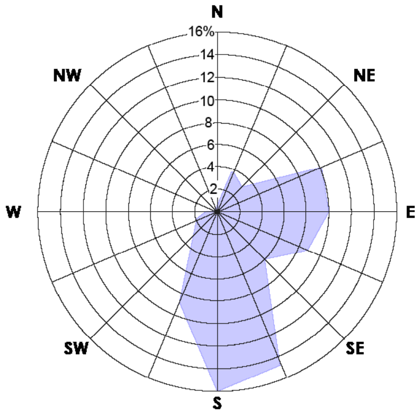
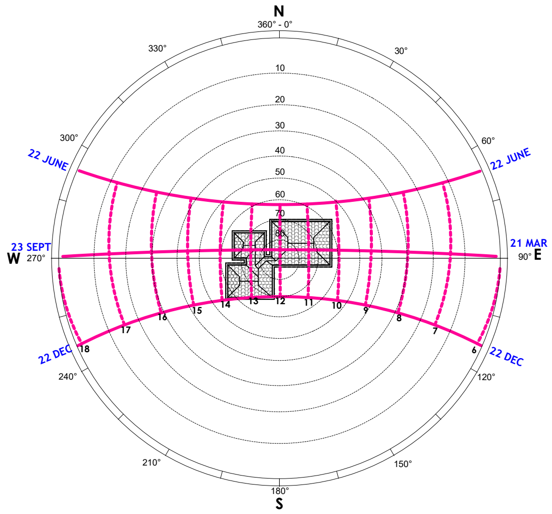


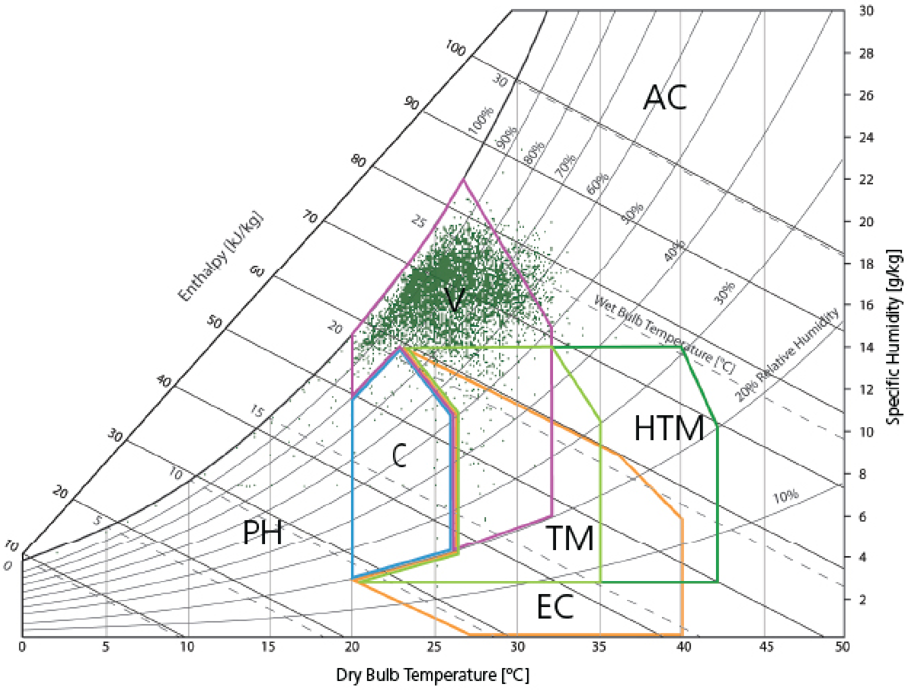
Figure 9: Sun path Diagram for Latitude 4° South

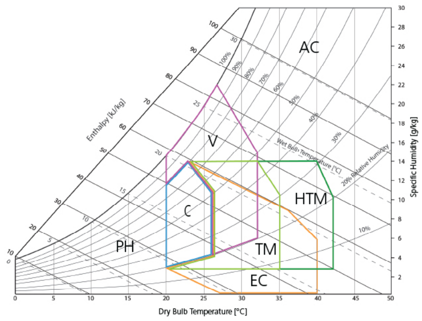


The principal wind direction is from the east direction during the North East monsoon period (December - February) and from the south during the South East monsoon period (April - October).

The wind direction and speed are very important for natural ventilation for cooling.

Figure 10: Psychrometric Chart with weather data for Mombasa





LEGEND

C	Comfort Zone
V	Ventilation
TM	Thermal Mass
HTM	High Thermal Mass
EC	Evaporative Cooling
PH	Passive Heating
H	Artificial Heating
AC	Air Conditioning

INTERPRETATION

- The prime design objective for this zone is to provide free air movement through the house while preventing internal temperature rising above the outdoor shade temperature.
- Natural ventilation and sun shading are the most effective passive design strategies for improving thermal comfort.
- Cross ventilation strategies should be adopted to improve the indoor thermal comfort, with each room having windows for ventilation on opposite sides.
- Buildings should be lightweight with minimum possible thermal storage capacity. They should be oriented with the long axis running east-west and window openings on the North and South facing facades.
- Air conditioning may be necessary to provide comfortable indoor conditions by cooling the air during high day temperatures and humidity levels during certain periods of the year.

CLIMATIC ZONE 1:
Hot and Humid climate

CASE STUDY 1

Multi dwelling housing

Figure 11: Site Plan

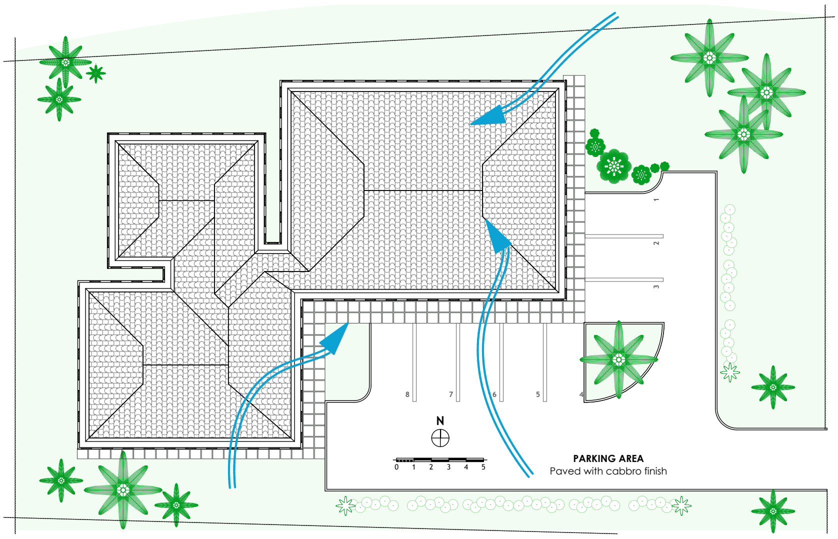


Figure 12: Typical Floor Plan

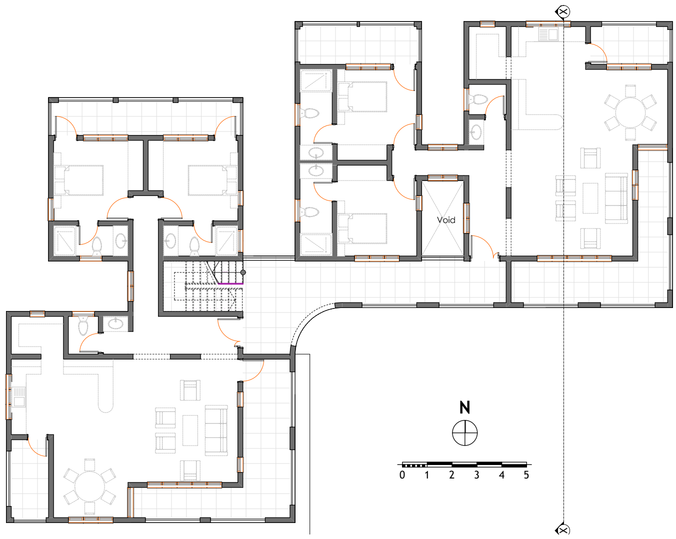


Figure 13: Position of the Sun at different times during the equinox

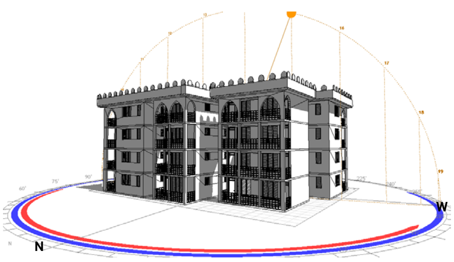
March 21st at 9.00 a.m.

Deep verandah on the eastern side protects openings from the low morning sun.

March 21st at 12.00 p.m.

At noon, the sun is overhead. The north and south facing openings are completely shaded using deep balconies and overhang at the top level.

March 21st at 3.00 p.m.



West facing walls are devoid of any major windows. This minimizes solar radiation by the low afternoon sun into the building.

