BUILDING ON THE EDGE

Climatic design guidelines for Emerging Cities of EtEthiopia

The case of Addis Ababa

Fasika Sahlemariam Gebremeskel

Project mentors

Jochen Lam

Matthias Rammig

Final presentation slides
June 25 2015
Stuttgart, Germany

Picture for cover
EiABC chair of Architectural design

BUILDING ON THE EDGE

Fasika Sahlemariam Gebremeskel

Architect from Ethiopia

Graduated in Architecture from EiABC in 2012

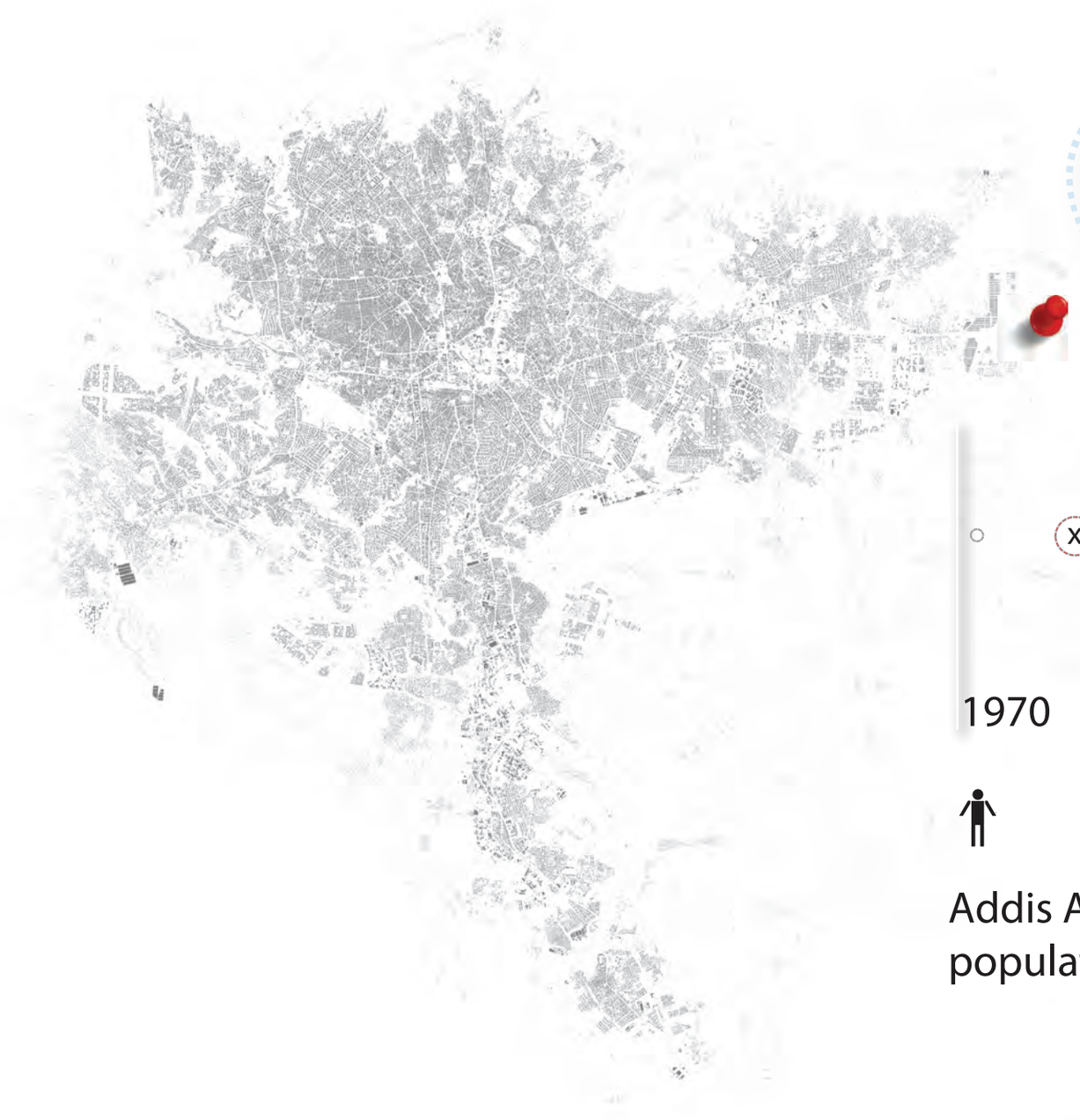
EiABC

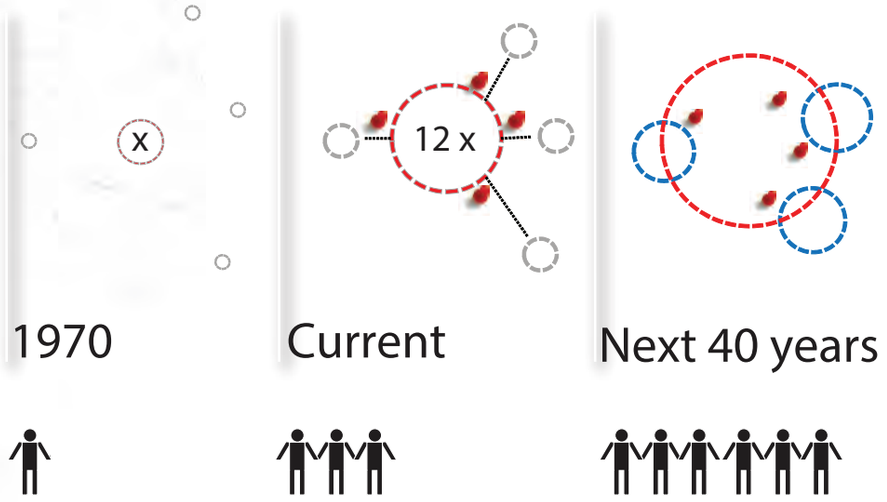
Ethiopian Institute of Architecture,
Building Construction and City Development
Addis Ababa University

www.eiabc.edu.et

Project overview

As climate is the major factor in the performance of the built environment, the project uses climate responsive design as a main tool to provide "Climatic design guideline" for rapidly expanding city of Addis Ababa



