

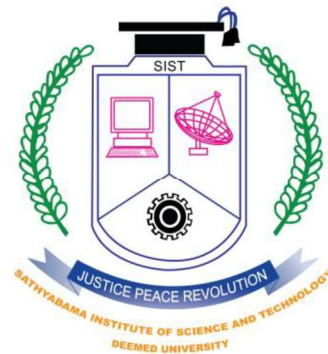
CO HOUSING FOR AUROVILLE INHABITANTS IN EARTH CONSTRUCTION

A Thesis

Submitted in partial fulfillment of the requirements for the award of
Master of Architecture degree in Sustainable Architecture

by

YAZHINI S (39890020)



**DEPARTMENT OF ARCHITECTURE
SCHOOL OF BUILDING AND ENVIRONMENT**

SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

Accredited with Grade "A" by NAAC

JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI - 600 119

MAY 2021



SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)

Accredited with Grade "A" by NAAC

JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI - 600 119

www.sathyabama.ac.in



DEPARTMENT OF ARCHITECTURE

BONAFIDE CERTIFICATE

This is to certify that this Report is the bonafide work of **YAZHINI S (39890020)** who carried out the Thesis entitled "**CO HOUSING FOR AUROVILLE INHABITANTS IN EARTH CONSTRUCTION**" under our supervision from January 2021 to May 2021.

Internal guide
(Ar. KAVITHA)

Internal Panel Member
(Ar. SHEETAL AMRAOTKAR)

External guide
(Ar. GANESH SIVAKUMAR)

DR. DEVYANI GANGOPADHYAY
Dean, School of Building and Environment
Department of Architecture

Submitted for Viva voce Examination held on _____

Internal Examiner

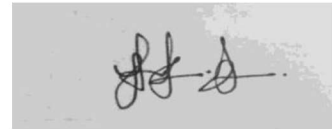
External Examiner

DECLARATION

I **YAZHINI S** hereby declare that the Thesis Report entitled “**CO HOUSING FOR AUROVILLE INHABITANTS IN EARTH CONSTRUCTION**” done by me under the guidance of **Ar. KAVITHA** (Internal) and **Ar. P.S. GANESH, Principal Architect GREENVIRON** (External) at Sathyabama Institute of Science and Technology is submitted in partial fulfillment of the requirements for the award of Master of Architecture degree in Sustainable Architecture.

DATE:

PLACE:

A rectangular box containing a handwritten signature in black ink. The signature appears to be 'Yazhini S' with a stylized flourish at the end.

SIGNATURE OF THE CANDIDATE

ACKNOWLEDGEMENT

I am pleased to acknowledge my sincere thanks to Board of Management of **SATHYABAMA** for their kind encouragement in doing this Thesis project and for completing it successfully. I am grateful to them.

I convey my thanks to **Dr. Devyani Gangopadhyay, Dean and Head of the department, Dept. of Architecture, School of Building and Environment**, for providing me necessary support and details at the right time during the progressive reviews.

My special thanks to **Dr. Suresh Kuppusamy**, our Design chair and **Ar. P.S. Ganesh**, (External guide) and **Ar. Sheetal Amraotkar** (Thesis Coordinator) for their valuable comments and guidance during the project work.

I would like to express my sincere and deep sense of gratitude to my Project Guide **Ar. KAVITHA** for her valuable guidance, suggestions and constant encouragement which paved way for the successful completion of my project work.

I wish to express my thanks to all Teaching and Non-teaching staff members of the Department of Architecture who were helpful in many ways for the completion of this Thesis.

ABSTRACT

Different types of construction materials respond to the different climatic condition due to its properties. Walls, roofs and openings are the three primary components of the envelope that contribute towards heat gain from the external environment. The aim of this study will compare about thermal comfort and energy performance of naturally ventilated earth building which compare with convention building in warm and humid climate. this study will also discuss different types construction techniques in earth architecture which suitable for warm and humid climate. This study will focus on thermal comfort and the energy use of earth building and convectional building are analyzed, compared and will be discussed. How a building envelope will react to outdoor conditions through graphic illustration will be demonstrated and ways in which the research will be included by the simulations using the software will be shown. This research will contribute to the promotion of solar passive and low energy architecture towards a sustainable future.

1.0 INTRODUCTION

According to scientists and researchers, the human impact on global warming is now a given fact. The burning of fossil fuels and consequent greenhouse emissions are deeply affecting the planet at a global scale. The building sector alone accounts for more than half of the primary energy consumption globally and consequently for the same portion of greenhouse gas emissions. There is hence an urgent need to tackle this serious problem, turning the building sector into part of the solution, and contribute towards a more sustainable world. The belief that earth as a building material can play a key role in a new more environmentally conscious building paradigm is currently being supported by numerous experts who point out its environmental, cultural and economic advantages when compared to other, more commonly used building materials. Furthermore, due to its qualities, earth has a lower impact when compared to more conventional building materials. The raw-material to be used in the construction is usually dug from the site, and even if some mechanized system is required to dig, mix or place the earth, the construction process still has a lower embodied energy than a similar construction in brick, concrete or steel. reinforces this idea and remarks that, in the context of the locally built houses, there is no other construction technique that can compete with the earthen ones in terms of its low environmental impact.

1.2 AIM:

To compare the energy performance and thermal comfort of earth construction in warm and humid region.

1.3 OBJECTIVE:

- To evaluate the thermal performance of earth and conventional building with various parameters in the warm and humid climate
- To research energy performance and indoor microclimate to provide high thermal comfort levels.
- To study different types of roofing techniques that suit earth construction and analyses thermal comfort and energy performance of the building

1.4 SCOPE AND LIMITATION:

- The scope of the study is limited to the flat roof exposed to the sun in warm and humid climate.
- Energy and Thermal comfort is being considered for the wall and roof Energy performance and Thermal comfort is measured using simulation by IESVE software
- The onsite monitor of the thermal comfort of materials and comparative analysis will be done in future study.
- The study will be done on the place mud is locally available to reduce the embodied energy and transportation cost of the materials.

1.4 RESEARCH QUESTION IDENTIFIED:

- What are the known benefits, limitation and barriers of earth architecture?
- What are the effects of using earth as a building material and in which extent it promotes thermal comfort in walls which compare to other conventional wall in a warm and humid climate?
- How does the different type of sustainable roofing system in warm and humid climate impact to improve energy performance and thermal comfort in the mud wall of the building?

3.0 METHODOLOGY

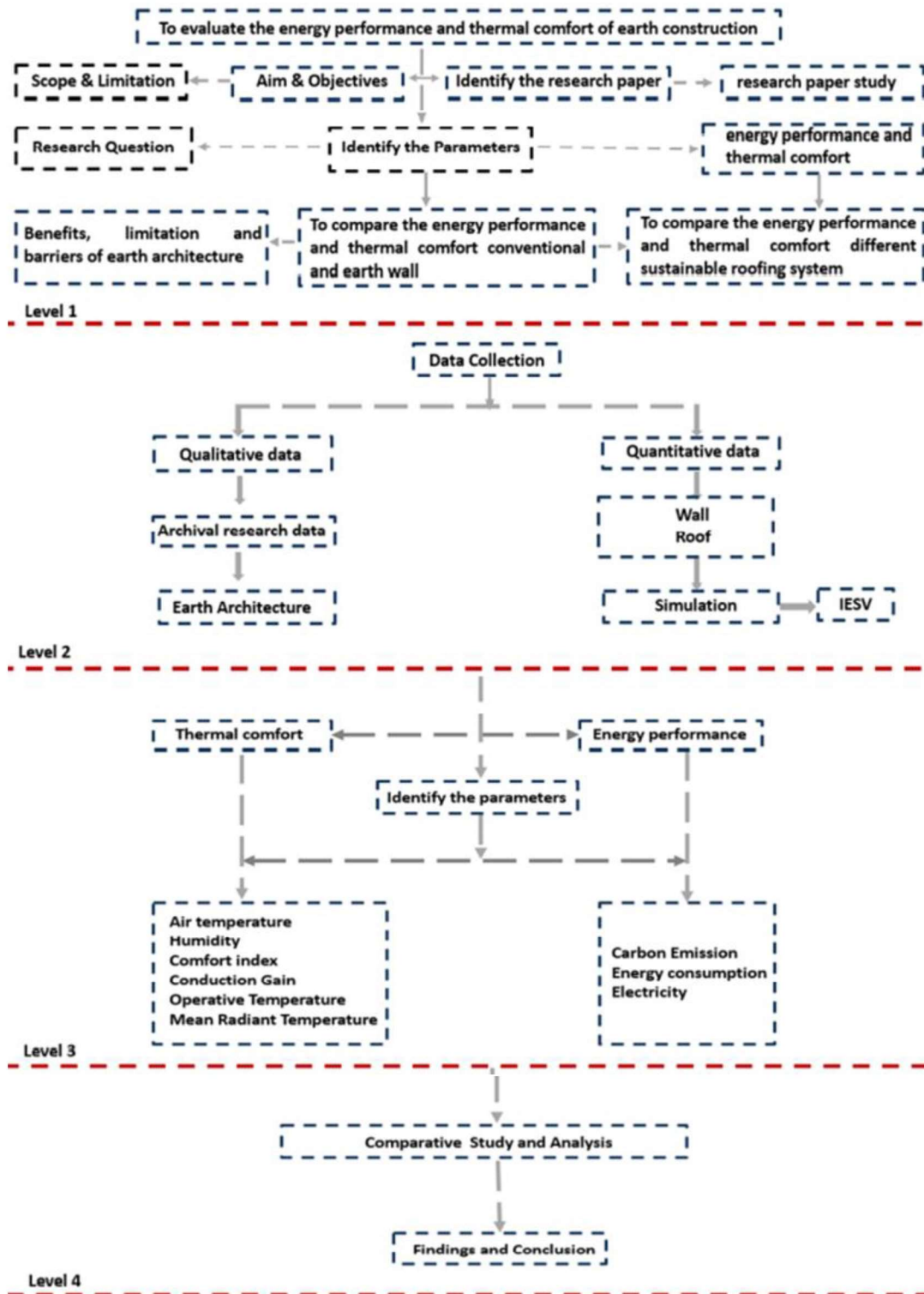


TABLE OF CONTENTS

CHAPTER No.	TITLE	PAGE No.
	ABSTRACT	v
	LIST OF TABLES	ix
	LIST OF FIGURES	x
1.1	INTRODUCTION	1
1.2	AIM:.....	1
1.3	RESEARCH QUESTION IDENTIFIED:	1
1.4	OBJECTIVE:.....	2
1.6	SCOPE AND LIMITATION:.....	2
2.0.	CLIMATE ANALYSIS:	3
2.1	AVERAGE HIGH AND LOW TEMPERATURE:	3
2.2	CLOUD COVER CATEGORIES:	3
2.3	AVERAGE MONTHLY RAINFALL:	4
2.4	TEMPERATURE RANGE:	4
2.5	SKY COVER:	4
2.6	MONTHLY DIURNAL AVERAGE:.....	5
2.7	RADIATION RANGE	5
1.9	ILLUMINANCE RANGE	7
2.10	WIND ROSE: JAN – DEC:	7
2.11	WIND ROSE:	8
2.12	Time Table Plot – Dry Bulb	9
2.16	DESIGN STRATEGIES – CLIMATE CONSULTANT:	11
2.17	Table for Indian adaptive comfort model:	11
2.18	For Naturally ventilated (NV) buildings:	12
2.20	COMFORT BAND FOR AUROVILLE:.....	13