Figure 14: North Elevation

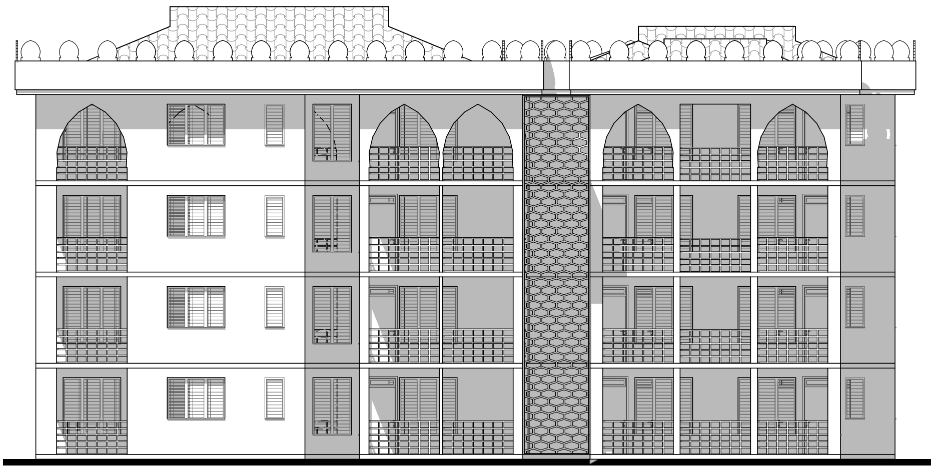


Figure 15: East Elevation

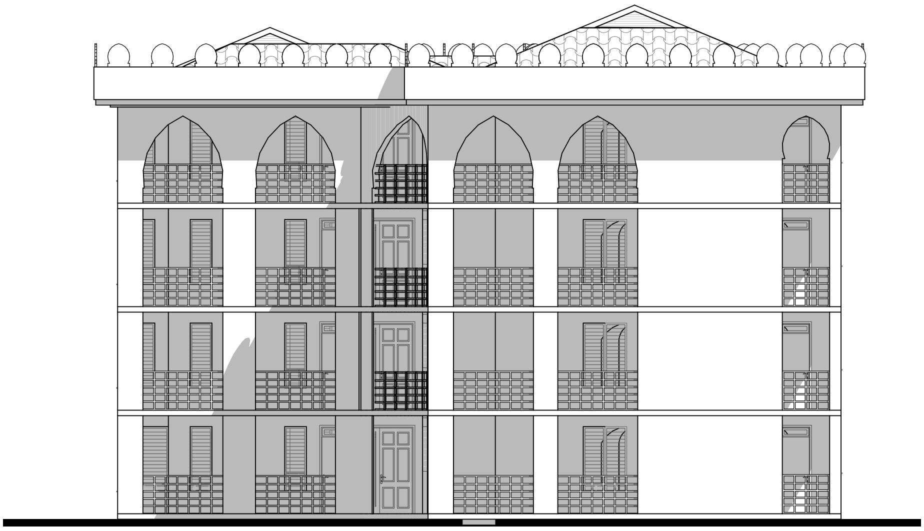


Figure 16: Section X-X showing cross ventilation

DESIGN RESPONSES

1 Orientation - This L-shaped apartment block is correctly oriented with the major façades facing the North-South direction.

2 Ventilation - To achieve cross ventilation, louvered windows have been provided in all rooms. Permanent ventilation vents have been provided on all openings. In addition, there are openings in the roofs to provide ventilation of accumulated hot air in the roof space. The open plan of the aids in cross ventilation.

3 Daylighting - Provision of large windows in the major spaces ensures that the rooms are adequately lit naturally during the day.

4 Sun shading - Windows on the North and South facing façades are provided with deep balconies to generate mid-day shade to the respective rooms and to provide cool outdoor living spaces. The upper floor windows have been shaded by horizontal overhang. Major windows have been avoided on the western and eastern facing walls. In case of windows on East and West facing façades, they must be fully sun shaded.

5 Building materials - Lightweight walls and roof with external reflective surfaces have been used to allow internal heat to quickly dissipate to the outside and to reflect unwanted solar radiation.

CLIMATIC ZONE 2:
Hot semi-arid / Savannah climate

Multi dwelling housing

Climatic Zone 2: Hot semi-arid / Savannah climate

Location	Makindu, Kenya
Latitude	2°28'S
Longitude	37°83'E
Altitude	1000 m above sea level
Temperature	Min average temp 16.1°C; Max average temp 28.3 °C
Annual Rainfall	Average 641 mm
Humidity	Average relative humidity is recorded at 68%
Prevalent Wind Direction	East Prevailing winds

Figure 17: MAKINDU (Hours of Sunshine / Temperature)

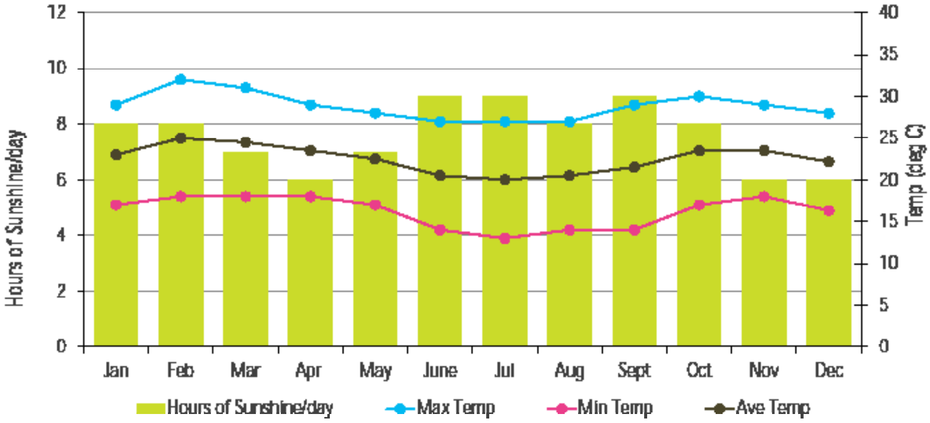


Figure 18: MAKINDU (Relative Humidity / Rainfall)

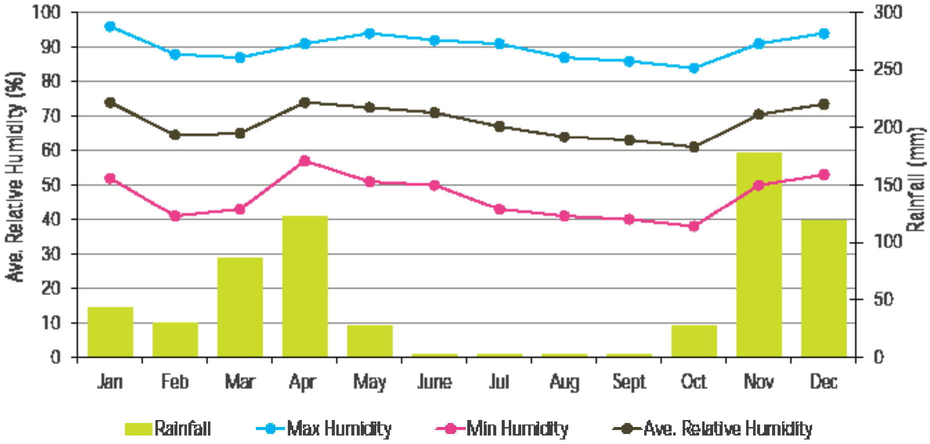


Figure 19: Prevailing Wind Analysis

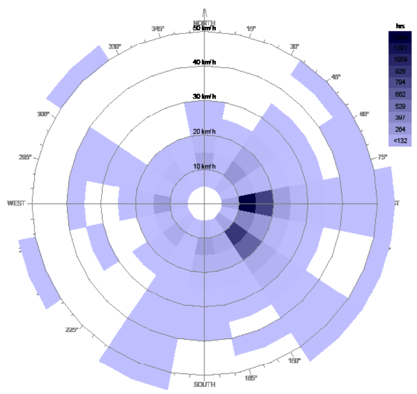


Figure 20: Sun path Diagram for Latitude 2° S

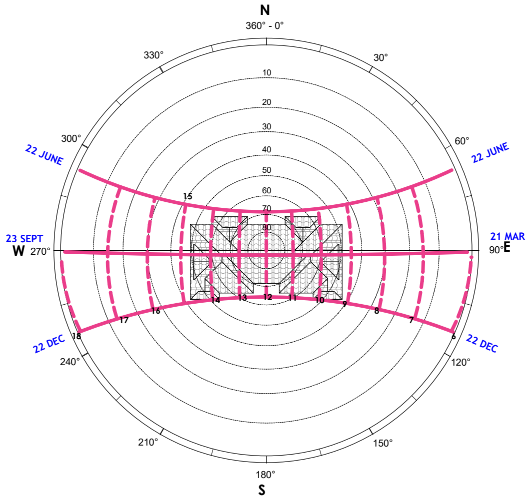
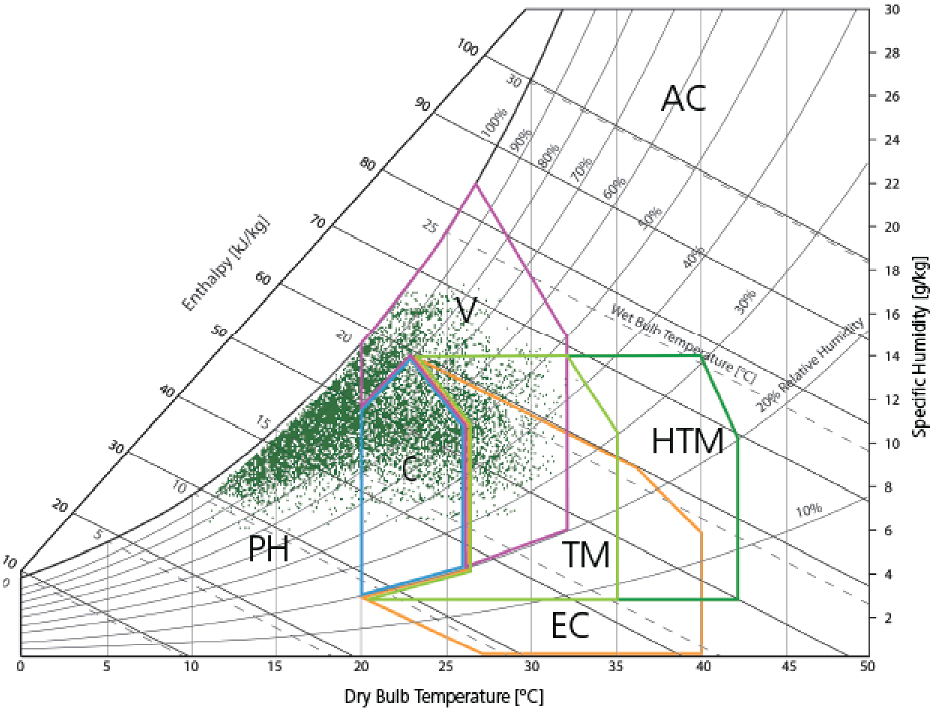
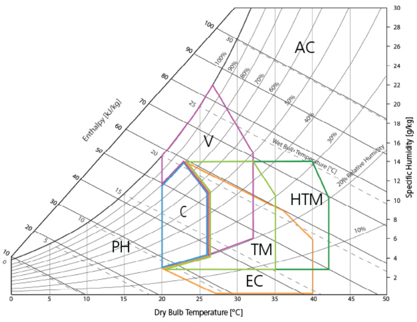