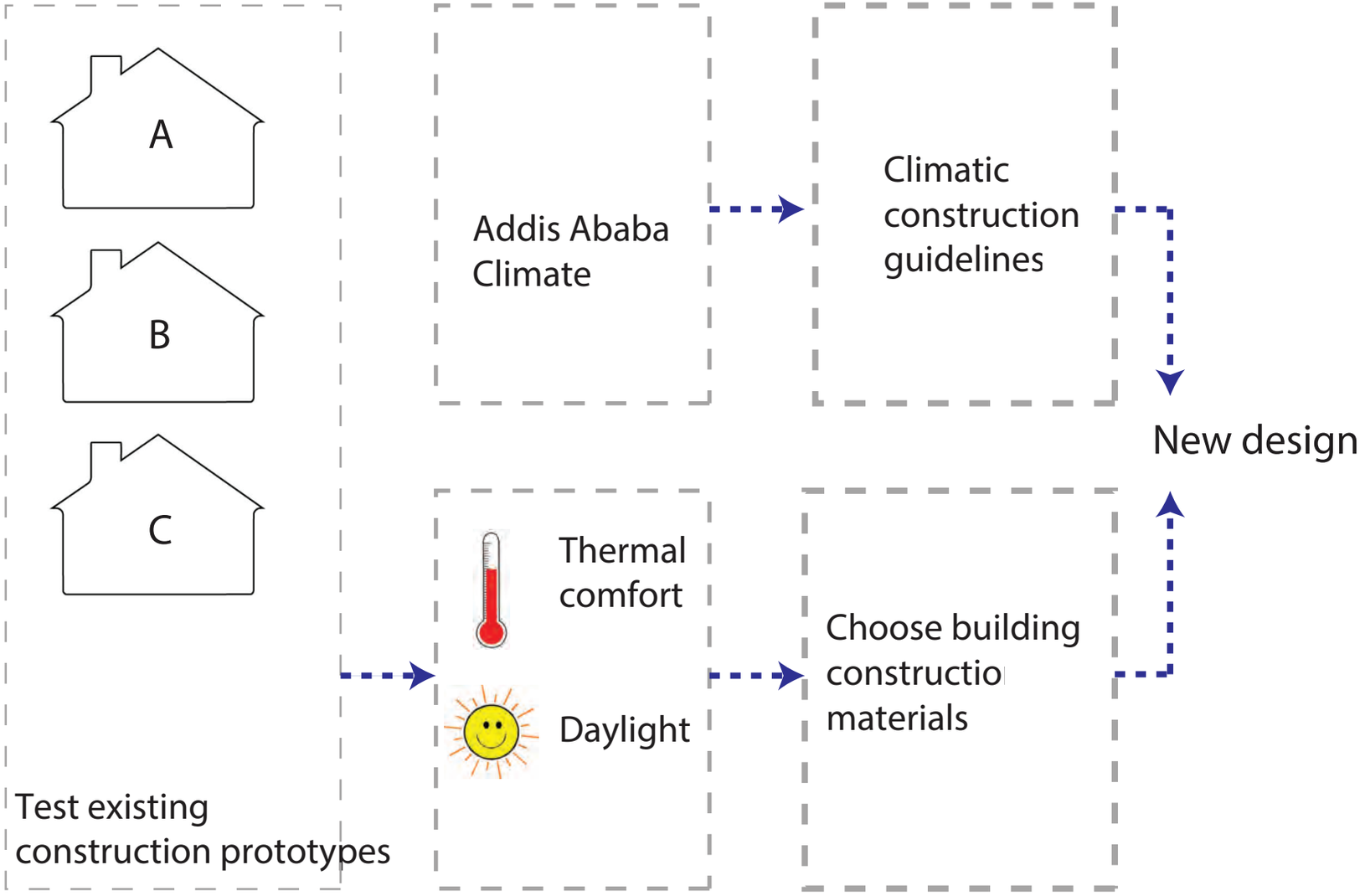


Addis Ababa recent years area expansion and population growth rate

Structure of the study

test | **investigation and Documentation** | **Design +Test**

The project uses analytic step-by-step, test and design methodology to come up with the guidelines.



Climatic design **guidelines and recommendations for Addis Ababa**

+

Building on the Edge

Design Proposal to be built at the city edge to show the application of the guideline

BUILDING ON THE EDGE

Test Buildings

These buildings were used because of their approach to alternative construction materials

2010-11
SUDU

[Sustainable Urban Dwelling Unit]

Rammed earth construction

2011-12
SECU

[Sustainable Emerging City Unit]

straw panel and timber construction

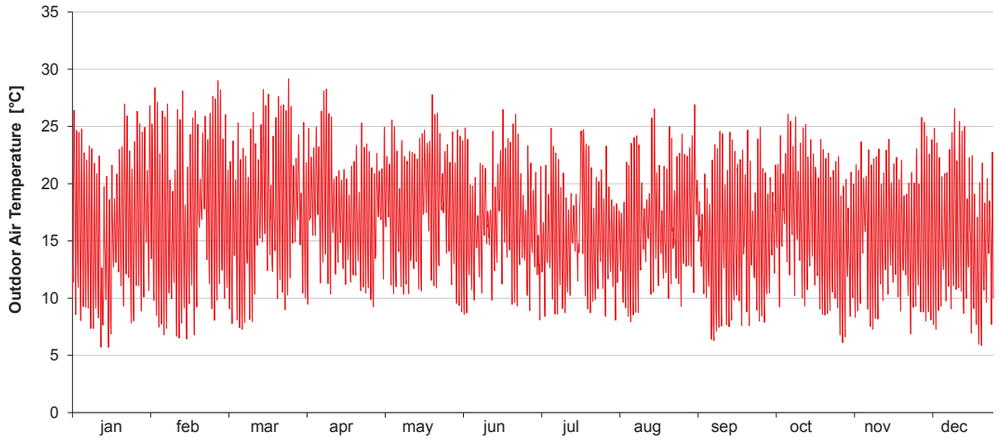
2012-13
SICU

[Sustainable Incremental City Unit]

Combined precast concrete and timber construction

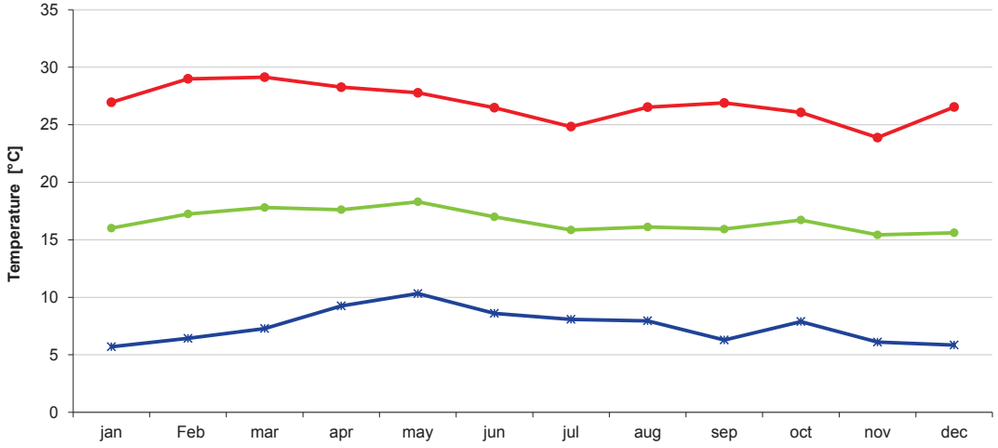
BUILDING ON THE EDGE

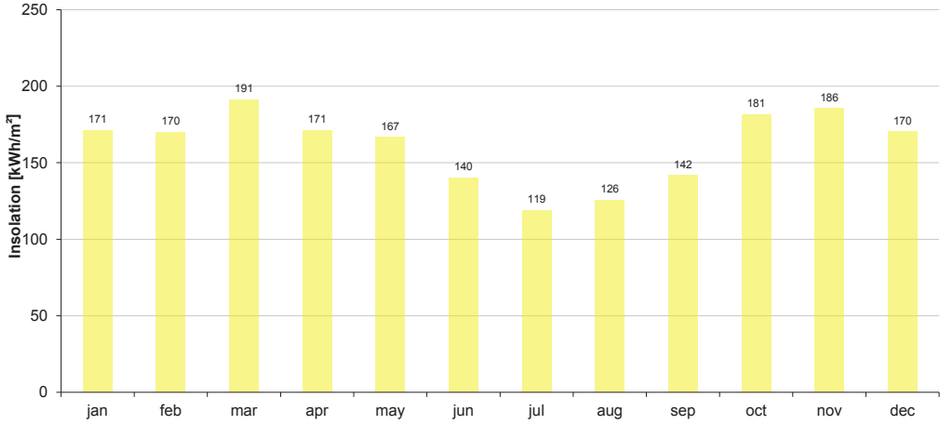
Climate



Addis Ababa has a minimum seasonal fluctuation in temperature as well as Total radiation throughout the year

The main challenge is the daily temperature swing which can reach up to 20 K in summer months [Nov-Jan] .