2.21 OVER HEATING PERIOD:	14
3.0. VIKAS LAY-OUT:	15
3.1 UNIQUE FEATURES OF THE THIRD BUILDING	16
3.2. HUMANSCAPE HABITAT URBAN LIVING:.....	18
3.3.1.DAY LIGHTING:.....	19
3.3.2. SURFACE TEMPERATURE – ROOF:.....	19
3.3.3. SURFACE TEMPERATURE – WALL:.....	20
3.3.4. SURFACE TEMPERATURE – FLOOR:	20
4.0.SITE ANALYSIS:	22
4.1. WIND SPEED (m/s):	27
4.2. RELATIVE HUMIDITY (%):	27
4.3. AIR CHANGE TEMPERATURE (K/h)	27
4.4. POTENTIAL AIR TEMPERATURE (°C):	27
The Potential Air Temperature falls between 32 °C – 20 °C.	28
4.6 OUTDOOR TEMPERATURE AND RELATIVE HUMIDITY:	28
4.7 COMPARATIVE CHART FOR OUTDOOR TEMPERATURE IN SITE:.....	29
4.8 DAY LIGHTING:.....	30
4.8.1 TABLE FOR DAY LIGHTING:	30
4.9.1 SURFACE TEMPERATURE - ROOF:.....	31
4.9.2. TABLE FOR SURFACE TEMPERATURE:	31
4.10.1. SURFACE TEMPERATURE – WALL:	32
4.10.2. TABLE FOR SURFACE TEMPERATURE:	32
4.11.1. SURFACE TEMPERATURE - FLOOR:.....	33
3.11.2. TABLE FOR SURFACE TEMPERATURE:	33
5.0. AREA STATEMENT – CO HOUSING:.....	34
6.0. ORIENTATION:.....	34
7.0. SOLAR ANALYSIS:.....	35
7.0.1. OPTION 1:	35

7.0.2. OPTION 2:	36
7.0.3. OPTION 3:	36
7.0.4. OPTION 4:	37
7.0.5. OPTION 5:	37
7.0.6. OPTION 6:	38
7.0.7. OPTION 7:	38
7.0.8. INFERENCE - SOLAR ANALYSIS:	39
7.0.9. CONCLUSION:	40
8.0. SHADOW ANALYSIS:	40
8.0.1. OPTION 2 – 22.5 °N:	40
8.0.2. OPTION 5 - 337.5 °NNW	41
9.0. WIND ANALYSIS:	41
9.0.1. OPTION 2 – 22.5 °N	41
9.0.2. Option 5 - 337.5 °NNW	42
9.1. CONCLUSION:	43
10.0. SITE ANALYSIS:	44
10.0.1. SITE ZONING:	44
10.0.2. SITE PLAN:	45
10.1. BLOCK A, B:	45
10.1.1. FLOOR PLANS:	45
10.2.1. WINDOW FLOOR RATIO – BLOCK A, B:	45
10.2.2. WINDOW WALL RATIO – BLOCK A, B:	46
10.2.3. SOLAR HEAT GAIN COEFFICIENT – BLOCK A, B:	46
10.2.4. RESIDENTIAL ENVELOPE TRANSMITTANCE VALUE:	47
10.2.5. RESIDENTIAL ENVELOPE TRANSMITTANCE:	48
10.2.6. INTERNAL LIGHT FIXTURE:	48
10.2.7. CROSS VENTILATION:	49
10.2.8. EXTERIOR CONNECTIVITY:	50
10.2.9. DAYLIGHT:	50

10.2.10. TIME LAG FOR THE DIFFERENT OF SUSTAINABLE ROOF:	50
10.2.11. TIME LAG:	50
11.0. BLOCK C, D:	51
11.1.1. FLOOR PLANS:	51
11.2.1. WINDOW FLOOR RATIO – BLOCK C, D:	52
11.2.2. WINDOW WALL RATIO – BLOCK C, D:	52
11.2.3. SOLAR HEAT GAIN COEFFICIENT – BLOCK C, D:	53
11.2.4. RESIDENTIAL ENVELOPE TRANSMITTANCE – BLOCK – C , D:	53
11.2.5. RESIDENTIAL ENVELOPE TRANSMITTANCE:	54
11.2.6. INTERNAL LIGHT FIXTURE:	54
11.2.7. CROSS VENTILATION:	55
11.2.8. EXTERIOR CONNECTIVITY:	55
11.2.9. DAYLIGHT:	56
12.0. BLOCK E:	56
12.1.1. FLOOR PLANS:	56
12.2.1. WINDOW FLOOR RATIO – BLOCK E:	56
12.2.2. WINDOW WALL RATIO – BLOCK E:	57
12.2.3. SOLAR HEAT GAIN COEFFICIENT:	57
12.2.4. RESIDENTIAL ENVELOPE TRANSMITTANCE – BLOCK - E:	58
12.2.5. RESIDENTIAL ENVELOPE TRANSMITTANCE:	59
12.2.6. INTERNAL LIGHT FIXTURE:	59
12.2.7. CROSS VENTILATION:	60
12.2.8. EXTERIOR CONNECTIVITY:	60
12.2.9. DAYLIGHT:	61
13.0. RAINFALL RUNOFF CALCULATION:	61
14.0. CONCLUSION:	62
REFERENCES	78
ANNEXURES	78

LIST OF TABLES

<i>Table 1.1 Methodology of the design process</i>	03
<i>Table 0.2 Framework analysis of Retrofit Net Zero Energy Building .</i>	04
<i>Table 2.1 On-site and Off-site energy efficient measures.</i>	07
<i>Table 2.2 LEED certification and points.</i>	09
<i>Table 2.3 LEED criteria and credits.</i>	10
<i>Table 2.4 Energy efficiency in commercial building.</i>	12
<i>Table 2.5 Energy simulation and its comparative analysis.</i>	19
<i>Table 3.0 Comparative analysis of various journal and its inference.</i>	24
<i>Table 4.1 Project description of alliance center.</i>	25
<i>Table 4.2 Energy performance of commercial building.</i>	26
<i>Table 4.3 Load reduction measures and its parameter.</i>	35
<i>Table 4.4 Energy conservation and its cost effective measure.</i>	37
<i>Table 4.5 Energy performance of baseline building.</i>	38

LIST OF FIGURES

<i>Fig 2.1 Energy Efficiency and green measure.</i>	<i>05</i>
<i>Fig 2.2 Average energy consumption in building.</i>	<i>06</i>
<i>Fig.2.3 Energy efficiency and green conservative measures.</i>	<i>06</i>
<i>Fig 2.4 Energy efficiency by lighting control.</i>	<i>13</i>
<i>Fig 2.5 Energy conservation by lighting control system.</i>	<i>14</i>
<i>Fig 4.1 Monitoring system in alliance center.</i>	<i>28</i>
<i>Fig 4.2 The byron g. rogers federal office building, denver.(top)</i>	<i>31</i>
<i>Fig 4.3 Building sectional view of cooling and heating mode.(below)</i>	<i>32</i>
<i>Fig .4.4 Axonometric view of federal office building.</i>	<i>33</i>
<i>Fig 4.5 The Aventine office building</i>	<i>37</i>
<i>Fig 6.1 Aerial view and building view of Ramaniyam building</i>	<i>44</i>
<i>Fig 6.2 Building view in various aspects.</i>	<i>45</i>
<i>Fig 6.3 Occupancy load of the building.</i>	<i>45</i>
<i>Fig 6.4 Spatial planning of the building.</i>	<i>46</i>
<i>Fig 6.5 Sectional topographic analysis of the site.</i>	<i>47</i>
<i>Fig 6.6 View of chiller plant and Air handling unit</i>	<i>47</i>
<i>Fig 6.7 HVAC sectional layout in the building</i>	<i>48</i>

1.1 INTRODUCTION

According to scientists and researchers, the human impact on global warming is now a given fact. The burning of fossil fuels and consequent greenhouse emissions are deeply affecting the planet at a global scale. The building sector alone accounts for more than half of the primary energy consumption globally and consequently for the same portion of greenhouse gas emissions. There is hence an urgent need to tackle this serious problem, turning the building sector into part of the solution, and contribute towards a more sustainable world. The belief that earth as a building material can play a key role in a new more environmentally conscious building paradigm is currently being supported by numerous experts who point out its environmental, cultural and economic advantages when compared to other, more commonly used building materials. Furthermore, due to its qualities, earth has a lower impact when compared to more conventional building materials. The raw-material to be used in the construction is usually dug from the site, and even if some mechanized system is required to dig, mix or place the earth, the construction process still has a lower embodied energy than a similar construction in brick, concrete or steel. reinforces this idea and remarks that, in the context of the locally built houses, there is no other construction technique that can compete with the earthen ones in terms of its low environmental impact.

1.2 AIM:

To enhances the indoor thermal comfort and energy performance of cohousing in earth construction for warm and humid climate.

1.3 RESEARCH QUESTION IDENTIFIED:

- What is the effect of sharing facilities and collective use of space on community building in co-living?
- What are the effects of using earth as a building material in co living and in which extent it promotes indoor thermal comfort in a warm and humid climate?
- What are the main key Factors can have used for sustainability in co living?

1.4 OBJECTIVE:

- To explore the emergence and characteristics of co-living in the Auroville
- explain the influence of sharing and collectivity on community building among residents in co-living typologies.
- To achieve the thermal comfort of earth building using passive strategies
- To evaluate the indoor thermal performance of earth building with various parameters in the warm and humid climate.

1.6 SCOPE AND LIMITATION:

- This empirical study is social sustainability which limited by characterized by a smaller private space compensated by several shared facilities and collective spaces.
- The scope of the study is reduction of virgin raw materials and using locally available materials for construction to reduce the embodied energy and transportation cost of the materials.
- The study is limited in warm and humid climate and the onsite monitor of the thermal comfort of materials and comparative analysis will be done in future study.