Figure 21: Psychrometric Chart with weather data for Makindu





LEGEND

C	Comfort Zone
V	Ventilation
TM	Thermal Mass
HTM	High Thermal Mass
EC	Evaporative Cooling
PH	Passive Heating
H	Artificial Heating
AC	Air Conditioning

INTERPRETATION

- Both temperature and humidity levels fall within the comfort zone for most periods of the year.
- Natural ventilation, high thermal mass and solar shading are the most effective passive design strategies for improving thermal comfort.
- Heavy weight walls are preferable in this zone to prevent heat gain during daytime due to the large time lag.
- At night, passive heating through thermal mass are appropriate ways to maintain thermal comfort inside the building.
- Buildings should be oriented with the long axis running east-west to provide effective shading.

CLIMATIC ZONE 2:
Hot semi-arid / Savannah climate

CASE STUDY 2

Multi dwelling housing

Figure 22: Site Plan

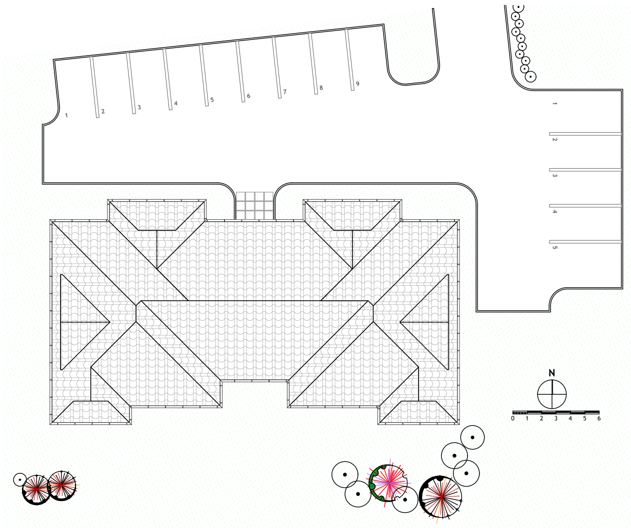


Figure 23: Typical Floor Plan

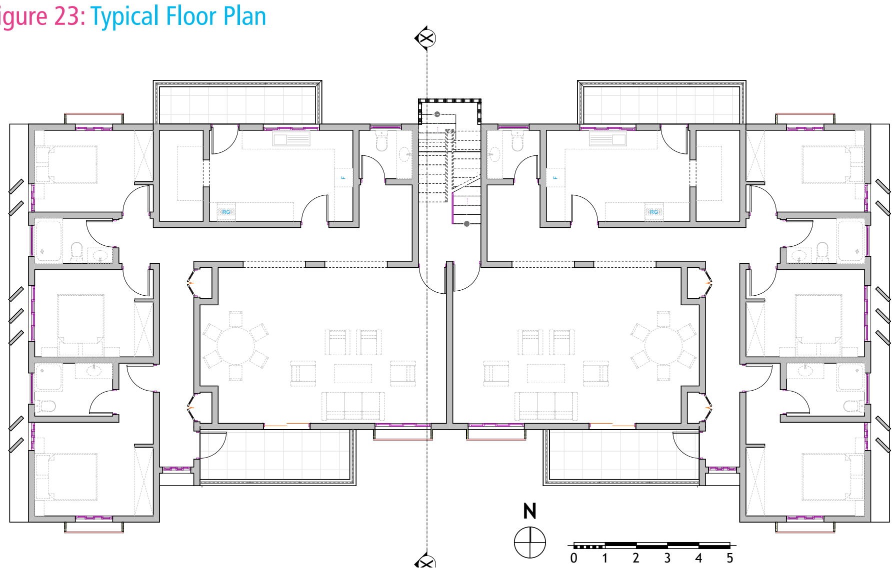
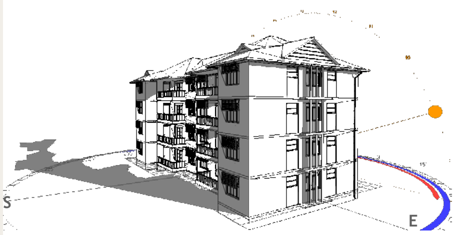


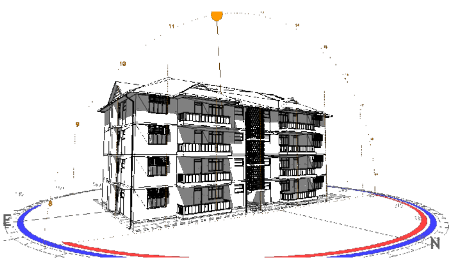
Figure 24: Position of the Sun at different times during the winter solstice

June 22nd at 9.00 a.m.



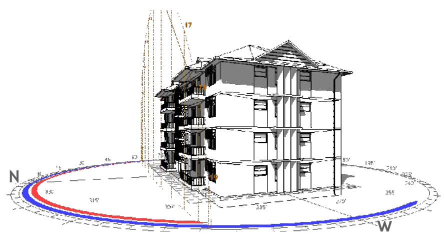
The oblique vertical sun shading devices protects the major windows on the eastern facing walls against the low morning sun.

June 22nd at 12.00 p.m.



The balconies, roof overhang and horizontal louvers on a vertical plane provide shading to the northern facing openings against the high mid-day sun.

June 22nd at 3.00 p.m.

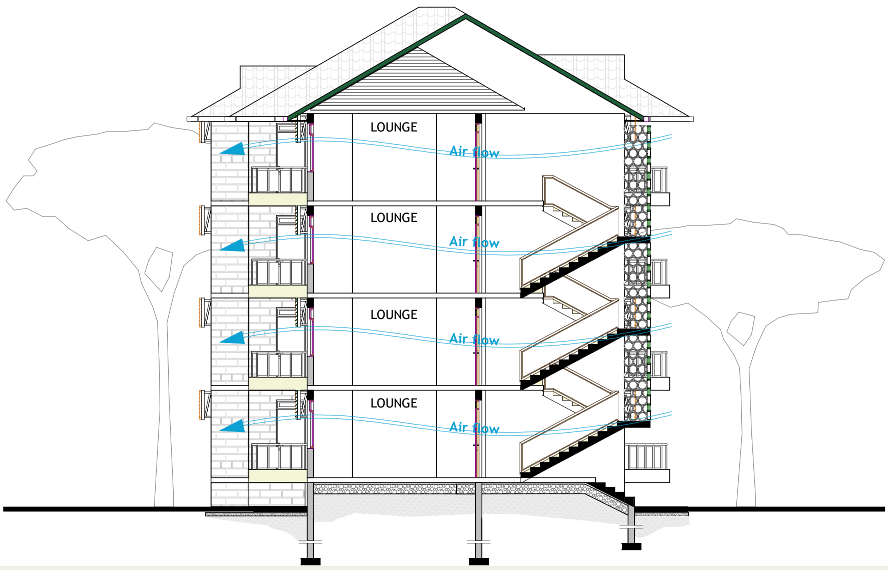


The oblique vertical sun shading devices protects the major windows on the western facing walls against the low and intense afternoon solar radiation.

Figure 25: North Elevation

Figure 26: West Elevation

Figure 27: Section X-X showing cross ventilation



DESIGN RESPONSES

1 **Orientation** - The building's major axis is optimally oriented along the east-west axis.

2 **Ventilation** - All the rooms are naturally ventilated through the windows and the permanent ventilation provided at the roof level through timber louvres.

- The staircase external walling is made of hollow concrete vent blocks which guarantee optimum ventilation and natural lighting.

- Roof vents enable air movement and heat release by stack ventilation.

3 **Daylighting** - All the rooms are naturally lit during through the windows. This eliminates artificial lighting during daytime thus reduces energy consumption. During the cold months, the openings on the East and West facing walls contribute to warm the building through heat gain from the morning and afternoon sun respectively.

4 **Sun shading** - North- and South-facing windows are protected from the high mid-day sun by the provision of balconies, horizontal sun shading elements above the windows and also roof overhangs at the top level.

- Windows on the East-and West-facing windows are minimized and appropriate oblique vertical sun shading elements provided to avoid unwanted solar gains by the early morning and late afternoon sun during the hot months.

- During the cold season, these windows are instrumental in letting in some heat to warm up the houses.

5 **Building materials** - High thermal mass materials are recommended as they store heat and regulate indoor temperatures during both the hot and cold seasons.