Annual average temperature fluctuation is less than 4 K

Horizontal Insolation: 1934 kWh/m²/a
Yearly Mean Outside Temperature 16.6 °C

Mean Outside Air Temperature [°C]
Minimum Outside Temperature [°C]
Maximum Outside Temperature [°C]

DAY = SUMMER

NIGHT = WINTER

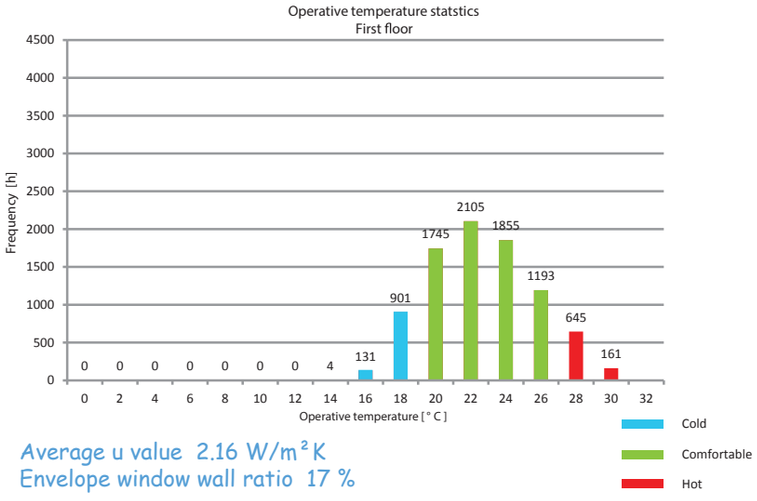
Minimum fluctuation during the rainy season June- August

for full climate analysis please refer to Project Report

BUILDING ON THE EDGE

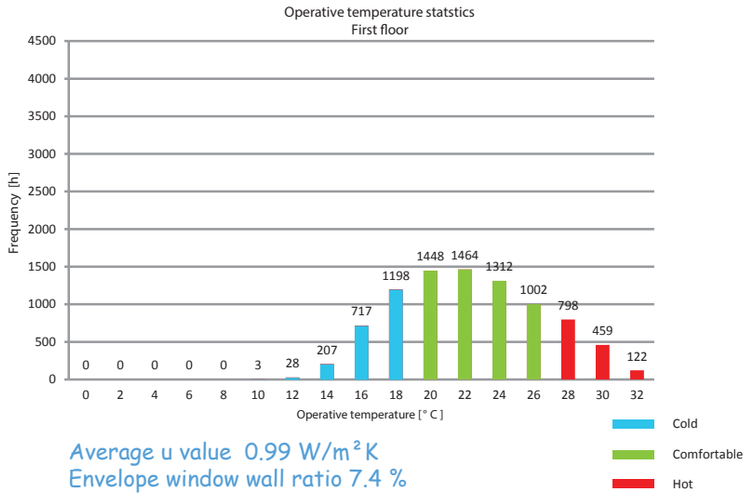
Thermal simulation results [Summary]

Hourly thermal simulation results of the first floor



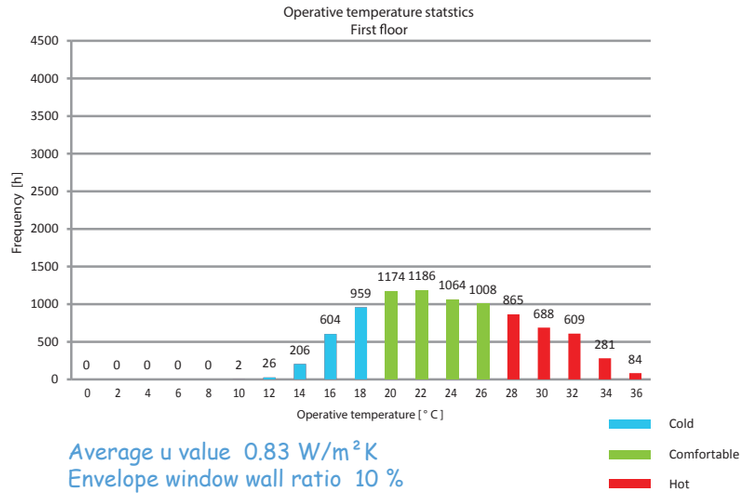
Average u value 2.16 W/m²K
Envelope window wall ratio 17 %

The 60 cm thick massive earth envelope uses its high thermal mass to store the heat from the high radiation and reduces heat flow during the night to create a stable indoor temperature.



Average u value 0.99 W/m²K
Envelope window wall ratio 7.4 %

Although this building has the lowest win wall ratio the effect of uninsulated roof meant that indoor temperatures were in the comfort limit for just above 60 % of the year.



Average u value 0.83 W/m²K
Envelope window wall ratio 10 %

Due to light weight construction especially the uninsulated metal roof exposed to maximum daily radiation and cold nights creates very high temperature above 30 ° C and over 1700 hrs below 18 °C.

All boundary conditions and assumptions on the full report

BUILDING ON THE EDGE

Daylight simulation result

Win wall ratio 20.5 %

Average daylight factor 3.6

Average daylight autonomy 82 %

Flexible opening size and position

With overall win wall ratio of 20 % with out any shading or overhangs ,the building achieved 3.6 % daylight factor more than the target value and also 300 lux illumination for more than 82 % of the daylight hours in Addis Ababa.

Win wall ratio 6.2 %

Average daylight factor 0.7

Average daylight autonomy 40 %

Small opening size in which location Determined by load-bearing modular straw board panel

This building has the lowest win wall ratio of 6.2 % in which the north and south facades are completely closed. This added with the roof overhang on all sides reduced the Daylight factor to only 0.7 , less than 30 % of the target value.

Daylight simulation showing the average value of the both floors

target Values [refer to full report]

DF > 3 %
DA 300 lux
fully occupied schedule

Win wall ratio 6.2 %

Average daylight factor 1.8

Average daylight autonomy 69 %

Semi-flexible opening size with over 2 m roof overhang on all sides

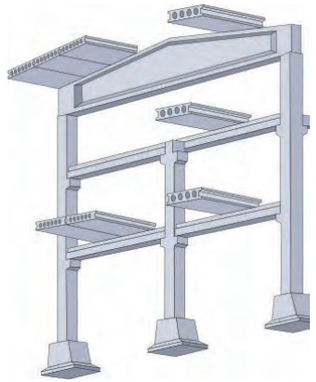
Here the main factor was the roof overhang of 2 m on all sides reduced the daylight values below the target value to 1.8 daylight factor .