2.0. CLIMATE ANALYSIS:

2.1 AVERAGE HIGH AND LOW TEMPERATURE:

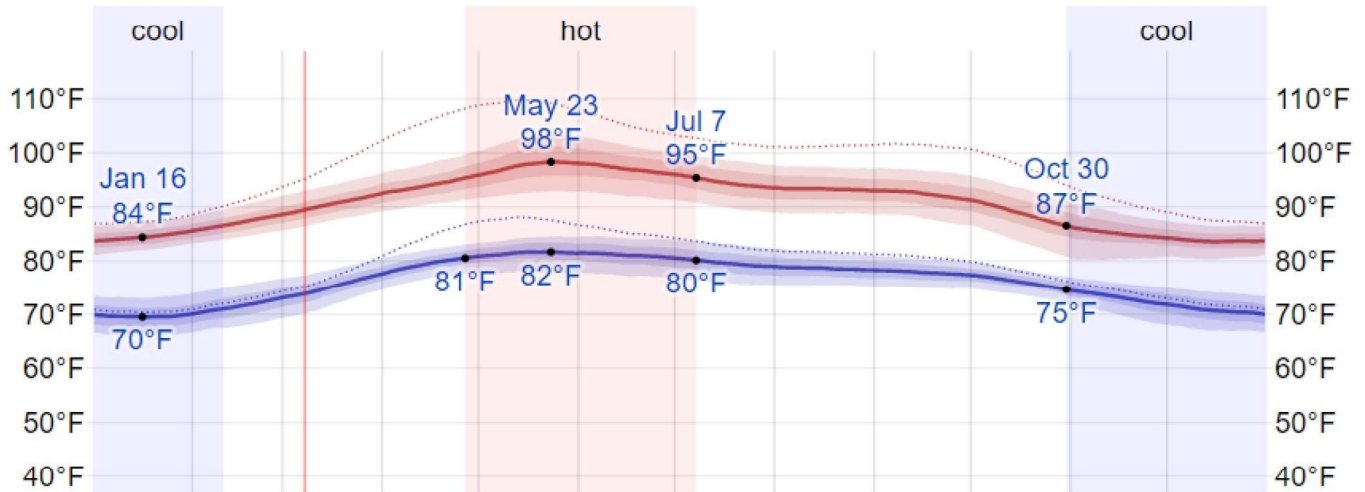


Fig : 1.1:Chart Of Average High And Low Temperature

In Auroville, the wet season is overcast, the dry season is windy and mostly cloudy, and it is hot and oppressive year round. Over the course of the year, the temperature typically varies from 21.1°C to 36.6°C and is rarely below 18.8°C or above 39.4°C.

2.2 CLOUD COVER CATEGORIES:

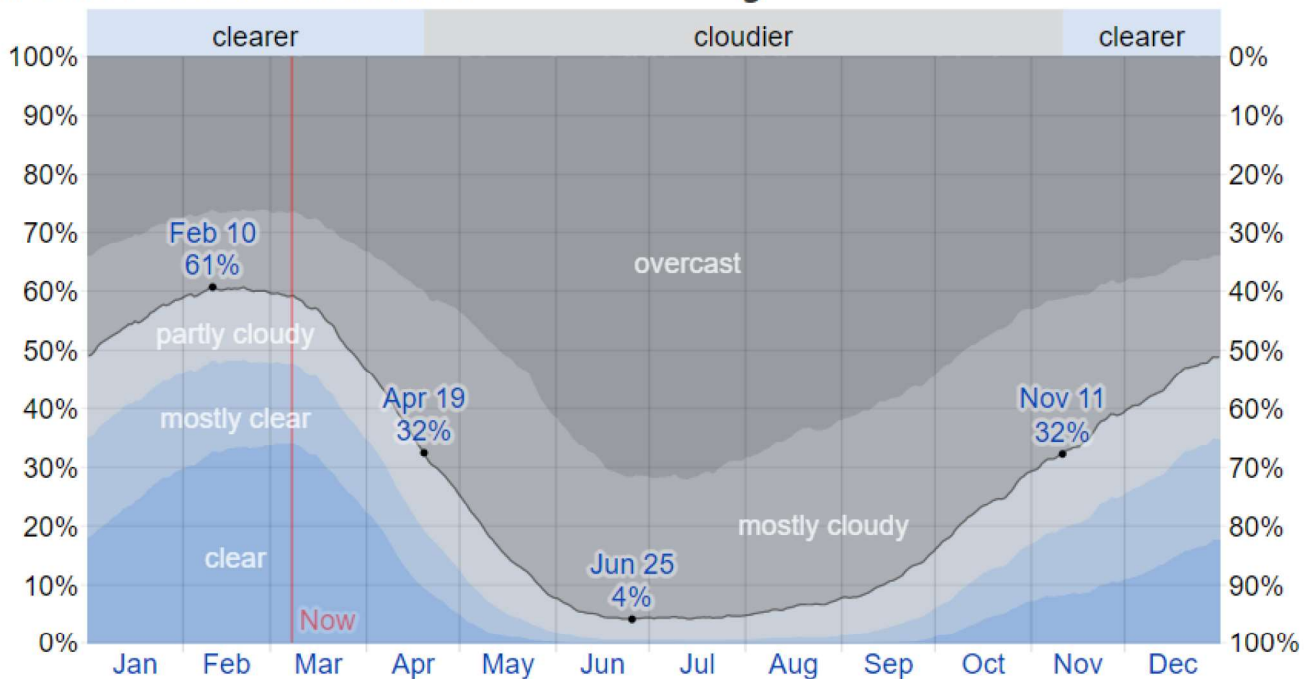
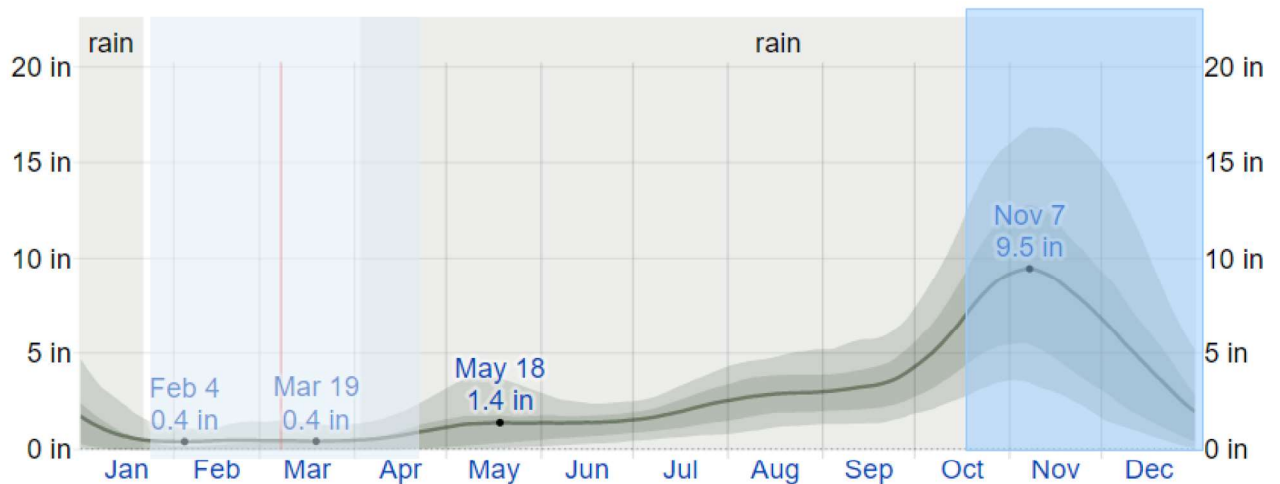


Fig : 1.2:Chart Of Cloud Cover

The clearer part of the year in Auroville begins around November 11 and lasts for 5.3 months, ending around April 19. The cloudier part of the year begins around April 19 and lasts for 6.7 months, ending around November 11.

2.3 AVERAGE MONTHLY RAINFALL:



The rainy period of the year lasts for 9.6 months, from April 2 to January 22, with a sliding 31-day rainfall of at least 0.5 inches. The rainless period of the year lasts for 2.4 months, from January 22 to April 2. The least rain falls around February 4, with an average total accumulation of 0.4 inches.

2.4 TEMPERATURE RANGE:

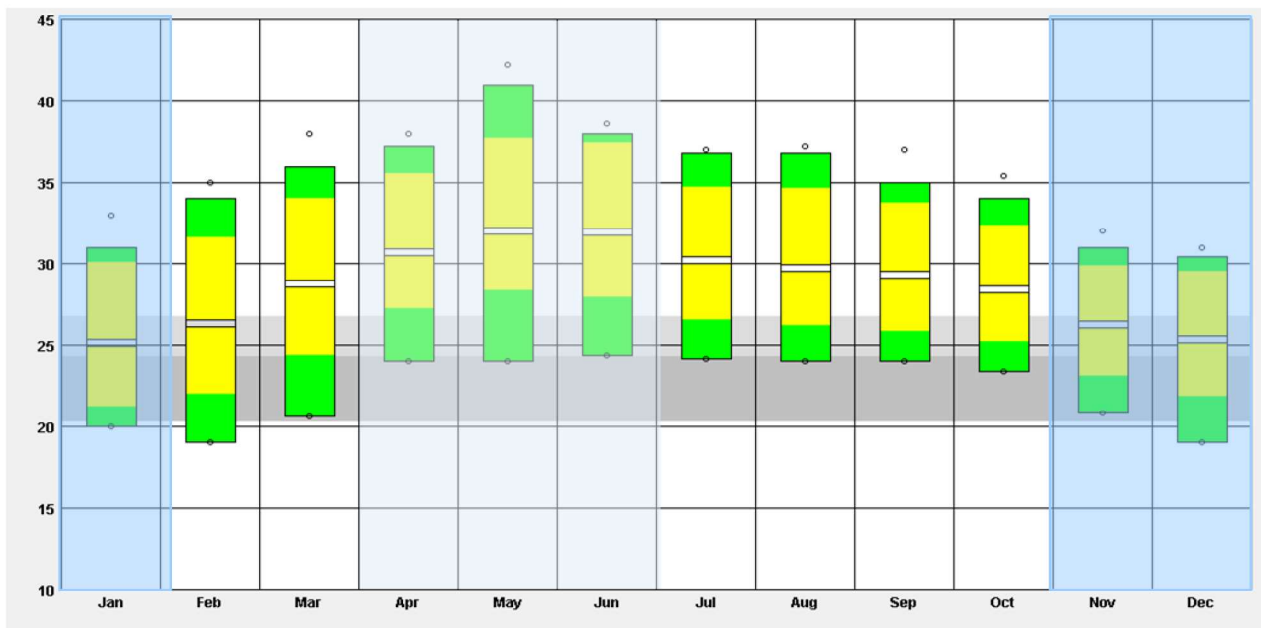


Fig: 1.4: Chart of Temperature Range

In Auroville, the wet season is overcast, the dry season is windy and mostly cloudy, and it is hot and oppressive year round. Over the course of the year, the temperature typically varies from 21.1°C to 36.6°C and is rarely below 18.8°C or above 39.4°C.