CLIMATIC ZONE 3:
Hot arid climate

Multi dwelling housing

Climatic Zone 3: Hot arid climate

Location	Garissa, Kenya
Latitude	0°26'S
Longitude	39°38'E
Altitude	147 m above sea level
Temperature	Min av. temp 22.81°C; Max av. temp 35.84°C
Annual Rainfall	Average 415 mm
Humidity	Average relative humidity is 62%
Prevalent Wind Direction	South prevailing winds

Figure 28: GARISSA (Hours of Sunshine / Temperature)

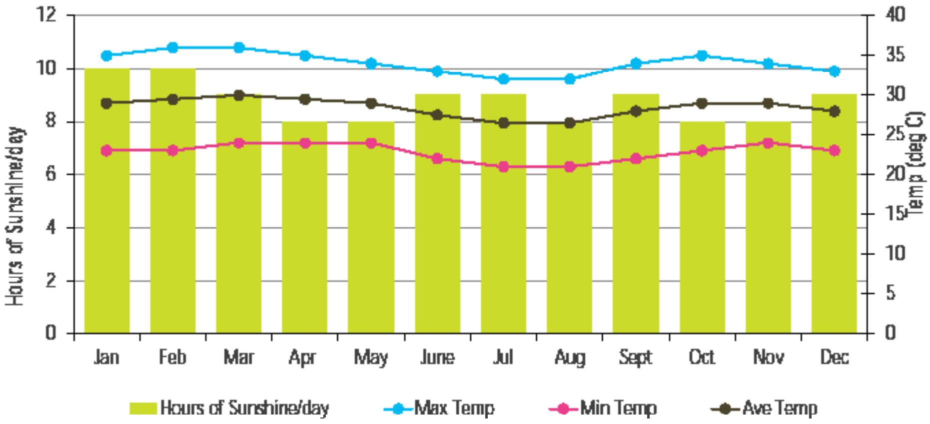


Figure 29: GARISSA (Relative Humidity / Rainfall)

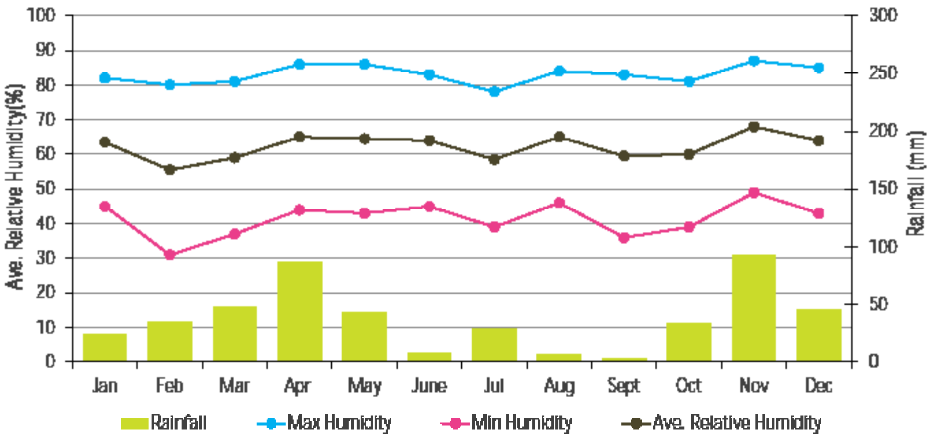


Figure 30: Prevailing Wind Analysis

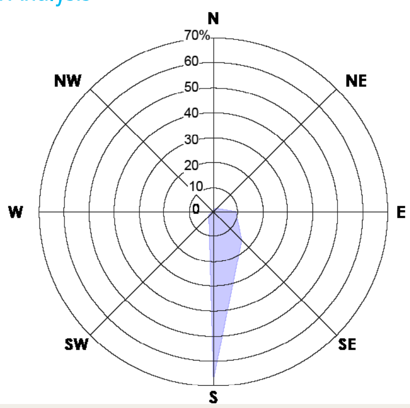


Figure 31: Sun path Diagram for Latitude 0° South

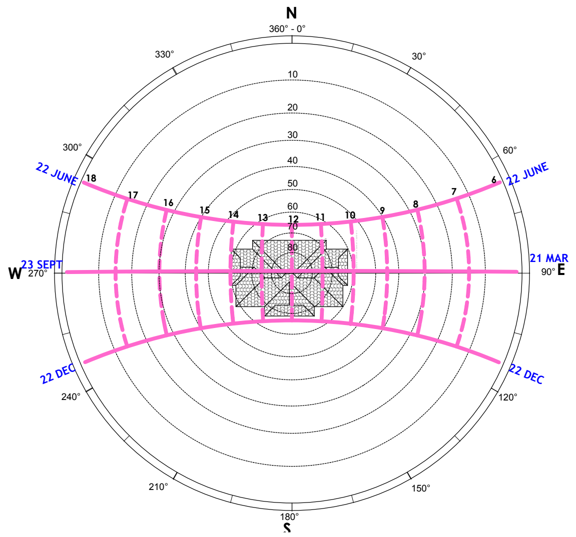
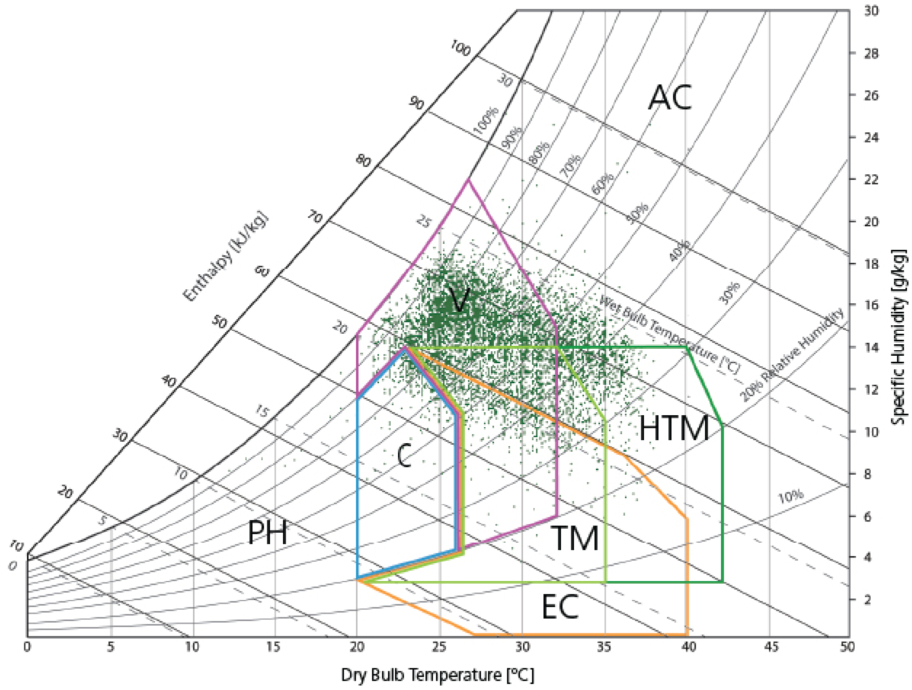
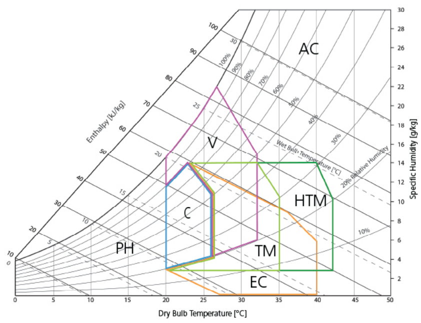


Figure 32: Psychrometric Chart with weather data for Garissa





LEGEND

C	Comfort Zone
V	Ventilation
TM	Thermal Mass
HTM	High Thermal Mass
EC	Evaporative Cooling
PH	Passive Heating
AH	Artificial Heating
AC	Air Conditioning

INTERPRETATION

- Days in this zone are invariably hot. High daytime temperatures are accompanied by moderate to low humidity levels.
- Due to the high daily temperature variation or diurnal range, it is best to keep heat out during the day and ventilate during the night i.e. night ventilation.
- Natural ventilation (night ventilation), high thermal mass, solar shading and evaporative cooling are the most effective passive design strategies for improving thermal comfort.
- The maximum temperatures in some months are outside the high thermal mass area, thus additional air conditioning means may be required to provide adequate thermal comfort indoors during the day.
- High thermal mass for walls and roofs prevents overheating during daytime while natural ventilation combined with evaporative cooling relieves heat delivered by the heavy structures at night.
- Buildings should be compact and oriented with the long axis running East-West to provide effective sun shading.