All boundary conditions and assumptions on the full report

SUMMARY

Selection of building technology

Structure



New block

Example building for Building on the edge Guideline

Precast concterte

[efficient lateral and vertical loac

Fast and minimize waste

Design flexibility

Local knowhow

Local codes are available

Separating the building envelope from the structure gives flexibility to design the envelope

Envelope

Rammed earth

[Thermal Mass

High thermal capacity

Flexible opening

Low embodied energy

Durability

Ideal due to the property to store thermal energy and allowing flexible opening for daylight

Interior structure

Out of the test buildings these materials were chosen for further study

Agro- stone [Compressed fiber board]

[Light weight and mass production]

Fast construction

Light weight [35 kg /m^2] for 10 cm board

Reduce load on beari

Finish ready

Modular in construction and light weight for reduction of dead load on bearing structure .

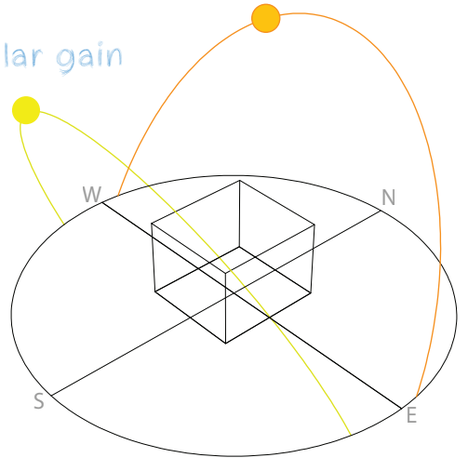
BUILDING ON THE EDGE

Thermal design guidelines

Passive heating

Direct morning sun access and afternoon shading

Heating loads can be covered by direct solar gain and thermal mass



Course of sun in Dec 21
with position of the sun at 2 pm

Course of sun in June 21
with position of the sun at 2 pm

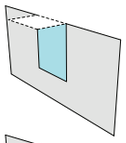
Openings for solar gain

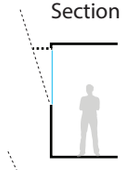
Perspective

Section

north

Minimum shading required

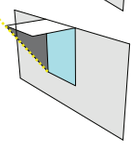


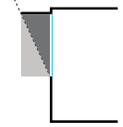


Optional horizontal overhang for June angle

south

Top and west shading required

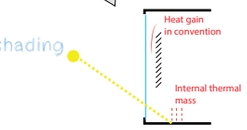




Horizontal overhang for Dec angle and west vertical shading .
Full access to the east for morning sun access

east

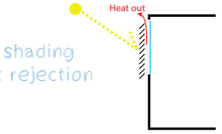
Internal movable shading for glare



Low windows for direct sun in the morning for exposing maximum internal thermal mass to radiation

west

External movable shading for glare and heat rejection



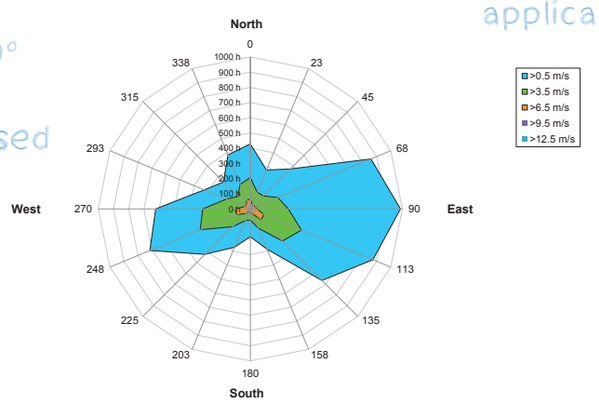
Movable external shading for glare and direct heat gain in the afternoon on external thermal mass

Passive cooling

Natural ventilation

With average outdoor temperature between 15-20° throughout the year, natural ventilation can be used for passive cooling

Due to the minor seasonal fluctuation of the outdoor temperature these passive strategies are tested to be applicable throughout the year



Major wind East to West

Available Wind Data: 8760 [h]

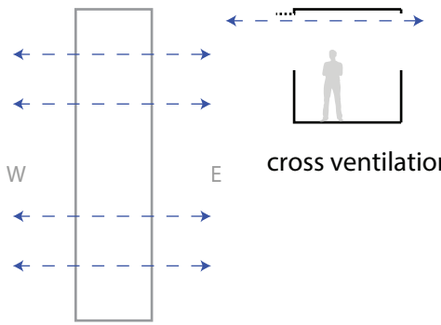
height: 10 m; wind velocity profile exponent: 0.22

Degree Value Marks The Middle Of The Angle Interval

Massing and orientation

Buildings with high internal load

maximize ventilation rate

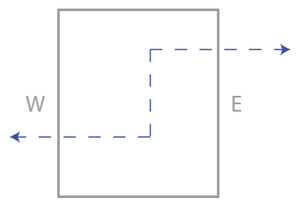


cross ventilation

East west orientation to allow efficient cross ventilation

Buildings with Low internal load

minimize excessive heat loss



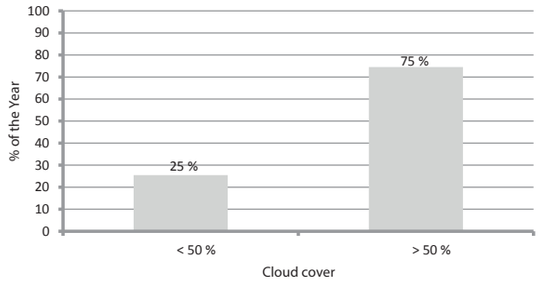
Stack ventilation

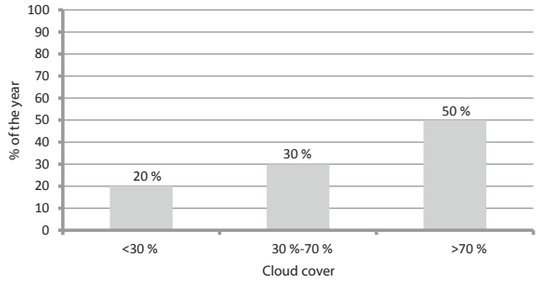
Compact design with reduced air speed

Full explanation on the full report

BUILDING ON THE EDGE

Daylight design guideline





Dominant overcast sky conditions
Cloud cover above 50 % 75 % of the year
Cloud cover above 75 % 50 % of the year

Outdoor Illuminance

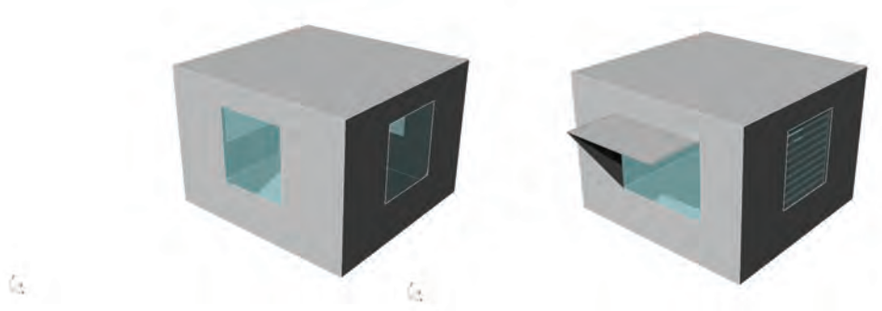
Daylight strategy is mainly based on diffused sky conditions