2.5 SKY COVER:

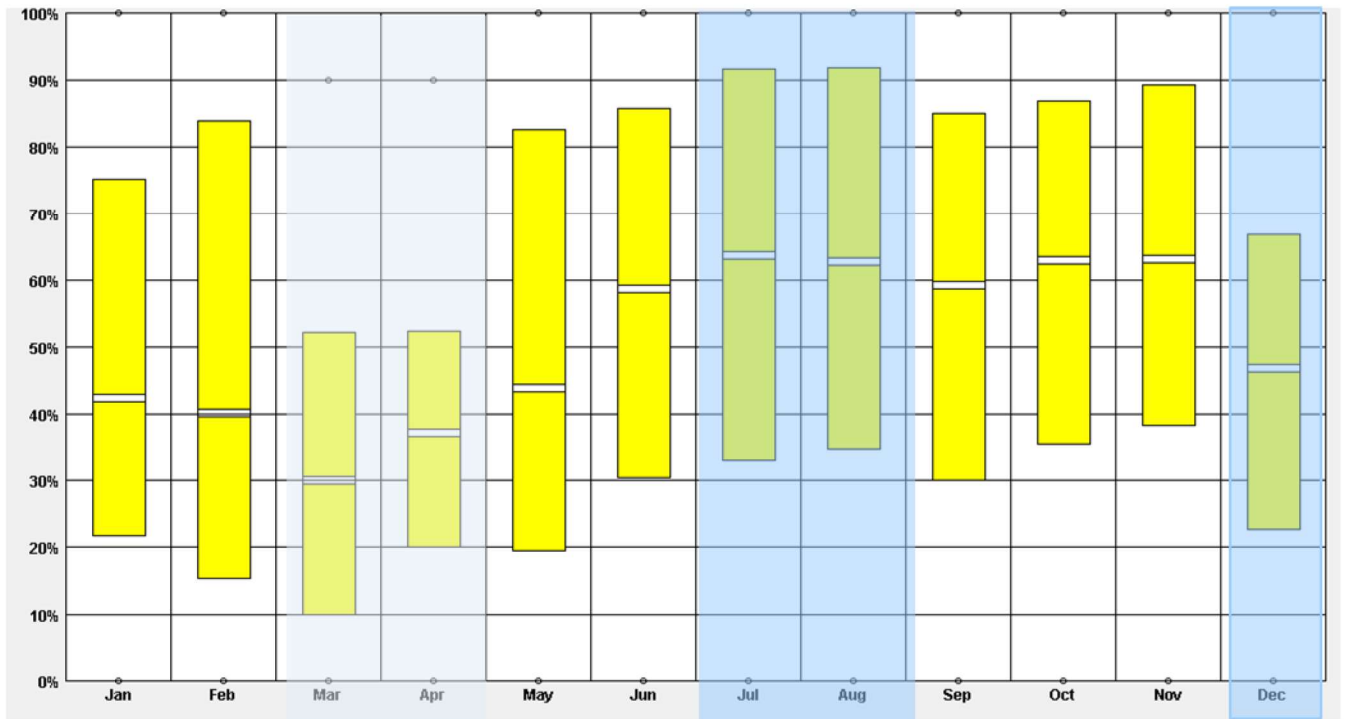


Fig: 1.5: Chart of Sky Cover

2.6 MONTHLY DIURNAL AVERAGE:

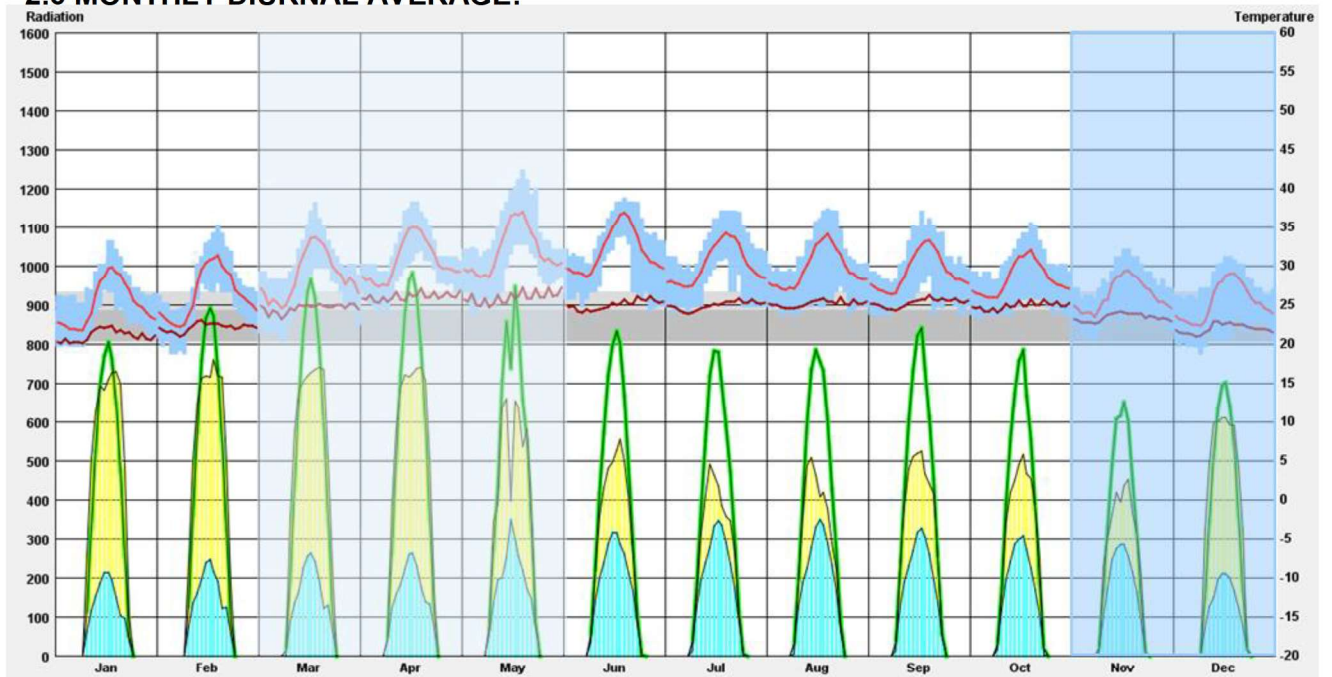


Fig: 1.5: Chart of Monthly Diurnal Average

2.7 RADIATION RANGE:

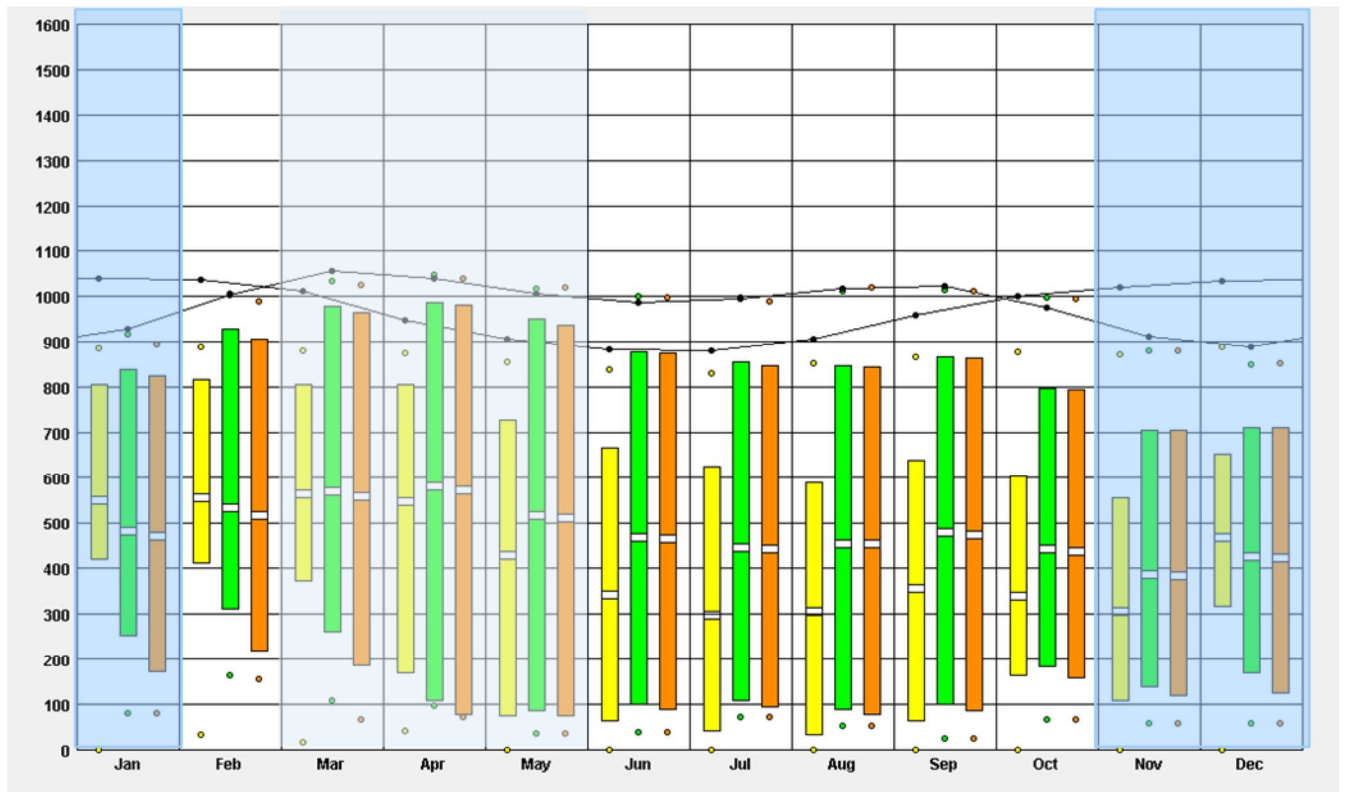


Fig: 1.6: Chart of Radiation Range

Fig: 1.6: Chart of Dry Bulb & Humidity

1.9 ILLUMINANCE RANGE:

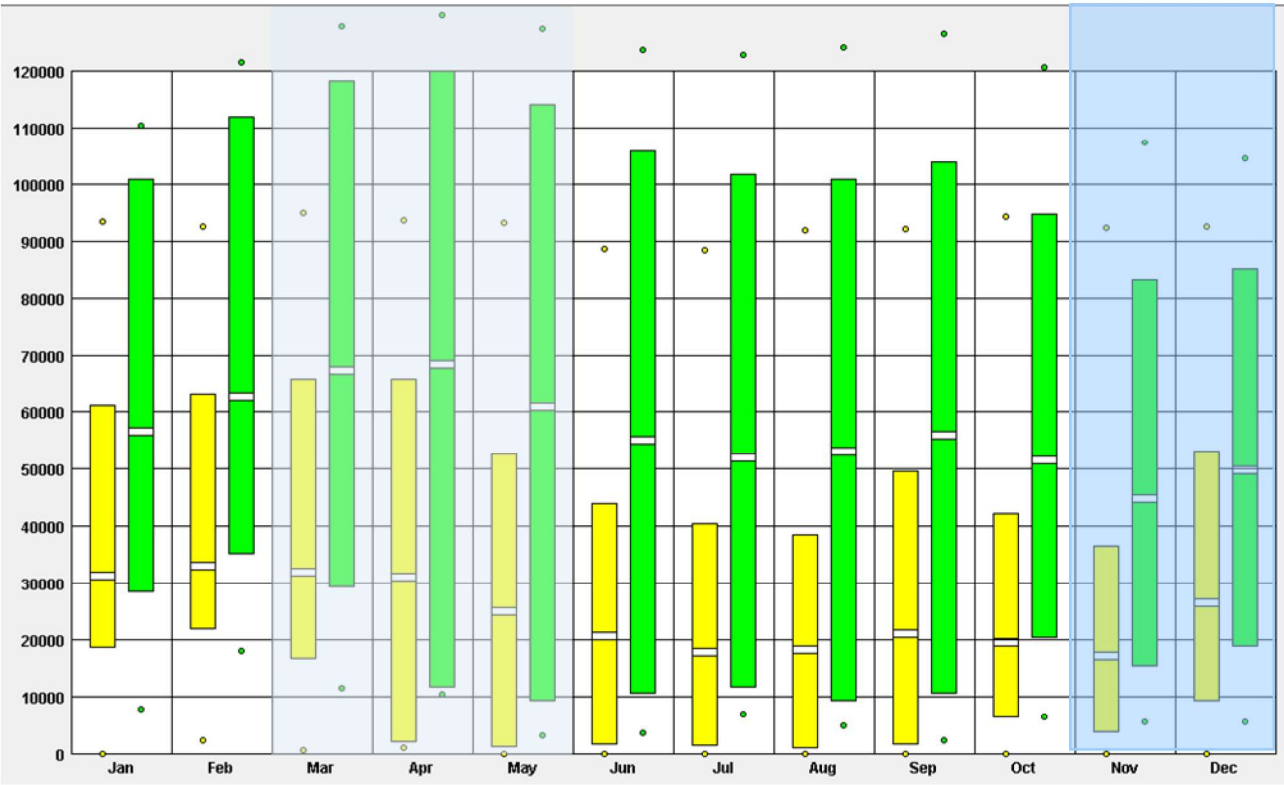


Fig: 1.6: Chart of Illuminance Range

2.10 WIND ROSE: JAN – DEC:

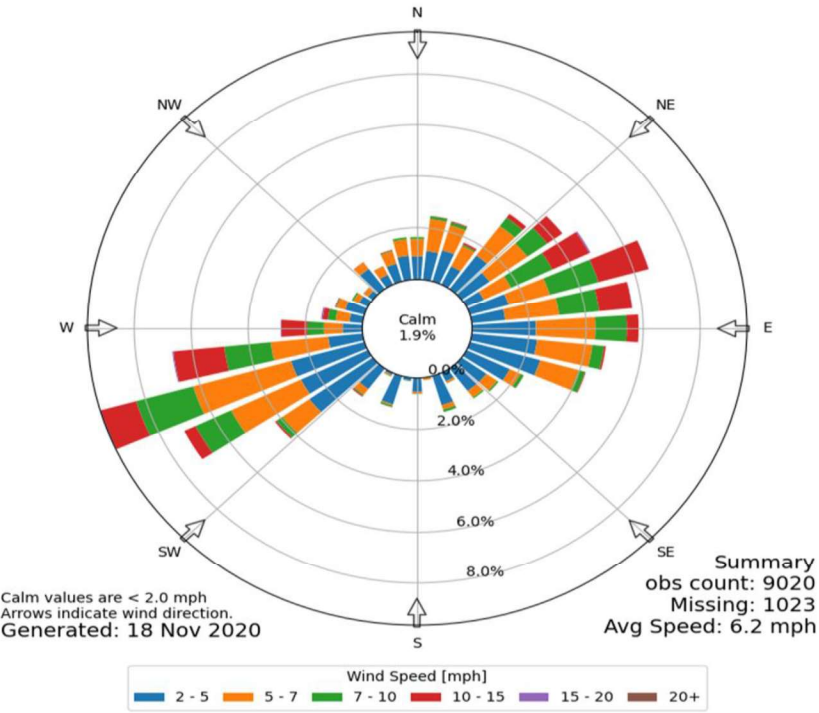


Fig: 1.6: Chart of WIND ROSE for Jan – Dec

The highest wind speed recorded on June and July

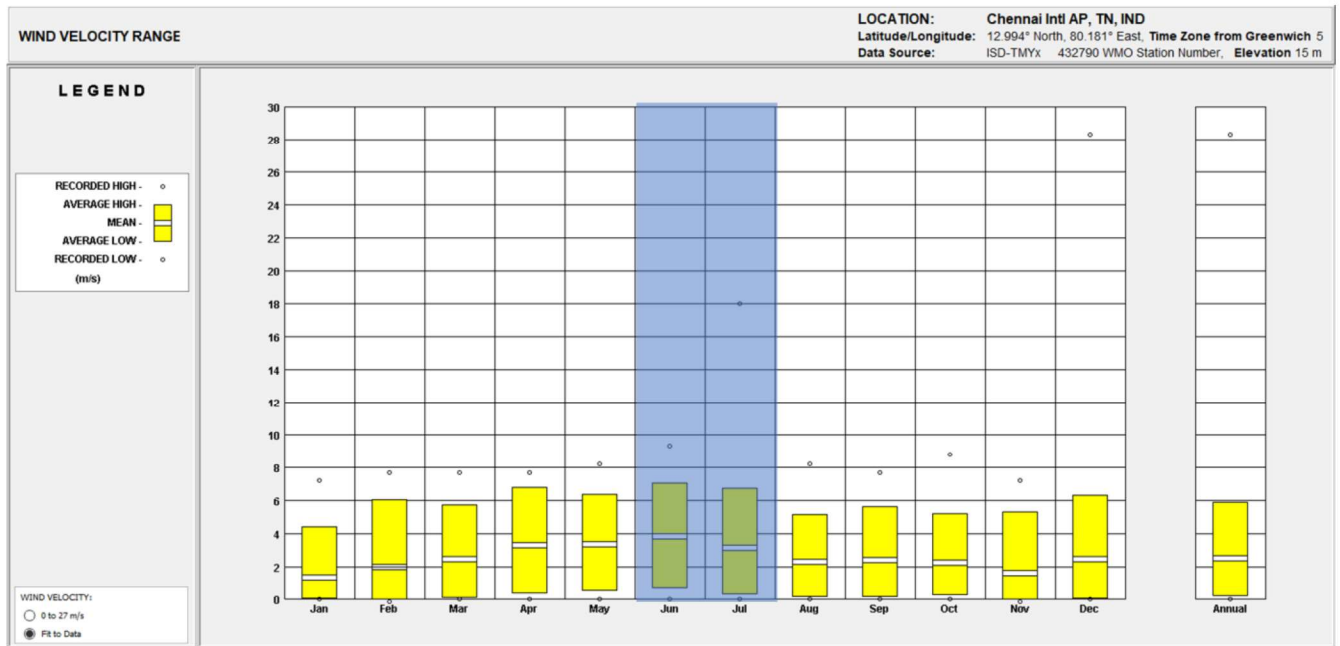
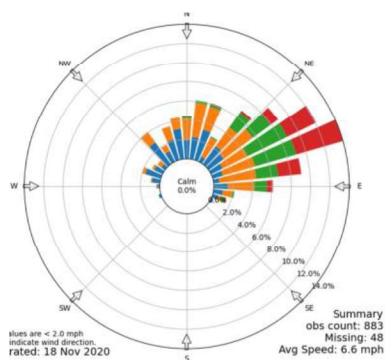
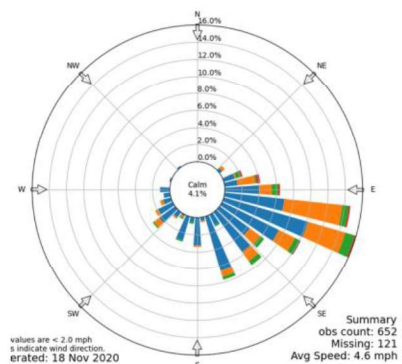


Fig: 1.6: Chart of Wind Velocity Range

2.11 WIND ROSE:



January



APRIL

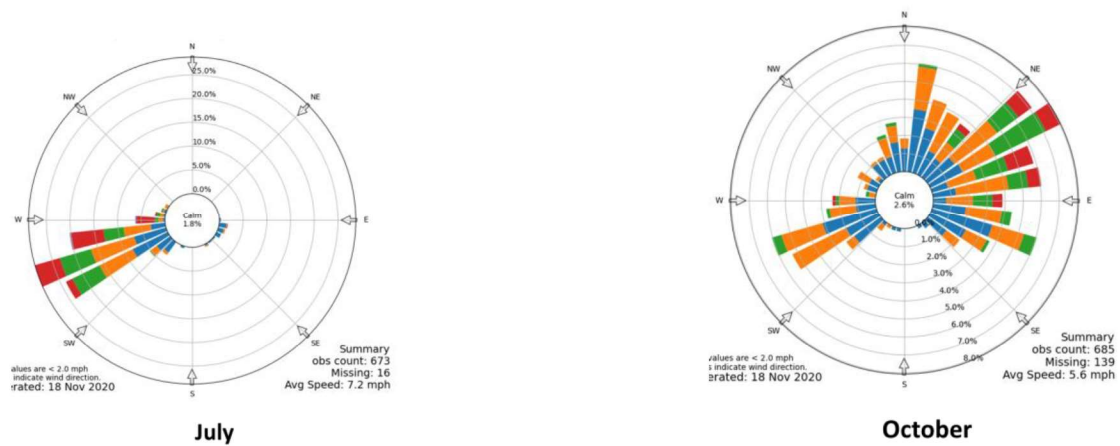


Fig: 1.7: Charts of Wind Rose

The predominant wind direction from southwest to north east. Average wind speed 2.3 m/s