CLIMATIC ZONE 3:
Hot arid climate

Multi dwelling housing

Figure 33: Site plan

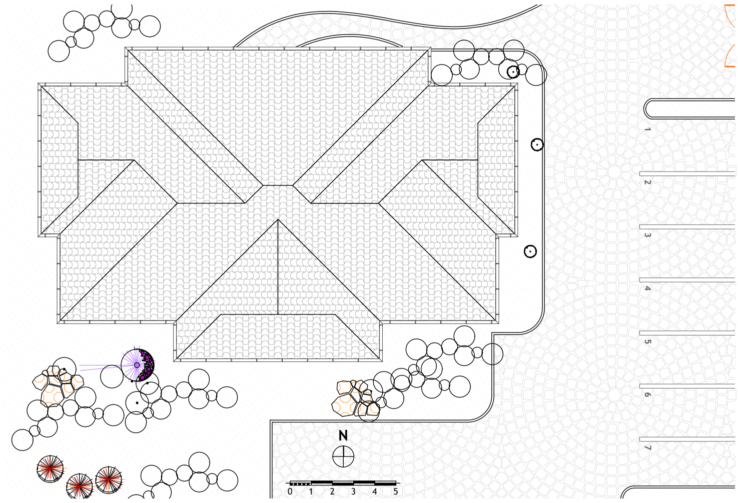


Figure 34: Typical floor plan

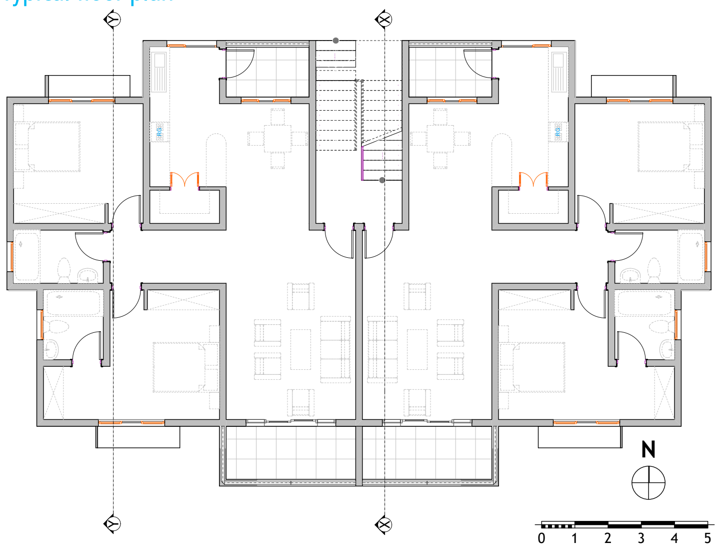
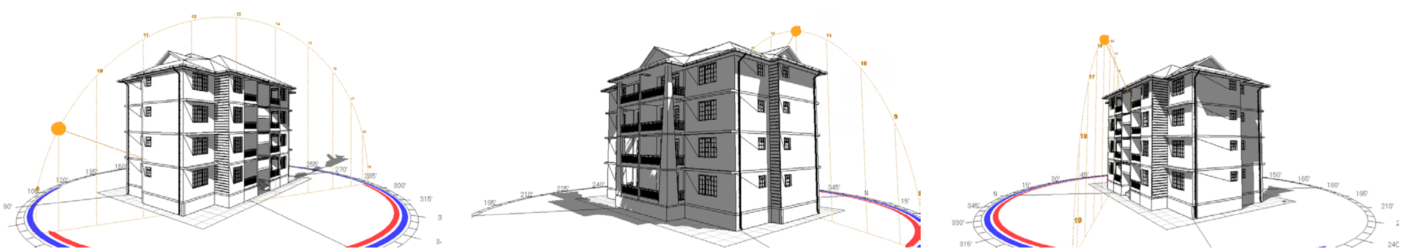


Figure 35: Position of the Sun at different times during the winter solstice

June 22nd at 9.00 a.m. | June 22nd at 12.00 p.m. | June 22nd at 3.00 p.m.



At this time of the year, the sun rises due north of east. The north facing walls are shaded by horizontal window overhangs and balconies against the overhead sun.

The south facing walls are not exposed to direct solar radiation at this time of the year.

The sun sets due north of west exposing the north west and west facing walls exposed to the sun. Balconies and horizontal window overhangs provide shade against the afternoon solar radiation.

Figure 36: South Elevation

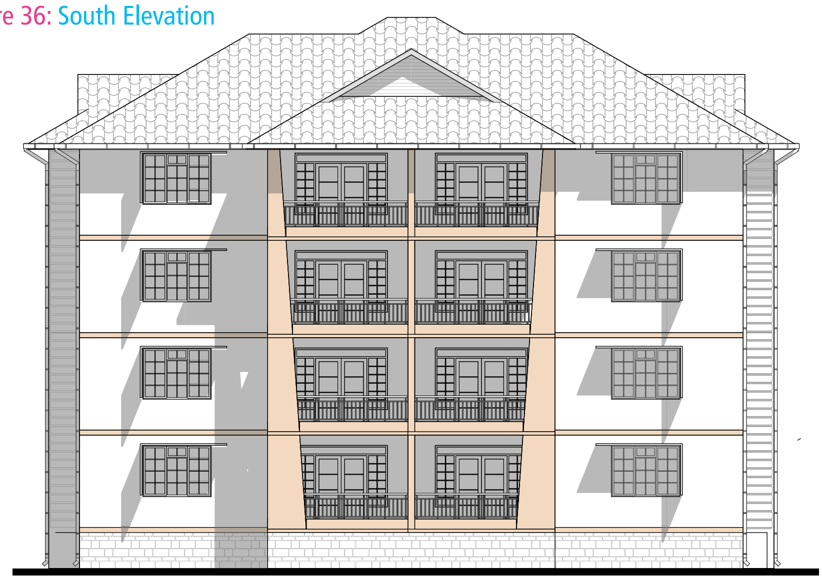
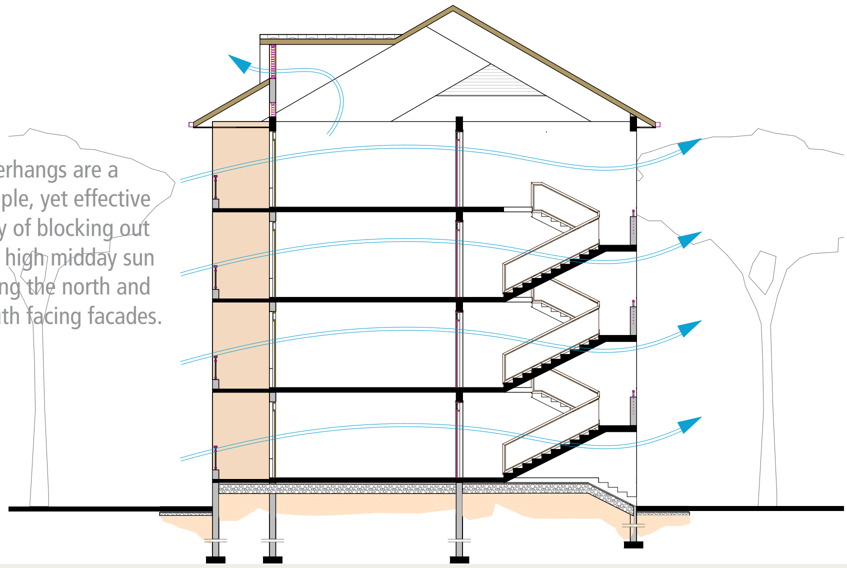


Figure 37: West Elevation

By maximizing north- and south-facing glass and minimizing east- and west-facing glass, energy performance is greatly enhanced, comfort conditions are improved, and initial costs associated with cooling are reduced.

Figure 38: Section X-X showing cross ventilation

Overhangs are a simple, yet effective way of blocking out the high midday sun along the north and south facing facades.



DESIGN RESPONSES

1 **Orientation** - This apartment block is elongated along the East-West axis and narrow on the North-South axis with the main openings along these facades.

- Coupled with the compact design, this orientation ensures heat gain is minimized.

2 **Ventilation** - Openings have been carefully aligned to take advantage of the prevailing winds and thus aid in cross ventilation.

- Openings in the East and West facades are restricted to the bathrooms, the rest of the walls on these facades are predominantly solid.

- The roof space is adequately ventilated via the permanent roof vents where hot air rises and escapes through.

3 **Day lighting** - The East-West orientation of this block exposes the major openings to the North-South direction thus minimizing on the heat gain and at the same time, due to the narrow North - South axis, maximizing on daylighting.

4 **Sun shading** - Walls and openings on the North-South facing facades are shaded by balconies, large roof and window overhangs so designed to exclude the high mid-day sun.

- Landscaping through indigenous vegetation is highly recommended to create cooling through evapotranspiration, very effective in the hot and dry climate.

5 **Building materials** - This climate experiences high daily (diurnal) temperature range and thus construction materials with high thermal mass are recommended. These absorb heat during the day and thus reduce internal temperature resulting in comfortable temperatures without the need for supplementary cooling.

Multi dwelling housing

CLIMATIC ZONE 4: Upper Highland climate

Climatic Zone 4: Upper Highland climate

Location	Eldoret, Kenya
Latitude	0°31'N
Longitude	35°17'E
Altitude	2,073 m above sea level
Temperature	Min average temp 13°C; Max average temp 21.5°C
Annual Rainfall	Average 1,219 mm
Humidity	Average relative humidity is recorded at 68%
Prevalent Wind Direction	Eastern prevailing winds

Figure 39: ELDORET (Hours of Sunshine / Temperature)

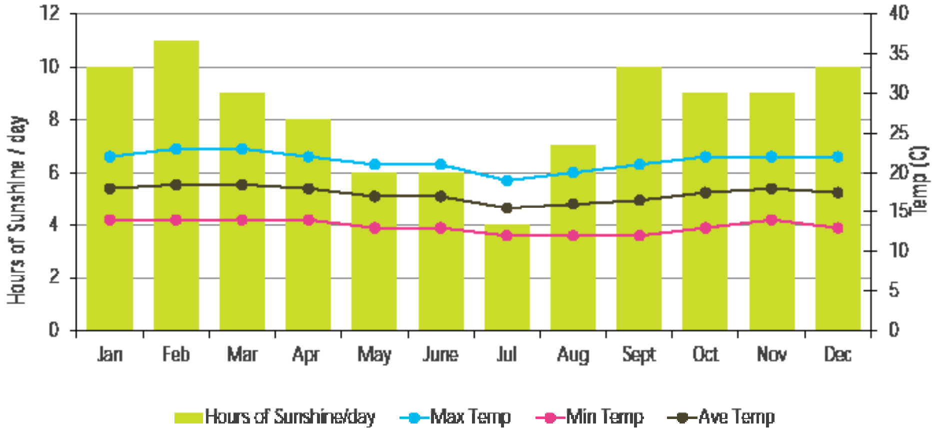


Figure 40: ELDORET (Relative Humidity / Rainfall)