Due to the overcast sky conditions in Addis Ababa Daylight factor was used to estimate the illumination target values

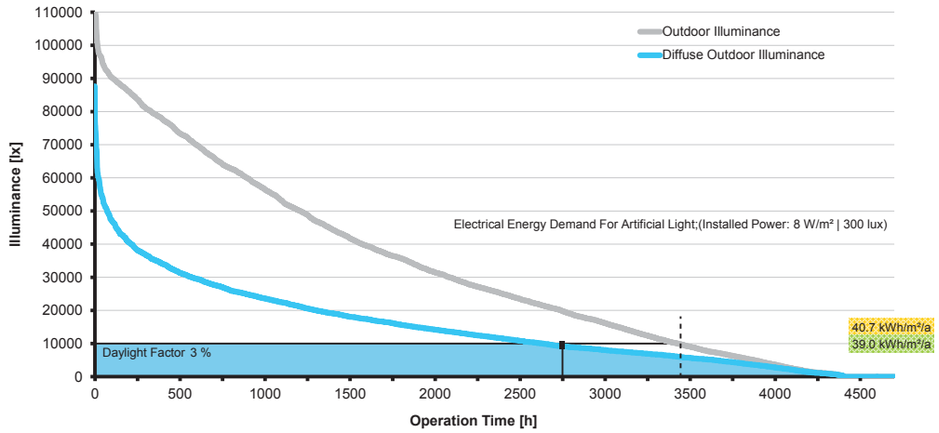
EBCS

Fully occupied working area 300 lx
DF 3% based on the dominant illumination of 10000 lx [70 % of daylight hours]

For this project local building code for Ethiopia [EBCS 10] was used for a fully occupied work place which requires 300 lux



Outdoor Illuminance



Total Operation Time: 8760 h

Outdoor illumination for Addis ababa with DF of 3 %

DF Target 3%

	Window wall ratio unshaded		Window wall ratio with thermal shading
N	20 %	N	30 %
E	20 %	E	20 %
W	20 %	W	20 %
S	20 %	S	46 %

n:b Glare problems on the East and West so movable shading required

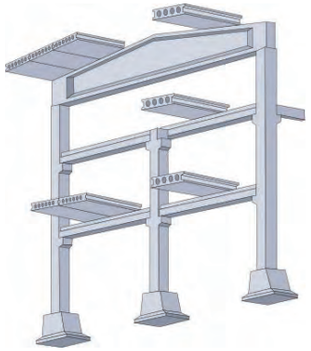
Test for window wall ratio to achieve 3% DF

Full explanation on the full report

BUILDING ON THE EDGE

Building design

Building material



Structure

Envelope

Interior structure

+

Guidelines

Thermal comfor

Daylight Desig

To be continue
and more detailed
.....

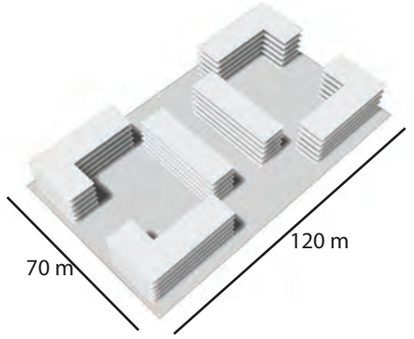
+

Architect

With the climatic guideline for thermal comfort and daylighting and the materials chosen from the prototype investigation a design proposal is made to show the application into a design

BUILDING ON THE EDGE

Building site and program



	Existing	New Block
building height	G +4	G +4
built up area	gross area 1700 m²	± 10 % 1700 m²
number of units	20 units per building	20 units per building
block density	20 units per building	< = Existing
daylight		EBCS code
Construction		Concrete structure rammed earth envelope agrostone interior

To provide a design proposal a site on the eastern city edge in which massive housing construction is taking place is chosen

The intention of the new building is to show the application into a real building program and provide comparable results

Detail building programming on the full report

BUILDING ON THE EDGE

Massing and orientation

The massing and orientation steps derived from the guidelines combined with the building program

Structure

Bad

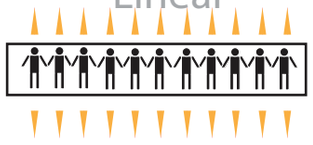
Good

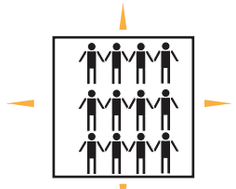
Ideal

Constructibility

Thermal efficiency

Linear





Compact

X

X

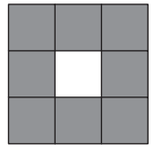
2 blocks togethe
[660 m²]

Square
[25x25 m]

Daylight

Excellent

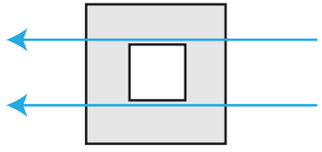
neutral



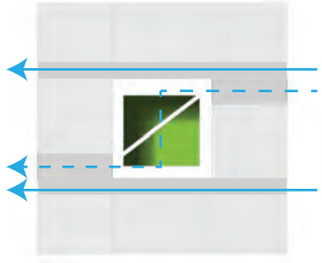
Courtyard
[648 m²]

Central courtyard
[27x27 m]

Passive cooling



W E



W E

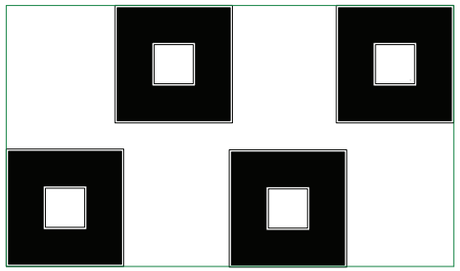
Openings to allow
natural ventilation

BUILDING ON THE EDGE

Density

Due to the compact design approach to increase thermal efficiency it was possible to achieve additional 40 apartment units in the same block area.