2.12 Time Table Plot – Dry Bulb

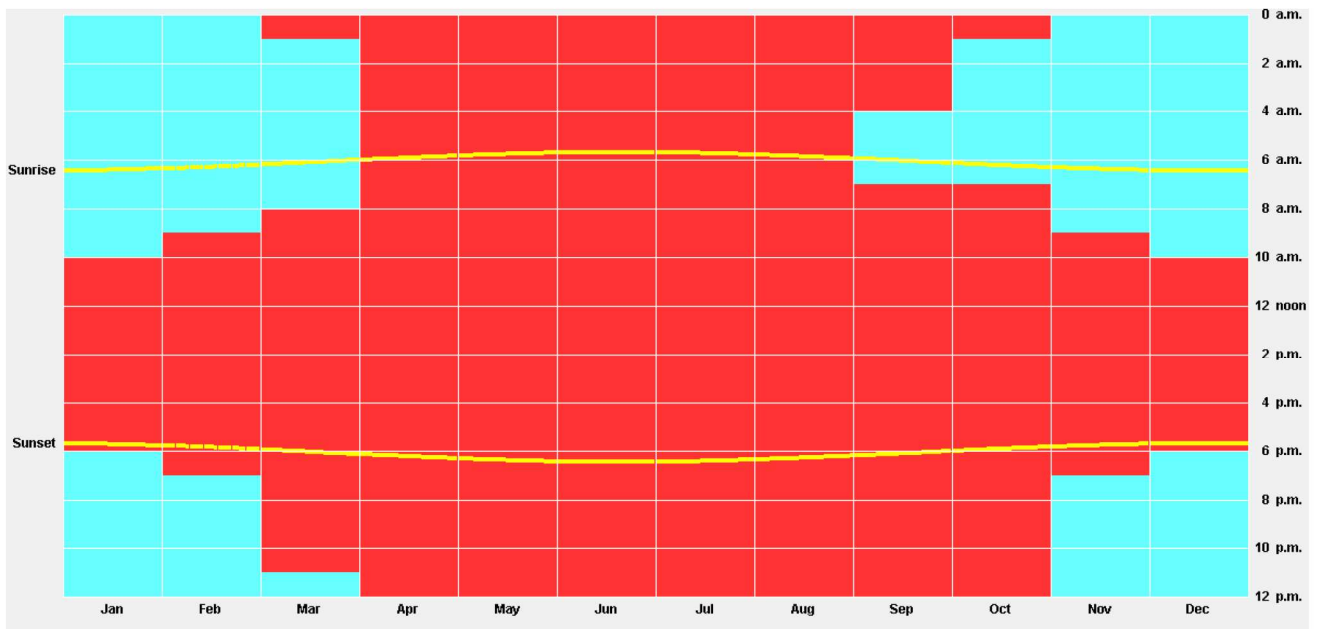


Fig: 1.8: Charts of Time Table Plot – Dry Bulb

According to **Time Table Plot** dry bulb temperature from **April to august** is uncomfortable months in year

1.13 PSYCHROMETRIC CHART

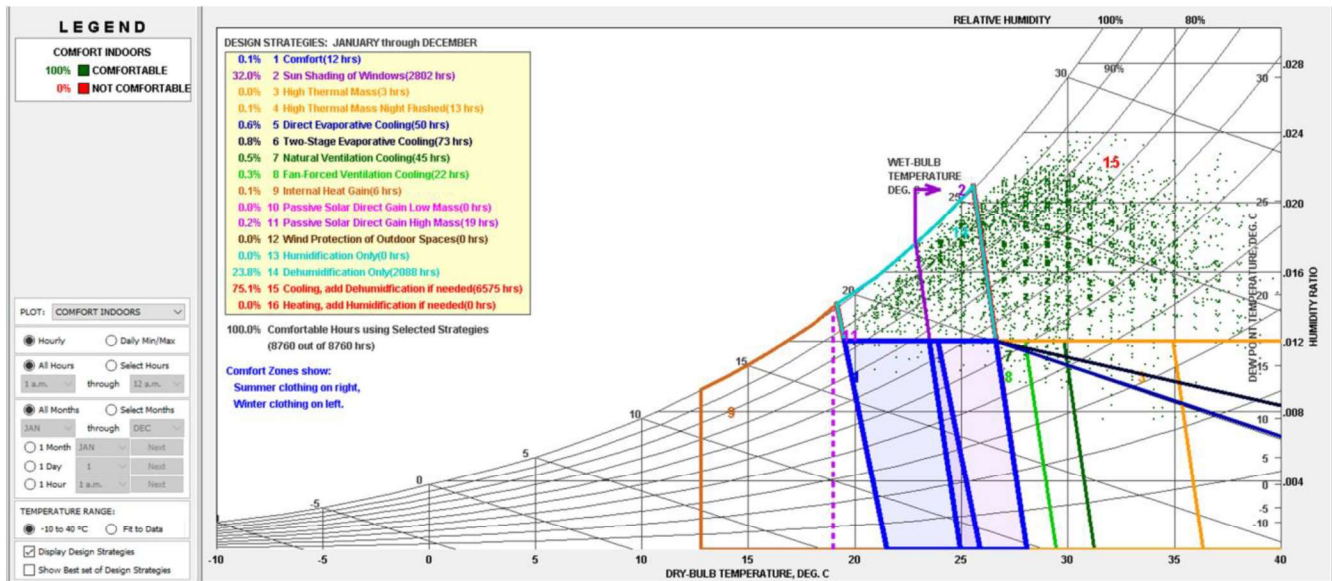


Fig: 1.8: Chart for psychrometric

According to Psychrometric chart **30.4% comfortable indoor** can be achieved by **Sun shade of windows(2802hrs)**

23.3% comfortable indoor can be achieved by **Dehumidification only (2088hrs)**.

75.1% comfortable indoor can be achieved by **Cooling, add dehumidification needed (6575hrs)**.

1.14 Sun chart Dec - Jun

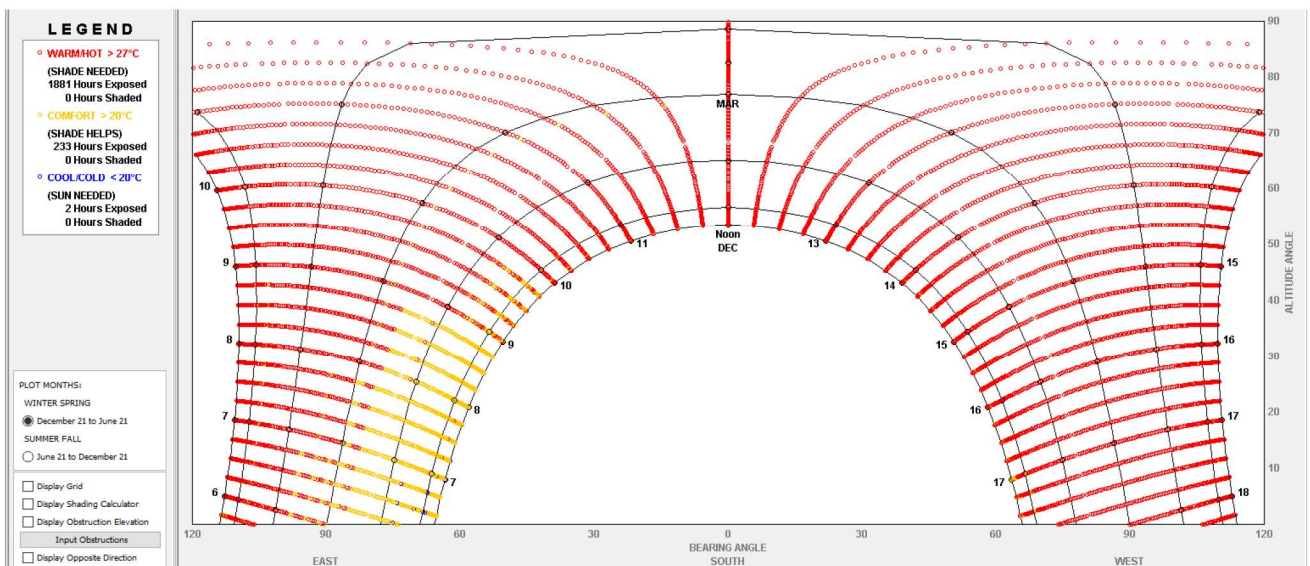


Fig: 1.9: Chart for Sun chart Dec - Jun

According to sun chart from **Dec to Jun 1881 hour** are hot, which greater than 27°C.
233 Hours are comfortable hours in a year which greater than 20°C
 hours in a year which less than 20°C