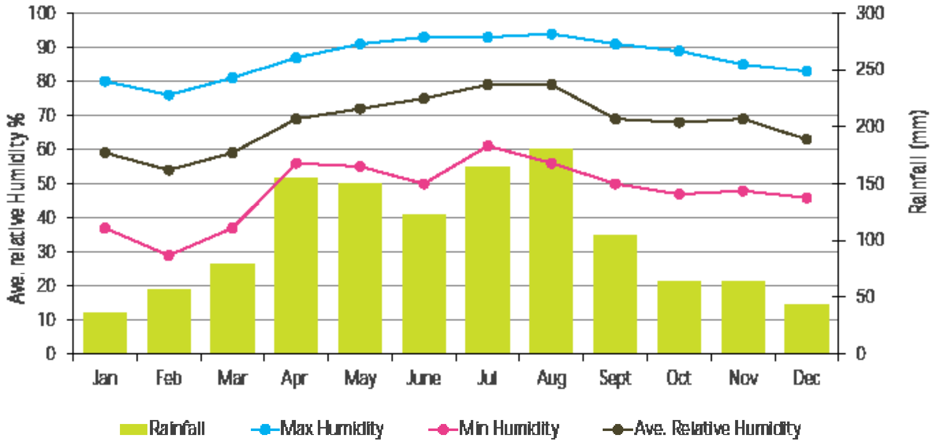


Figure 41: Prevailing wind direction

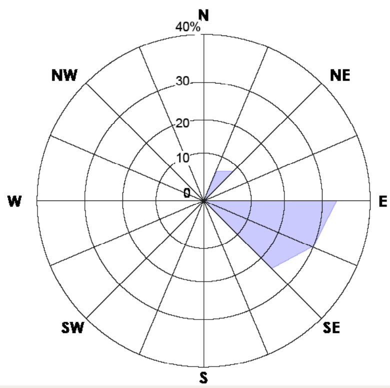


Figure 42: Sun path Diagram for Latitude 0°

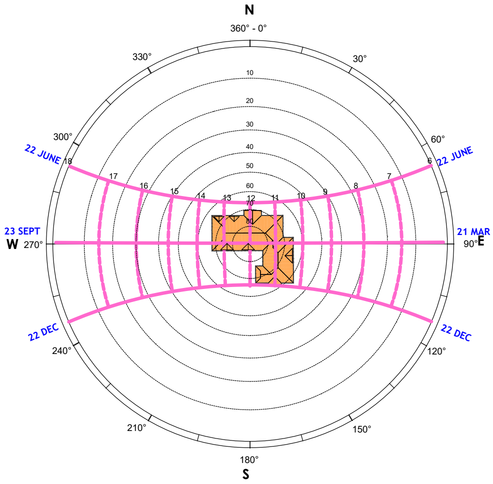
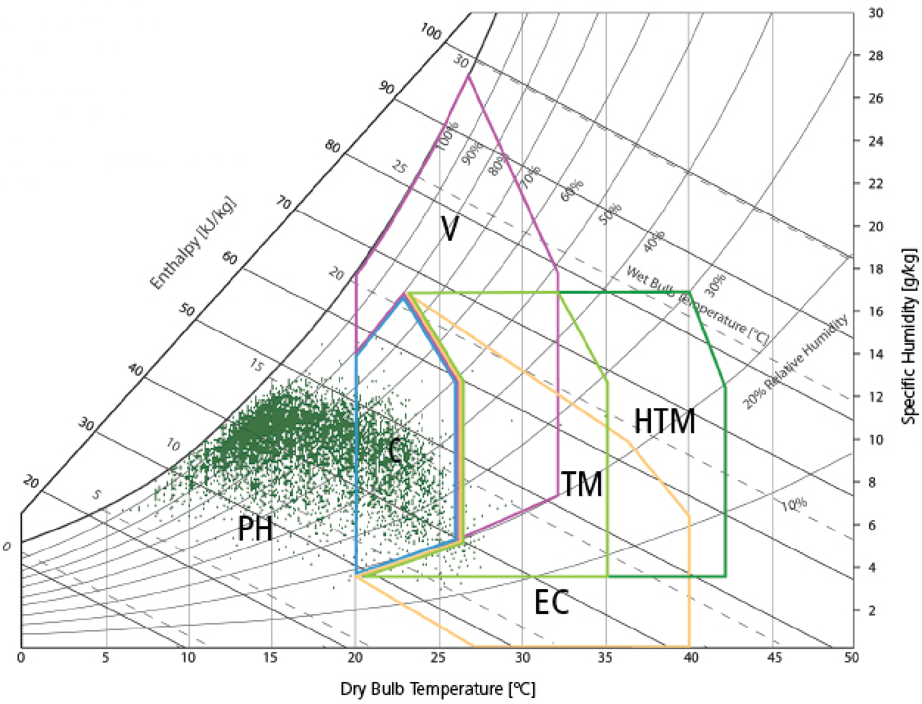
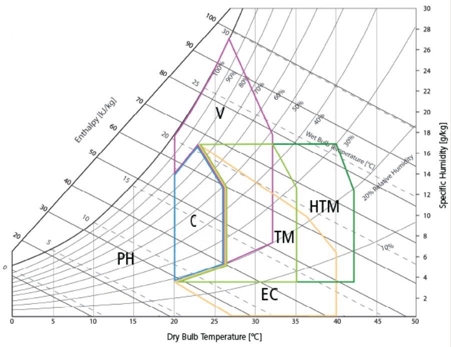


Figure 43: Psychrometric Chart with weather data for Eldoret





LEGEND

C	Comfort Zone
V	Ventilation
TM	Thermal Mass
HTM	High Thermal Mass
EC	Evaporative Cooling
PH	Passive Heating
AH	Artificial Heating
AC	Air Conditioning

INTERPRETATION

- Extremes of temperatures in this zone rarely rise above the upper limits of the comfort zone although they regularly drop below the lower limits.
- Passive heating and high thermal mass are the most effective design strategies for improving on the thermal comfort.
- Due to low temperatures, some passive heating (e.g. by sunshine) is welcome during the cold period of the year.
- Natural ventilation is important for indoor comfort. Nevertheless, air temperature rarely exceeds the upper limit of the comfort zone.
- Thick walled structures are recommended in order to limit the heat admitted to interiors during hours of strong sunshine, and to store some of the day's heat so it may be re-emitted to interiors during the cold nights.
- Buildings should be oriented with the long axis running East-West to minimise exposure to the sun as it moves from sunrise to sunset.

CLIMATIC ZONE 4:
Upper Highland climate

Multi dwelling housing

Figure 44: Site plan

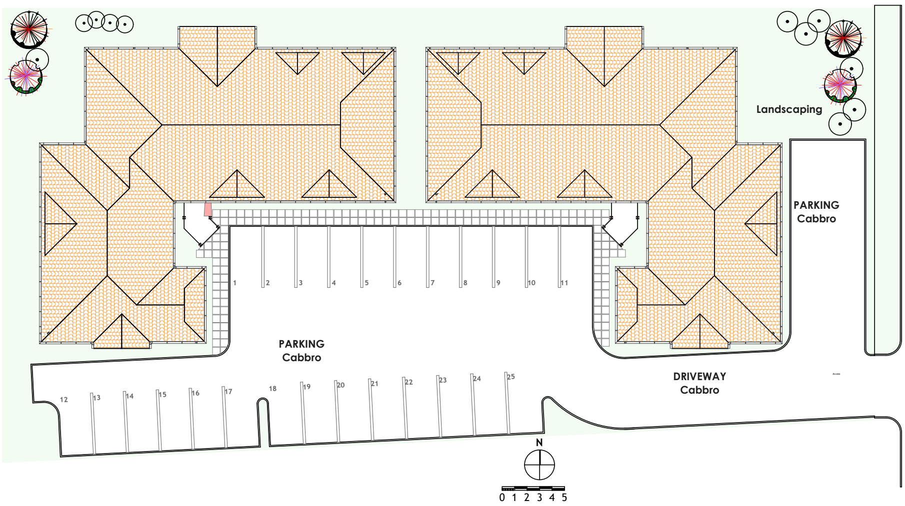
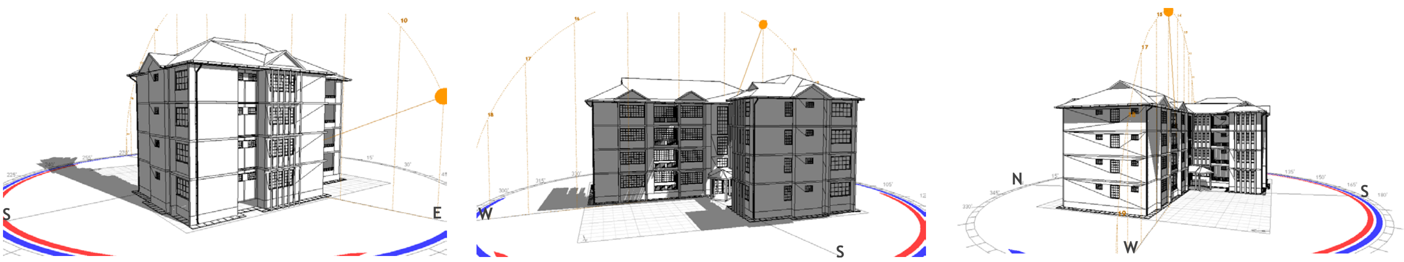


Figure 45: Typical Floor plan

Figure 46: Position of the Sun at different times during the equinox



The vertical sun shading devices provide shade to the major windows on the East facing walls.

The sun is overhead at noon. The roof eaves provide shading to windows on the top floor while horizontal overhangs and balconies provide shade to South and North facing windows against the noon sun.