The building positioning creates minimum shading by neighboring buildings and creates a hierarchy of open spaces

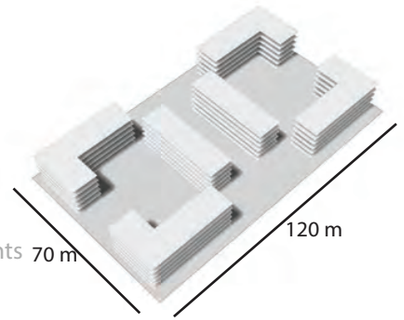


Density

Block Area	8400 m^2
Built up area rratio	40 %
Floor area ratio	1.9
Total number ϕ units	160 apa rtments

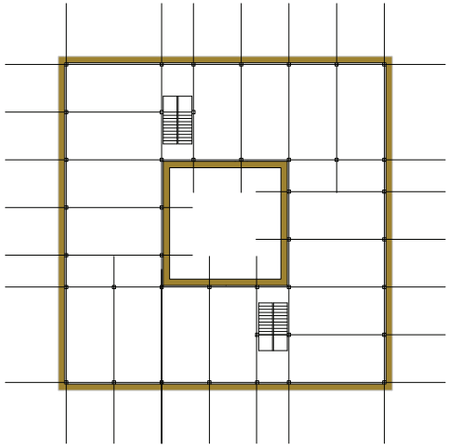
Existing Density

Block Area	8400 m^2
Built up area ratio	23 %
Floor area ratio	1.17
Total number ϕ units	120apa rtments