1.15 Sun chart Jun - Dec

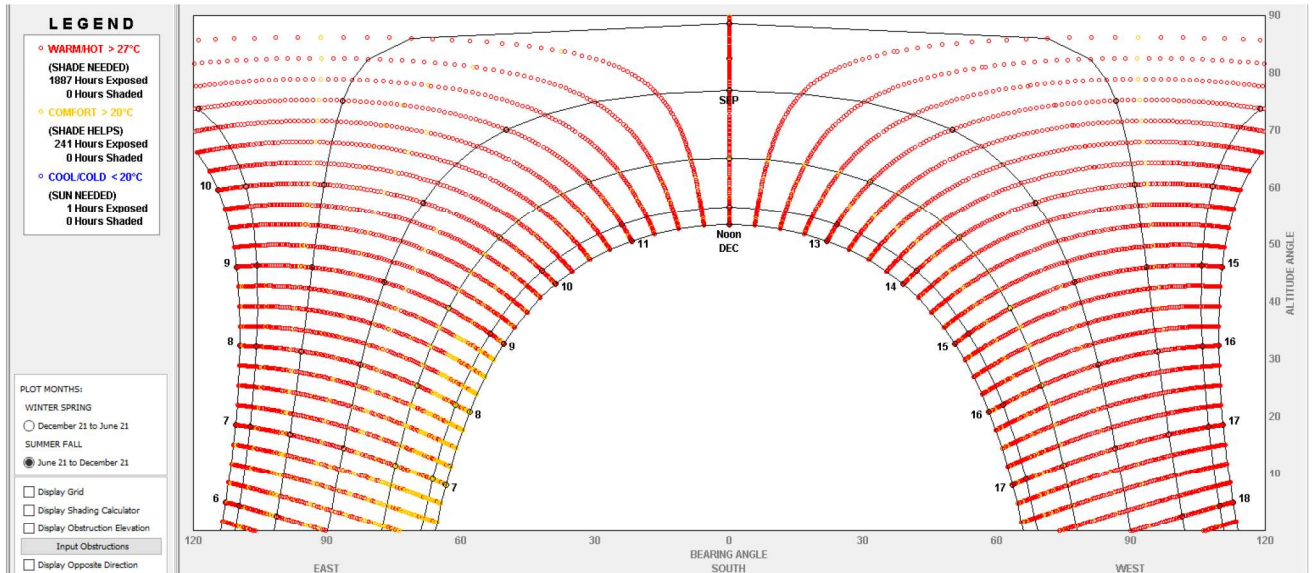
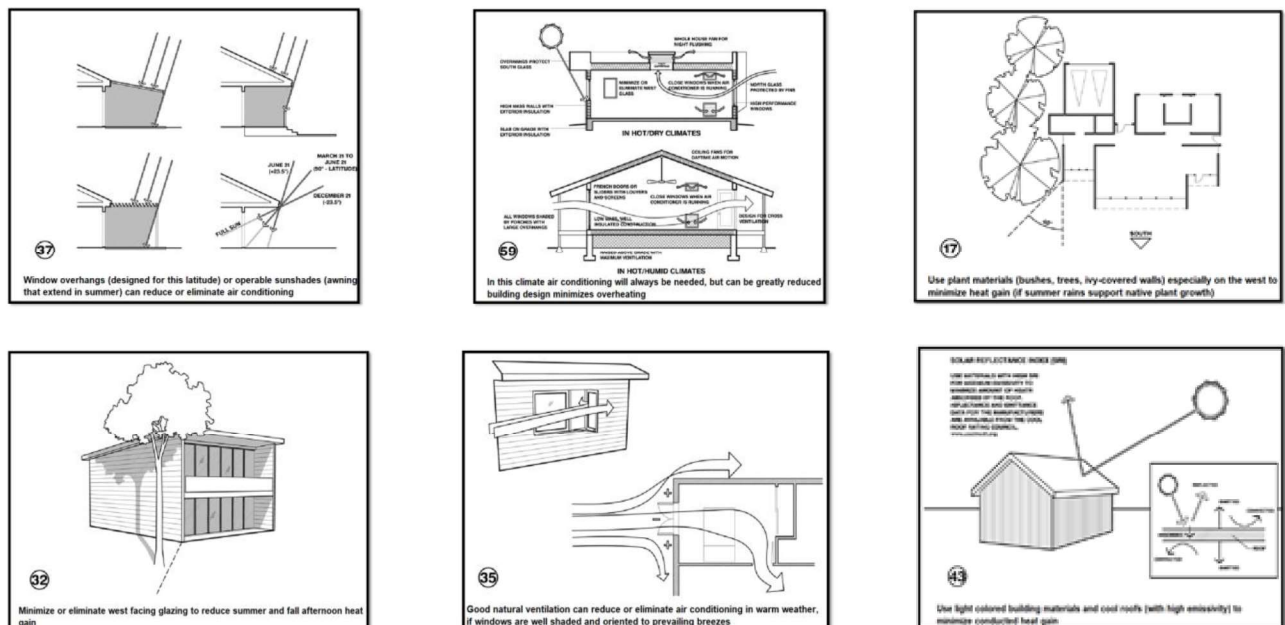


Fig. 1.9: Chart for Sun chart Jun - Dec

According to sun chart from Jun to Dec 1887 hour are hot, which greater than 27°C. 241 Hours are comfortable hours in a year which greater than 20°C .1 Hours are Cold hours in a year which less than 20°C.

2.16 DESIGN STRATEGIES – CLIMATE CONSULTANT:



2.17 Table for Indian adaptive comfort model:

Months	Min .temp	Max.temp	Avg.temp	Netural	Lower Limit	Upper Limit
Jan	21.9	27.5	24.7	26.168	23.788	28.548
Feb	22.3	28.9	25.6	26.654	24.274	29.034
Mar	24.1	30.7	27.4	27.626	25.246	30.006
Apr	26.7	32.4	29.55	28.787	26.407	31.167
May	28	33.9	30.95	29.543	27.163	31.923
Jun	27.7	33.7	30.7	29.408	27.028	31.788
Jul	27.3	33.3	30.3	29.192	26.812	31.572
Aug	26.7	32.5	29.6	28.814	26.434	31.194
Sep	26.3	31.9	29.1	28.544	26.164	30.924
Oct	25.1	30.1	27.6	27.734	25.354	30.114
Nov	23.7	28.2	25.95	26.843	24.463	29.223
Dec	22.5	27.3	24.9	26.276	23.896	28.656

Table 1.1: Table for Indian adaptive comfort model

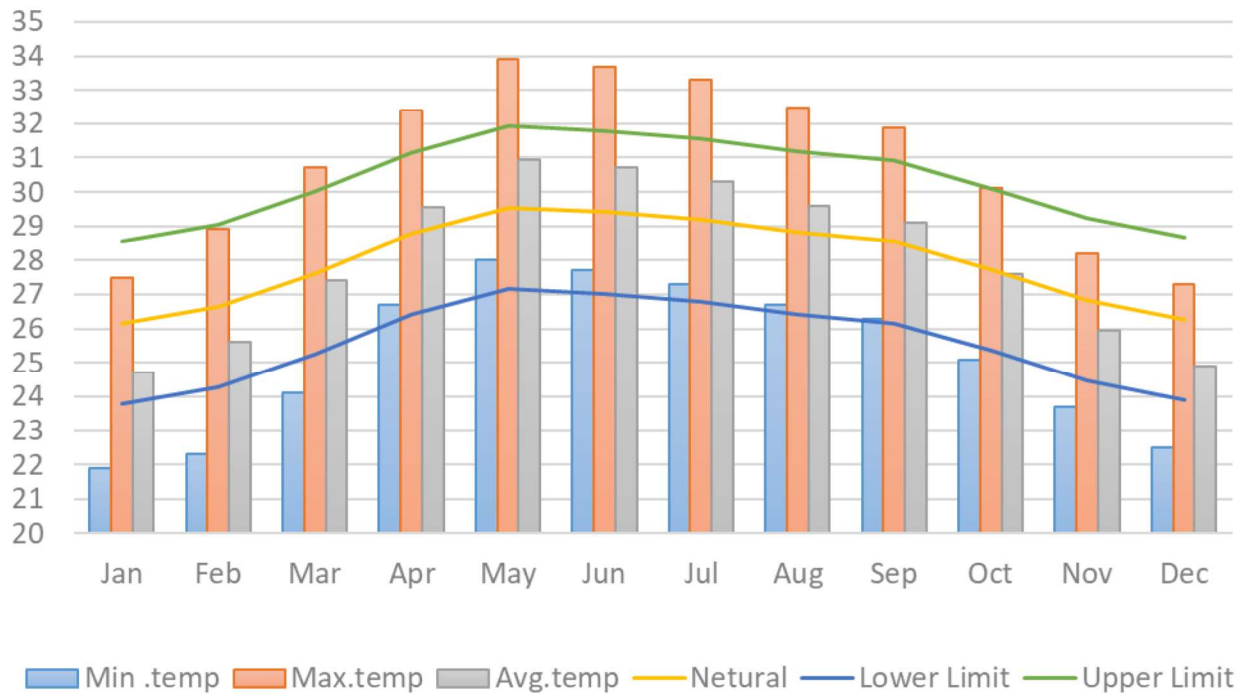
2.18 For Naturally ventilated (NV) buildings:

The following equation should be used for design and operation of naturally ventilated (NV) buildings. It indicates that occupants in NV buildings thermally adapt to the outdoor temperature of their location. It is based on the 30-day outdoor running mean*.

Equation: Indoor Operative Temp. (°C) = 0.54 * outdoor temp. + 12.83

Where indoor operative temperature (°C) is neutral temperature, and outdoor temperature is the 30-day outdoor running mean air temperature (°C) The 90% acceptability range for the India specific adaptive models for naturally ventilated buildings is **±2.38°C.**

Indian adaptive comfort model



Graph 1.1: Indian adaptive comfort model

2.20 COMFORT BAND FOR AUROVILLE:

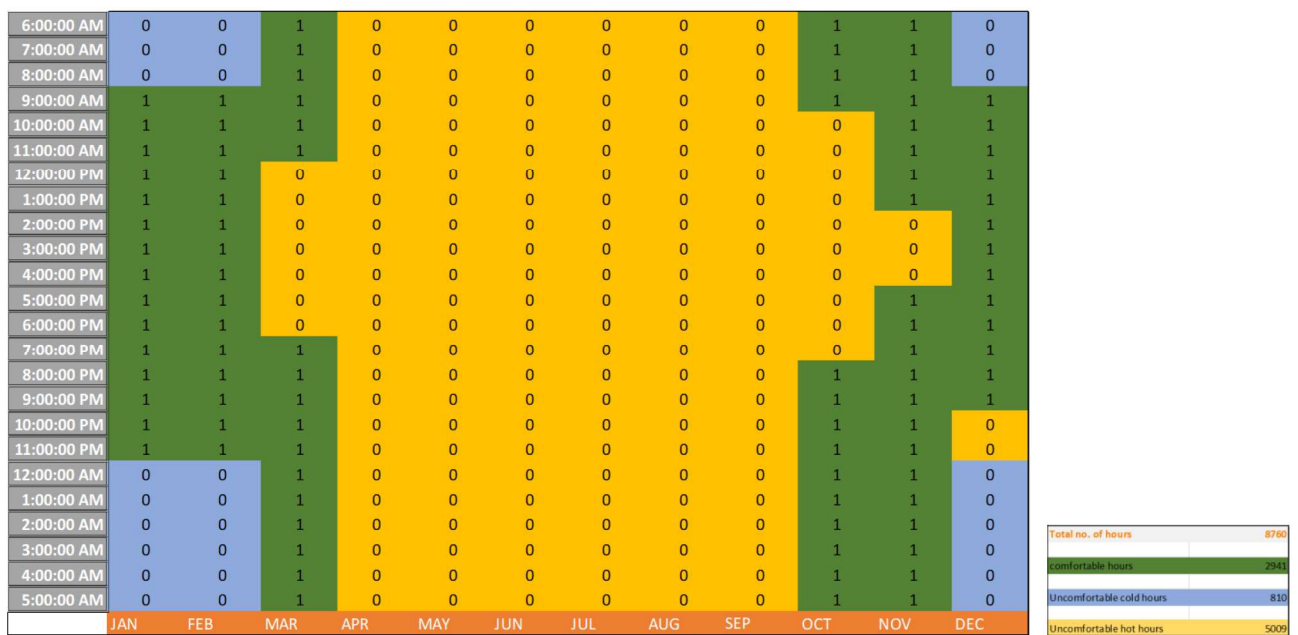


Fig: 1.10: Comfort Band

According to comfort band the month of **April to September** which experienced uncomfortable **hours**

AIR TEMPERATURE DEGREE CELSIUS												
	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEP	OCT	NOV	DEC
MONTHLY MEAN MAX	27.5	28.9	30.7	32.4	33.9	33.7	33.3	32.5	31.9	30.1	28.2	27.3
MONTHLY MEAN MIN	21.9	22.3	24.1	26.7	28	27.7	27.3	26.7	26.3	25.1	23.7	22.5
MONTHLY MEAN RANGE	24.7	25.6	27.4	29.55	30.95	30.7	30.3	29.6	29.1	27.6	25.95	24.9

RELATIVE HUMIDITY %												
	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEP	OCT	NOV	DEC
AVERAGE HUMIDITY GROUP	74	73	74	75	70	65	64	68	73	79	80	77
Y GROUP	4	4	4	4	4	3	3	3	4	4	4	4

RAINFALL AND WIND:												
RAINFALL MM	23	13	22	34	48	48	60	93	104	228	259	132

Table 1.2: Mahoney's table.