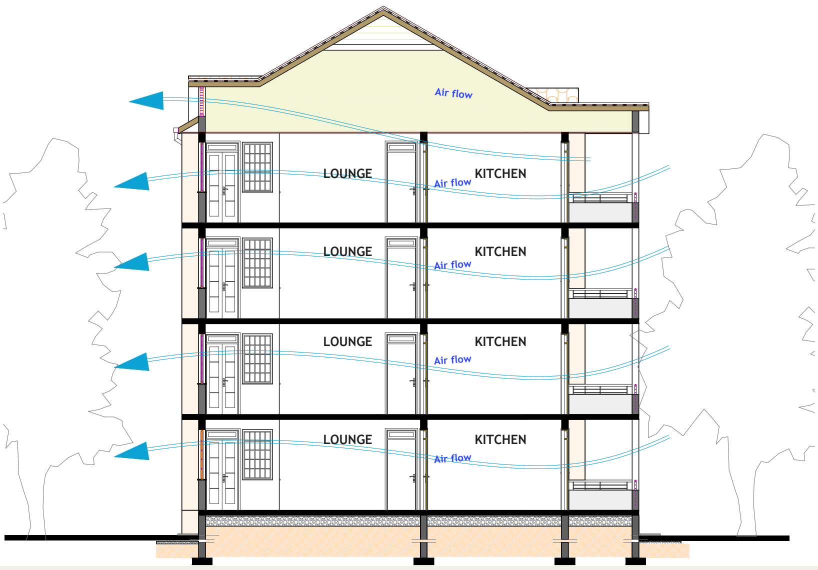
To minimize solar radiation into the house, there are few openings on the Western walls located at secondary spaces (e.g. bathrooms) where comfort needs are not a priority. Unavoidable major openings on the west facing walls are adequately shaded using vertical sun shading devices.

Figure 47: South Elevation

Figure 48: West Elevation

Oblique vertical sun shading devices have been used on the west facing elevation against the low strong afternoon sun

Figure 49: Section X-X showing cross ventilation



DESIGN RESPONSES

1 Orientation - This L-shaped apartment block has one wing correctly oriented with its major façade facing the North-South direction. The second wing has its major façades facing the undesirable East-West direction.

2 Ventilation - Windows openings are used to achieve cross ventilation. Permanent ventilation vents have been provided on all openings. In addition, there are openings in the roofs to provide the exit of accumulated hot air in the roof space.

3 Daylighting - All windows in all the rooms meet the minimum required area of 20 per cent of elevation area for the provision of natural day lighting.

4 Sun shading - Windows on the North and South facing façades have been provided with 900 mm overhangs to generate mid-day shade to the respective rooms.

-The major windows on the East and West facing façades are shaded using pre-cast vertical shading devices against the low morning and afternoon sun respectively. This minimizes unwanted solar gains.

5 Building materials - Natural stone has been used for the building envelope walling which stores the sun's heat and release it back into the building at night during the cold months. During the hot season, this absorbs excess heat during the day therefore lowering the internal temperature.

- Light coloured clay roofing tiles have been used to reflect unwanted solar radiation.

CLIMATIC ZONE 5: Lake region climate

Multi dwelling housing

Climatic Zone 5: Lake region climate

Location	Kisumu, Kenya
Latitude	0°6’S
Longitude	34°45’E
Altitude	1149 m above sea level
Temperature	Min average temp 14°C; Max average temp 34°C
Annual Rainfall	Average 1740 - 1940 mm
Humidity	
Prevailing Wind Direction	South west and East prevailing winds

Figure 50: KISUMU (Hours of Sunshine / Temperature)

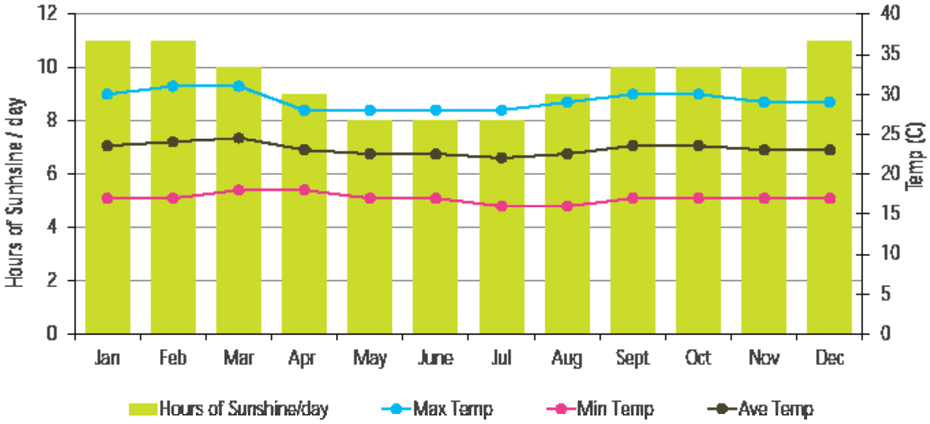


Figure 51: KISUMU (Relative Humidity / Rainfall)

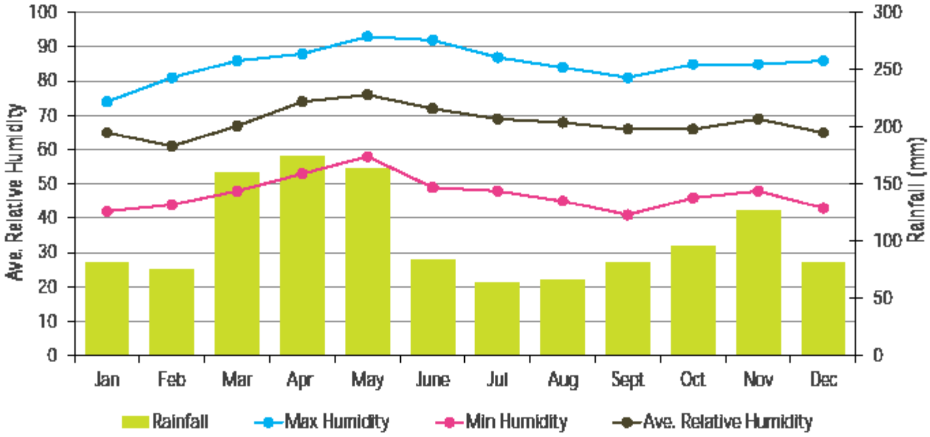


Figure 52: Prevailing wind direction

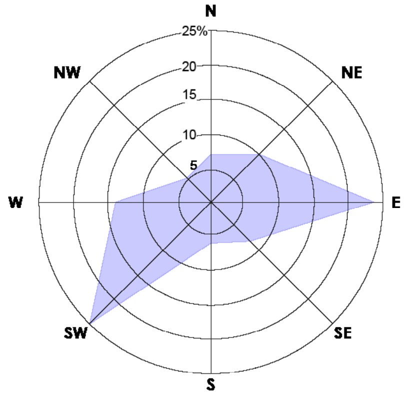


Figure 53: Sun path Diagram for Latitude 0° South

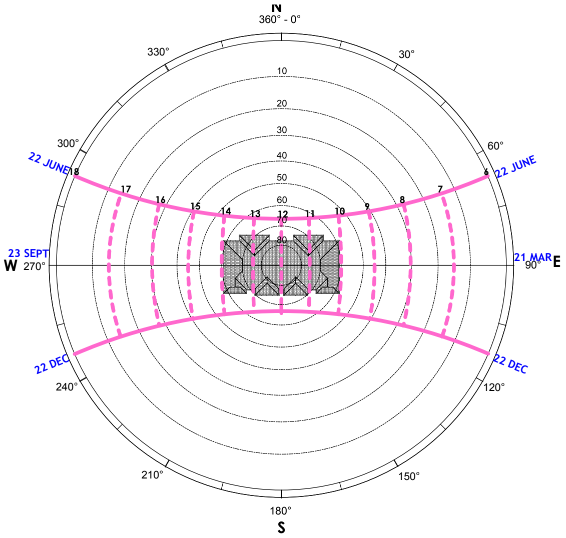
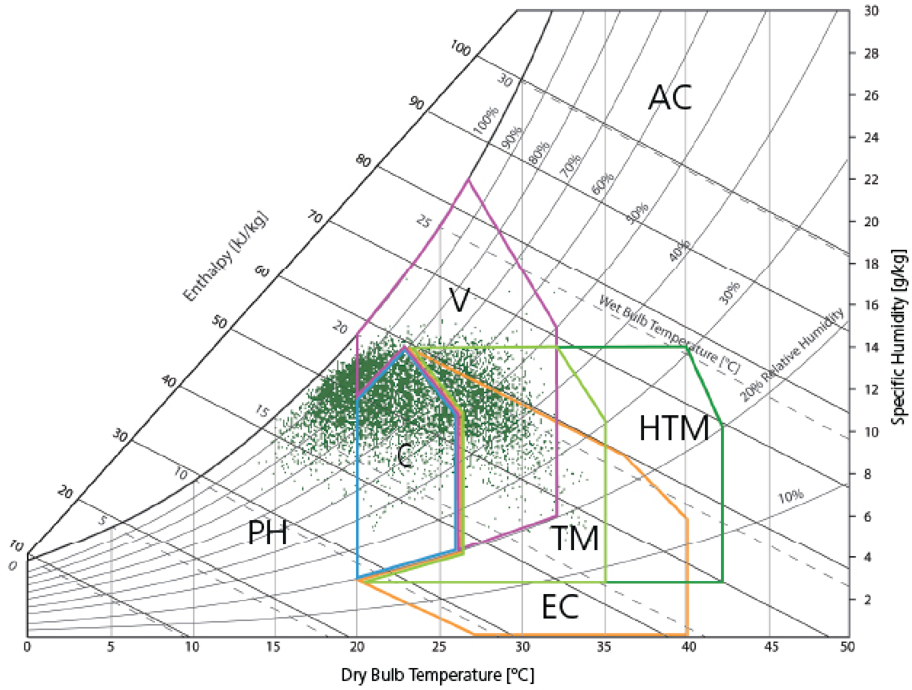
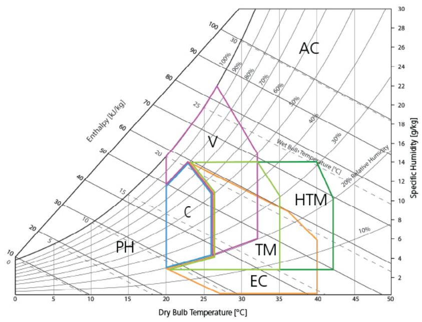


Figure 54: Psychrometric Chart with weather data for Kisumu





LEGEND

C	Comfort Zone
V	Ventilation
TM	Thermal Mass
HTM	High Thermal Mass
EC	Evaporative Cooling
PH	Passive Heating
AH	Artificial Heating
AC	Air Conditioning

INTERPRETATION

- This zone experiences high day time temperatures and low night time temperatures for some periods of the year.