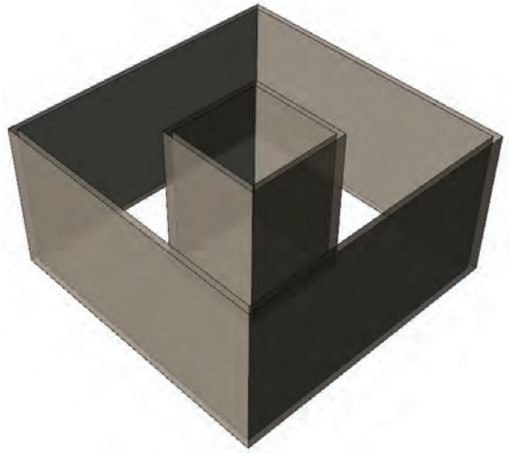


BUILDING ON THE EDGE

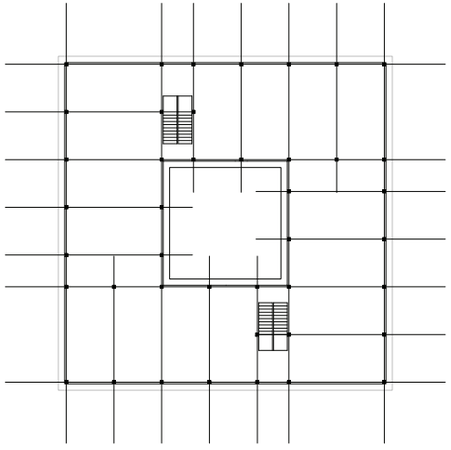
Building construction



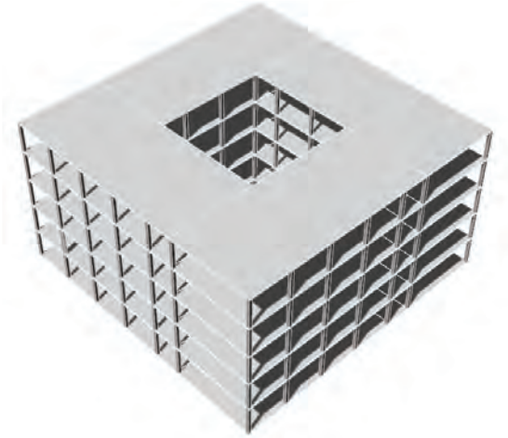
EXTERIOR RAMMED EARTH WALL



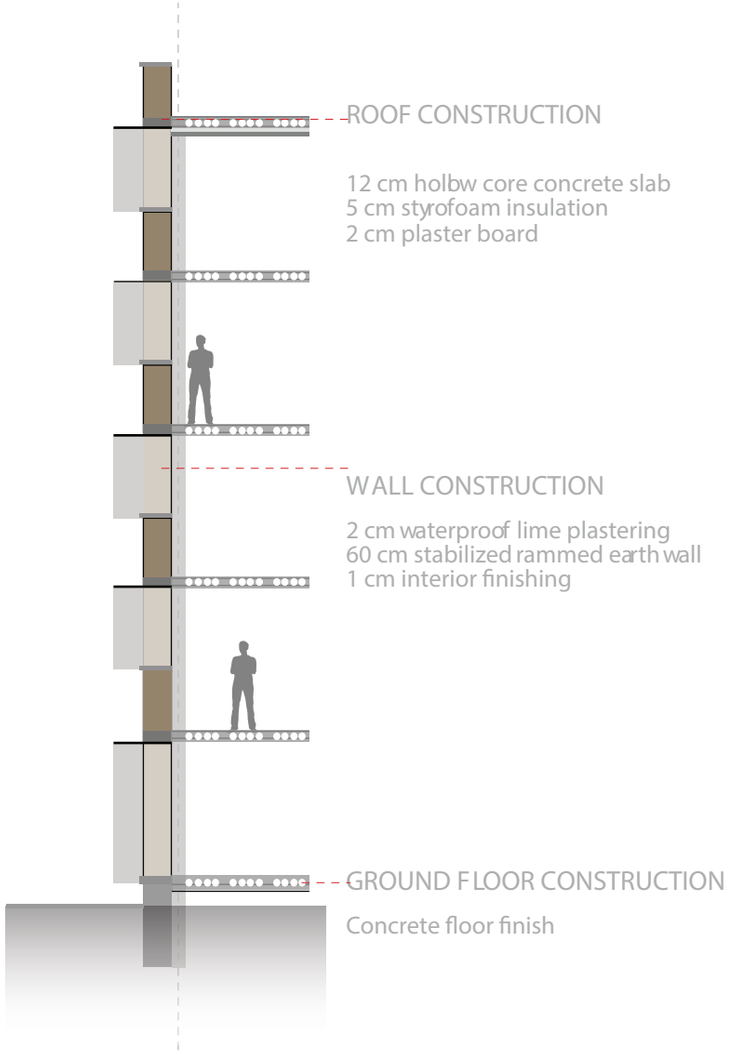
EXTERIOR RAMMED EARTH WALL



PRECAST CONCRETE STRUCTURE



PRECAST COLUMNS AND HOLLOW CORE SLAB

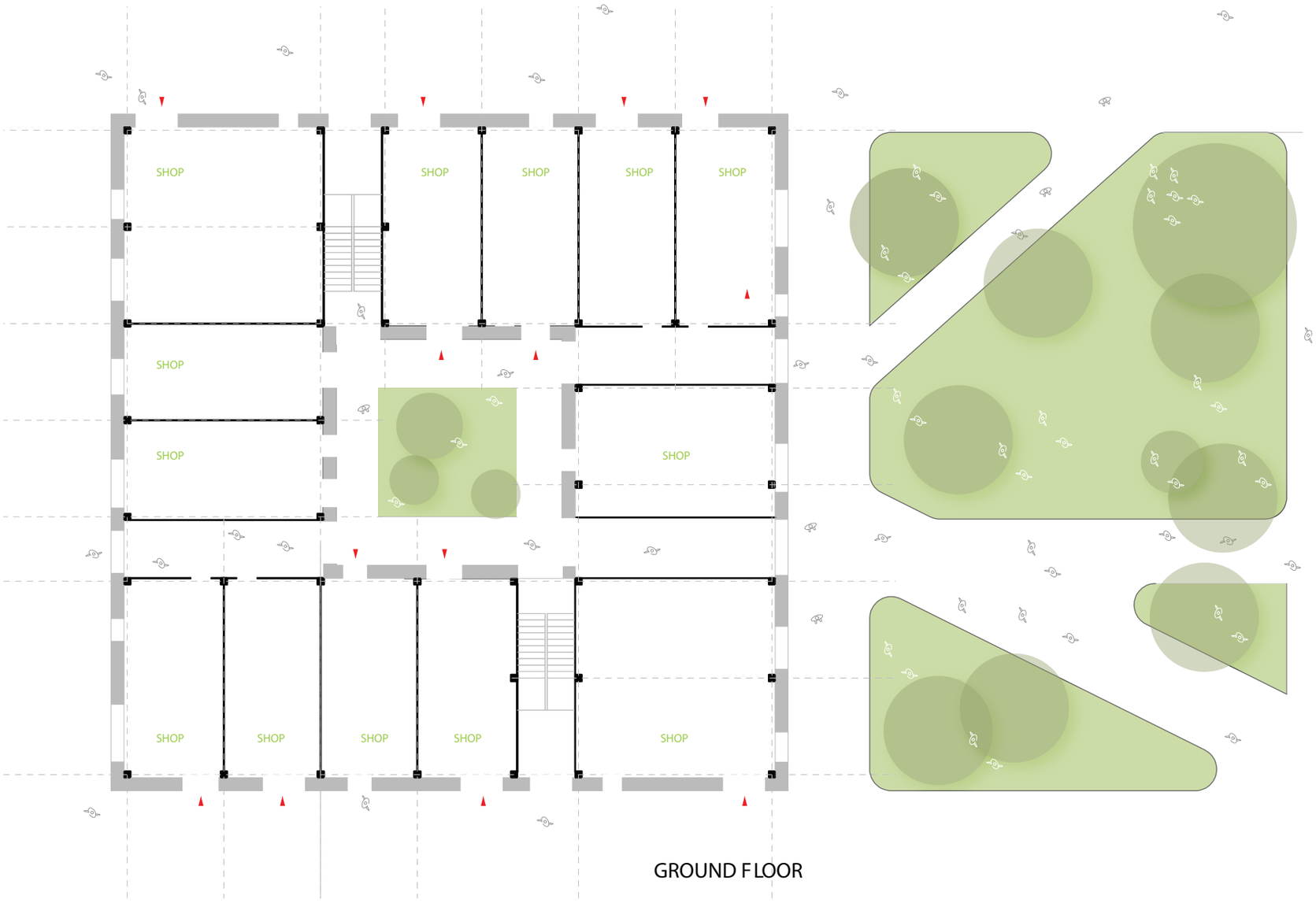


For efficient application of precast concrete a modular grid is designed for the interior load bearing structure

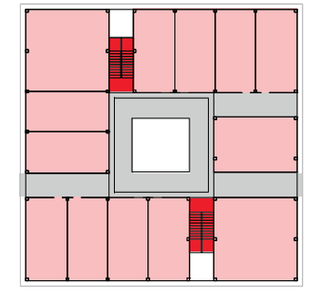
The envelope is independent self bearing rammed earth wall

BUILDING ON THE EDGE

Ground floor plan



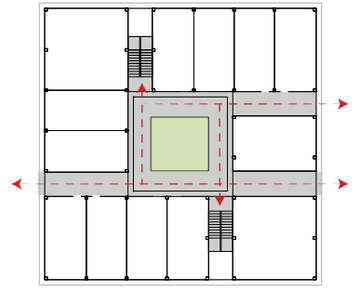
GROUND F LOOR



Commercial units

Circulation

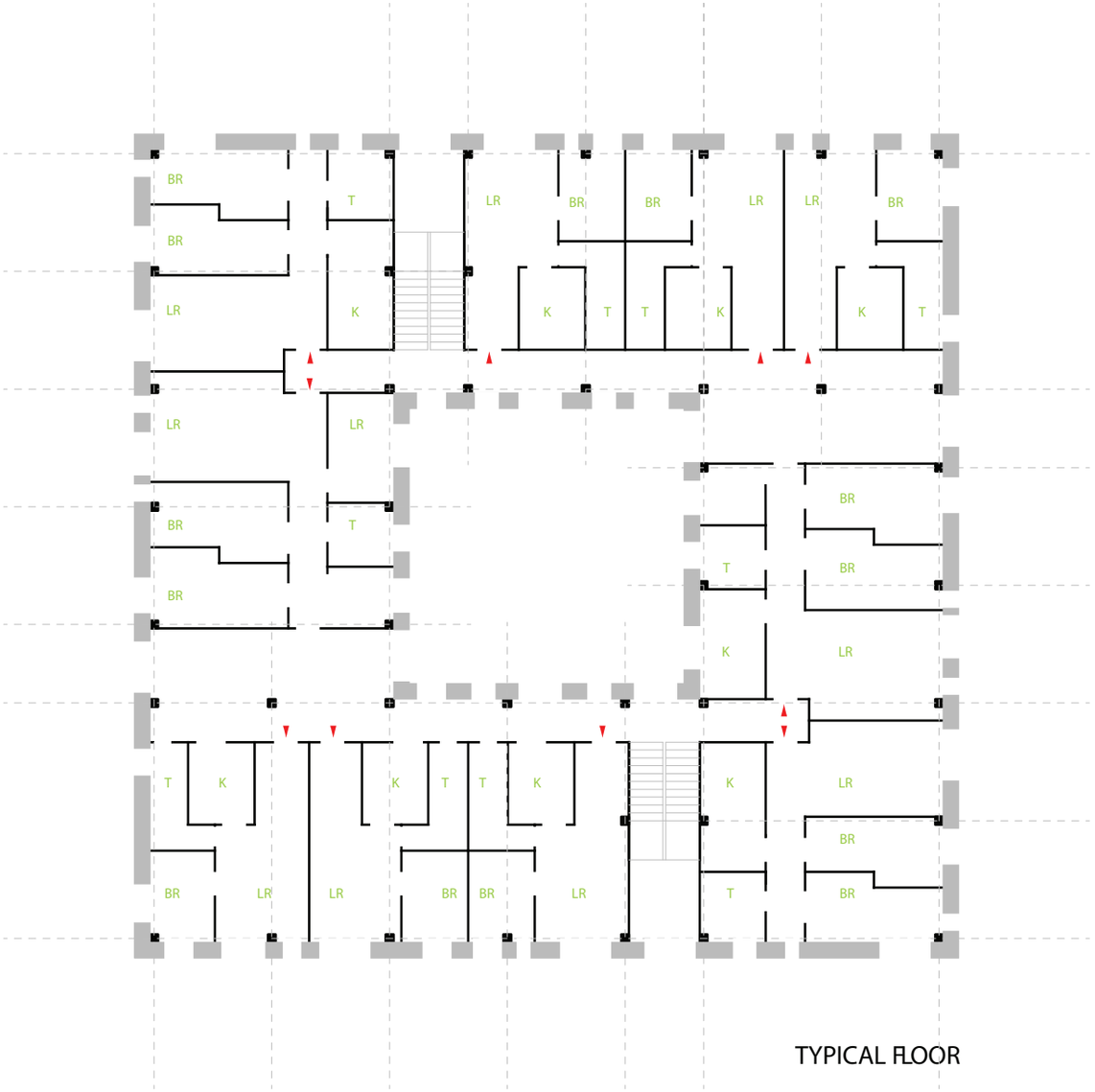
Building access



FUNCTIONAL ZONING

BUILDING ON THE EDGE

Typical floor plan



TYPICAL FLOOR

Ten apartment units arranged around a courtyard per floor

Service areas are facing towards the inner courtyard with all in direct access for natural ventilation

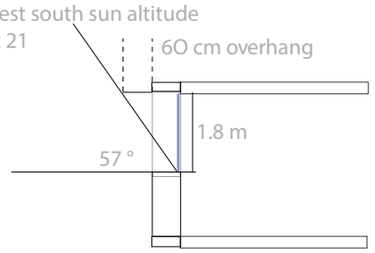
FUNCTIONAL ZONING

Living areas are facing towards the outside for efficient daylighting and solar gain for passive heating.

BUILDING ON THE EDGE

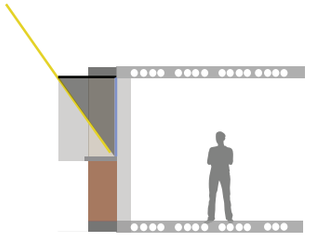
Design for solar protection and passive heating

EXTERIOR WALL CONSTRUCTION



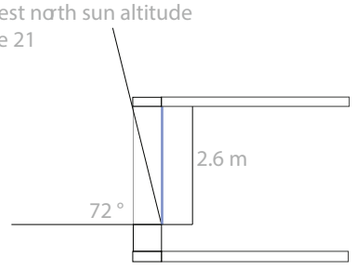
South opening

60 cm overhang angle to calculate the window height



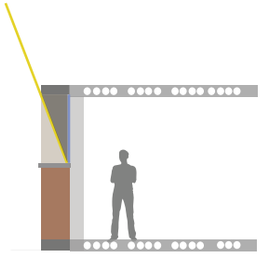
Thermal mass storage during the day time

Shading for horizontal and west insolation with exposed thermal mass



North opening

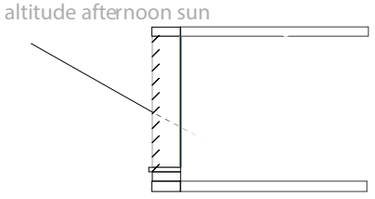
No overhang required due to the wall depth of 60 cm and high angle sun



Direct Thermal mass storage only during winter [June -August]

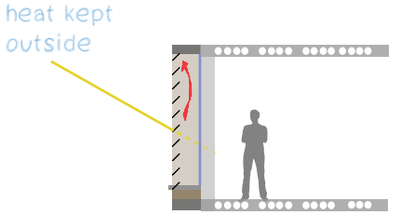
Reduced winwall ratio to lower thermal loss through glazing

Minimum direct solar gain with optional shading



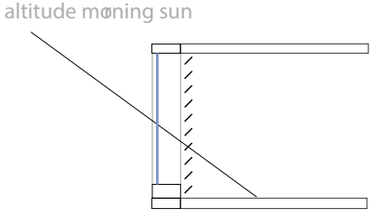
West opening

External moveable shading with windows on the inner facade



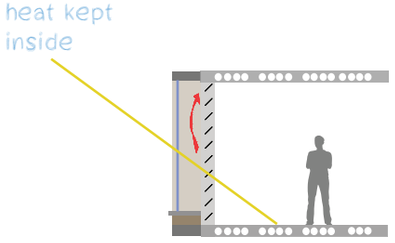
Moveable shading reduction of afternoon overheating

Recessed windows with external shading for avoiding glare and afternoon overheating



East opening

Internal moveable shading low sill windows for direct solar radiation on interior thermal mass



Low sill windows to maximize thermal mass storage on the concrete floo

Openings with internal shading to maximize direct solar gain and avoid glare

BUILDING ON THE EDGE

Elevation with fixed shading and movable shading

SOUTH ELEVATION

South elevation with fixed shading

WEST ELEVATION

West elevation with external movable shading

BUILDING ON THE EDGE

Passive cooling with natural ventilation

To provide a design proposal a site on the eastern city edge in which massive housing construction is taking place is chosen

the intention of the new building is to show the application into a real building program and provide comparable results

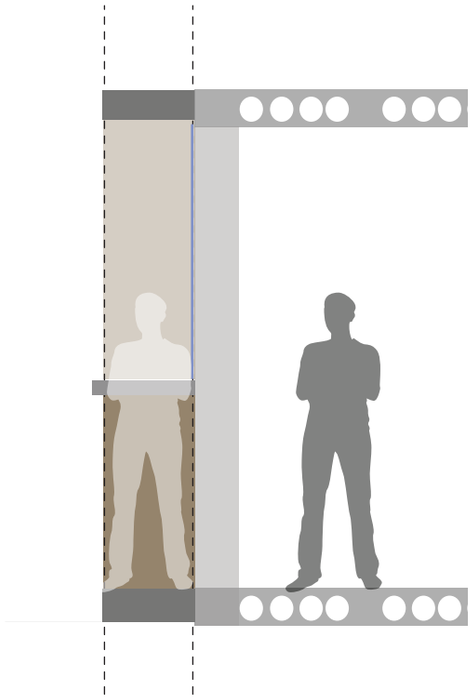
Passive cooling

Natural ventilation

Block cross ventilation

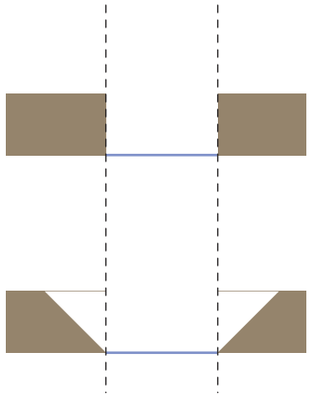
Major facade openings on all sides for efficient ventilation.

Daylighting



Deep Wall section

The thickness of the wall required larger openings to reach desired Daylight factor values

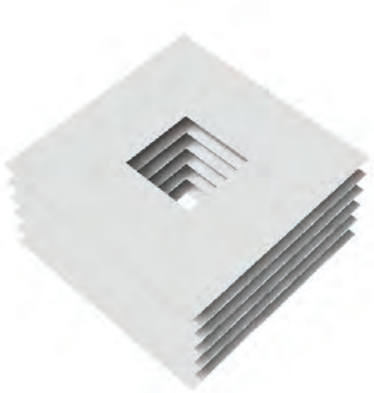


Same window width but chamfered edges to maximize daylight

Testing to follow.....

Whats next...?

Building



\+

Initial Guidelines

Design development + further testing

Climatic design **guidelines and recommendations for Addis Ababa**

\+

Building on the Edge

Design Proposal to be built at the city edge to show the application of the guideline

BUILDING ON THE EDGE Thank YOU !!! i had a great year !!!

Mentors JOCHEN LAM + MATTHIAS RAMMIG !!!!!!!!!

Structural Design Support Knippers Helbig Advanced Engineering

Academy group

+ Christian Degenhardt

Jan Mehnert, Moni Lauster, Alejandra Cassis, Joshua Vanwyck ,Thomas Auer + All Transsolar Group

Fasika Sahlemariam
June 25 2015

Please look at the final report for details