- Natural ventilation, passive heating through thermal mass during the day, and solar shading are the most effective strategies for improving thermal comfort.

- The most critical climatic requirements of buildings in this zone are the needs for cool indoor spaces during the high day temperatures and, warm interiors during the night. High thermal mass walls are therefore recommended to even out the indoor temperatures.

- Cross ventilation should be achieved in all habitable rooms by having openings on both external and internal walls and by having permanent openings that admit air but not direct sunlight to interiors.

- Buildings should be oriented with the long axis running east-west.

- All window openings should be fully sun shaded throughout daytime.

CLIMATIC ZONE 5:
Lake region climate

Multi dwelling housing

Figure 55: Site plan

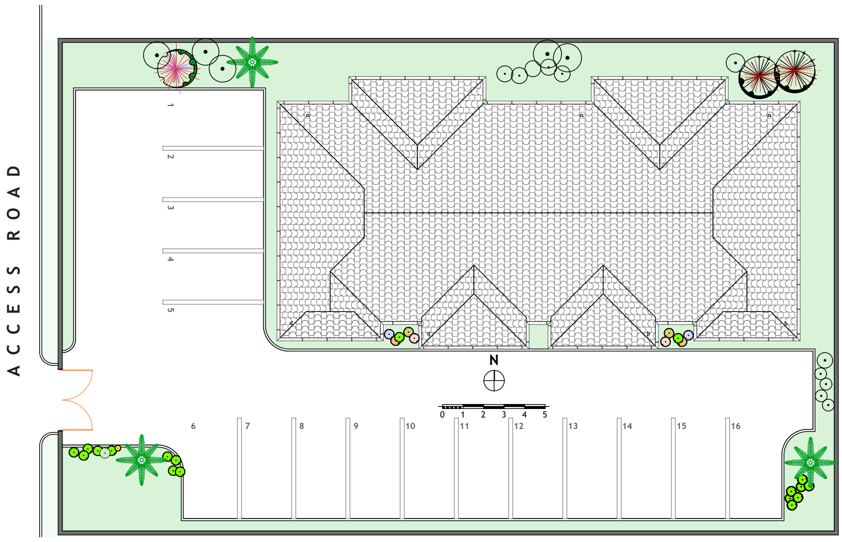


Figure 56: Typical floor plan

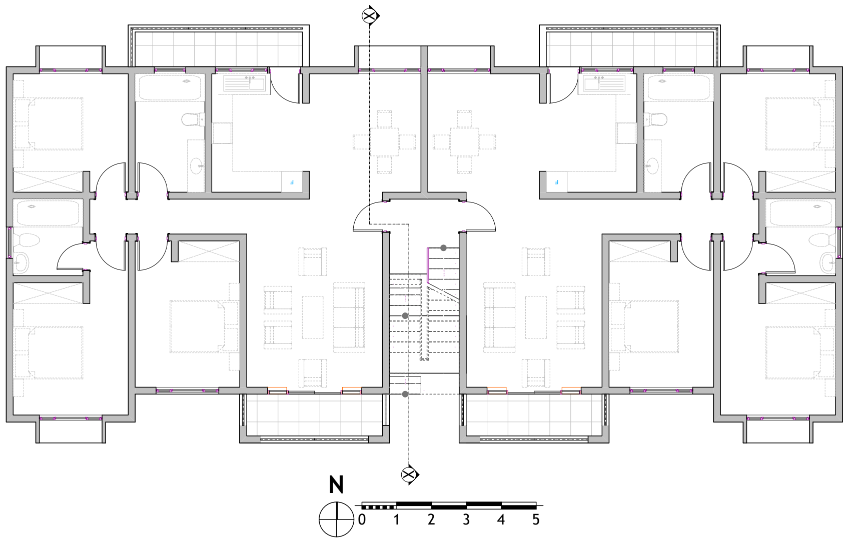
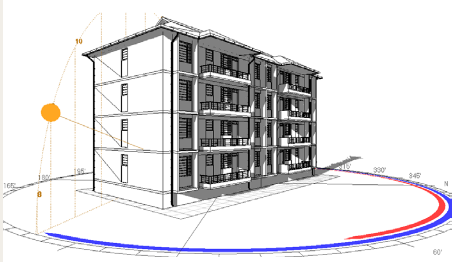


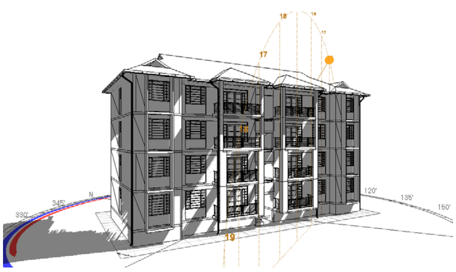
Figure 57: Position of the Sun at different times when the sun is in the Southern hemisphere

December 22nd at 9.00 a.m.



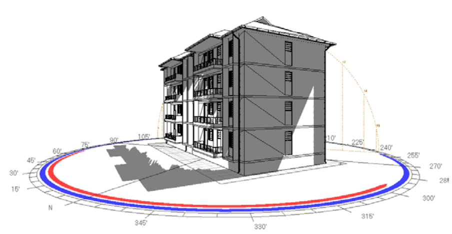
Minimal windows on the east facing walls minimizes exposure to the morning solar radiation.

December 22nd at 12.00 p.m.



The balconies and horizontal window overhangs shade the openings against solar radiation at noon.

December 22nd at 3.00 p.m.



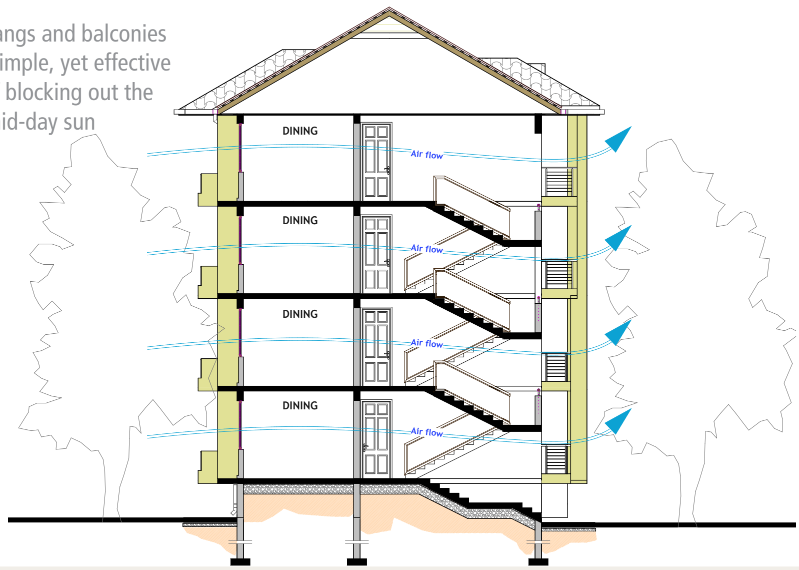
At this time of the year, the west facing wall is not exposed to the afternoon solar radiation because of the optimal orientation of the building.

Figure 58: North Elevation

Figure 59: South Elevation

Figure 60: Section X-X showing cross ventilation

Overhangs and balconies are a simple, yet effective way of blocking out the high mid-day sun



DESIGN RESPONSES

1 Orientation - The block is optimally oriented along the East-West axis with the major opening facing North - South directions. The rectangular shape of the building ensures that minimal surface area is exposed to the East and West sun.

2 Ventilation - All the rooms are naturally ventilated through the windows and the permanent vents provided at the roof level using timber louvres.

- The open stairwell acts as a solar chimney. The hot air rises through the open space and exits at the top through the permanent vent louvres at the roof.

- The living, dining and kitchen are designed as open plan as part of the block's natural ventilation through cross ventilation. This eliminates heat build-up during the hot season.

3 Daylighting - Natural lighting is allowed to penetrate all the rooms through the windows and thus prevent the use of artificial lighting during time.

4 Sun shading - The balconies, slab and roof overhangs (600 mm deep) have been included to cut out unwanted direct solar radiation from the mid-day sun on the north and south facing façades.

- Windows have been minimized on the East and West facing façades to reduce solar gains from the low morning and afternoon sun respectively.

5 Building materials - High thermal mass (thick walls) local stone is used as a major construction material for the building envelope. This helps to reduce the diurnal temperature swings.

- Light coloured roofing clay tiles have been used to reflect heat away during the hot months.

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Simulation tool: SOLANGLES

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The project Promoting Energy Efficiency in Buildings in East Africa is an initiative of UN-Habitat in collaboration with the United Nations Environment Programme (UNEP), the Global Environment Facility (GEF) and the governments of Kenya, Tanzania, Uganda, Rwanda and Burundi.

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