2.21 OVER HEATING PERIOD:

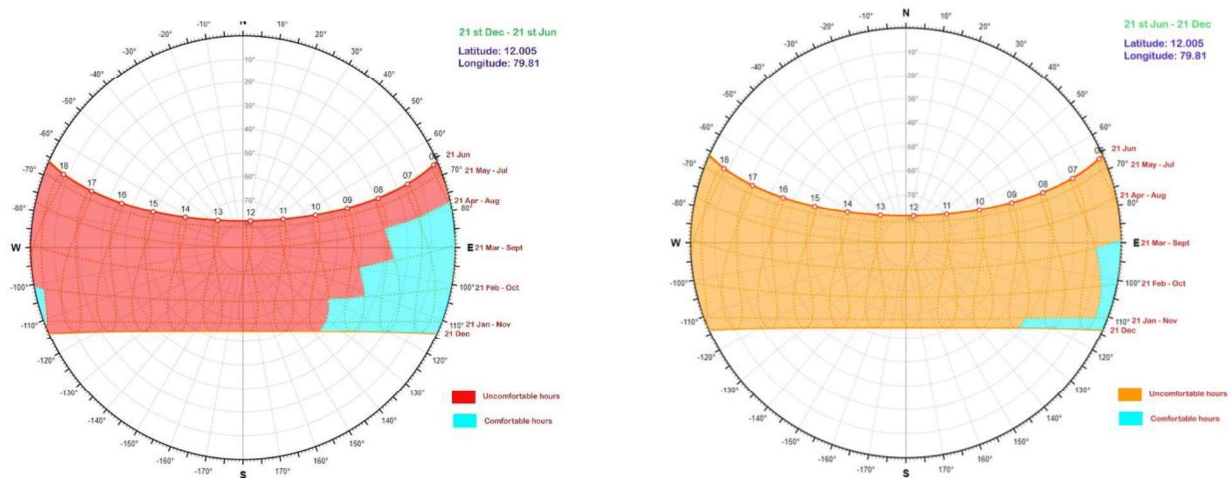


Fig: 1.11: Over Heating Period

During month of May – July the air temperature is high around 33.3 to 33.9 °C

Relative Humidity is high on Oct. Nov which 79 to 80%.

The highest rainfall record on Nov which is 259mm.

3.0. VIKAS LAY-OUT:

The creation of this community was based on a particular spirit, life style and appropriate architectural design. It was related to Sri Aurobindo's integral yoga and Auroville ideal.

The extensive use of **environmentally sound materials, appropriate building technologies, (earth and Ferro cement), renewable energies (solar and wind) and ecological water management (watershed harvesting and biological waste water treatment),** were the basis of its material implementation.

Individual apartments, a few individual houses and common facilities were built. The community was built in several steps, from **1992 to 1998**, and the **third block of thirteen apartments was built on four floors: a basement floor with three floors above it.** The concept of this building was such that it should be self-sufficient for its soil needs.

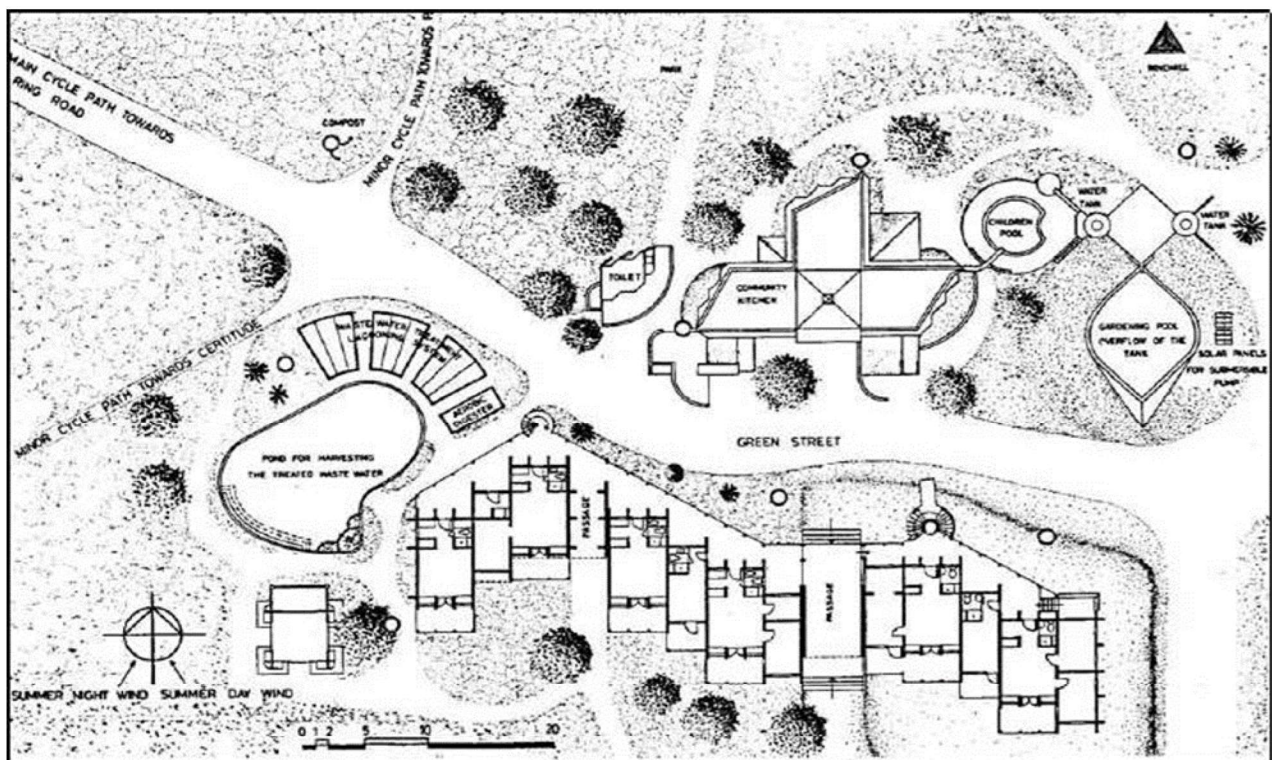


Fig: 2.1 VIKAS LAY-OUT – 1448 m² carpet area, collective kitchen and toilets 23 apartments, collective kitchen and toilets for 50 people for 50 people



Fig: 2.2 Excavation of the basement floor – 1.2 m below the third building



Fig: 2.2 Excavation of the basement ground level

The **soil was dug from the basement floor (1.20m below the original ground level) to produce compressed stabilised earth blocks for building the structure of 819 m², carpet area, on 4 floors.**

The foundations were done with **stabilised rammed earth** and the **13.40m high walls were done with CSEB of 24 cm thick.**

All floors and roofs were made of very flat vaults and domes for the living rooms. These vaults and domes were built with CSEB, by using the “Free-spanning” technique. **All stabilisation used 5 % cement by weight.**

3.1 UNIQUE FEATURES OF THE THIRD BUILDING:

Earth was used, from the first developments of Vikas, in all parts of the buildings, from foundations to roof. The proper management of earth resources was always the first priority. The quarries where the soil was taken from were always planned first. This procedure allowed a perfect integration of the excavations with the buildings and landscape.

The first and second developments of the collective kitchen and **10 apartments on two floors** could integrate the quarries as **a garden reservoir and for wastewater treatment.** The soil needs for these developments were already exceeding the outcome of excavations, and some soil had to be supplied from elsewhere.

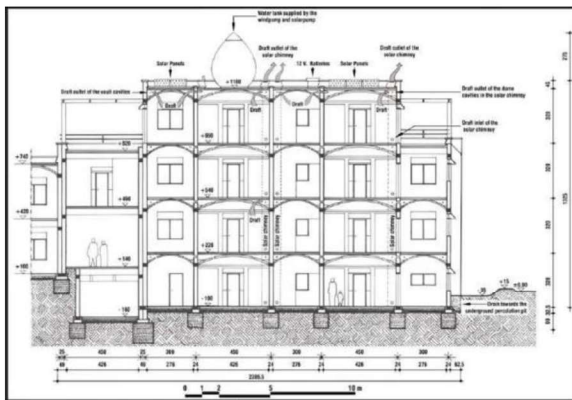


Fig: 2.3 Section of the third building

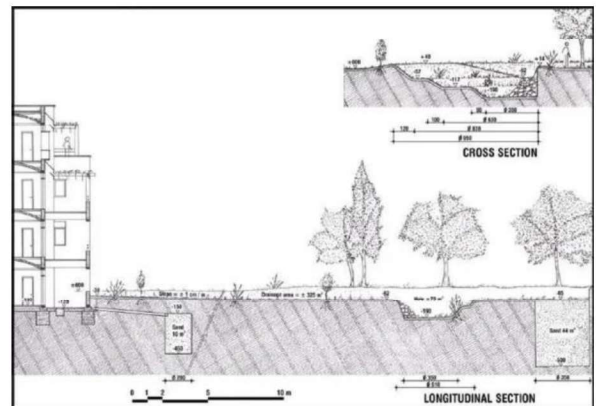


Fig: 2.4 Percolation system of the third building



Fig: 2.5 Principle for the percolation pit

To protect the basement from the **inflow of rainwater a particular landscape was designed**. The immediate surrounding has been shaped like **a shallow crater to drain rainwater into a percolation pit**. This landscape design generated even more soil than needed for the building sites at Vikas. It was given to other projects in Auroville, which could not implement the concept of a basement floor.

To protect the basement from the **inflow of rainwater a particular landscape was designed**. The immediate surrounding has been shaped like **a shallow crater to drain rainwater into a percolation pit**. This landscape design generated even more soil than needed for the building sites at Vikas. It was given to other projects in Auroville, which could not implement the concept of a basement floor.

MAIN SPECIFICATIONS OF THE THIRD BUILDING

WORK	TECHNIQUE
FOUNDATIONS	Stabilised rammed earth
BASEMENT	AURAM plain blocks 240
PLINTH BEAM	RCC plinth beam cast in a block shuttering with AURAM blocks 240 – ½ size
BASEMENT WATERPROOFING	- Walls: with bitumen paint on a stabilised earth plaster - Floor: with a layer of pebbles
BASEMENT DRAIN	- Underground drainage, (ø3" slotted PVC pipe) sent to an underground percolation pit - Surface drainage with a percolation pit
GALLERIES' FLOORING	AURAM tiles 240
APARTMENTS FLOORING	The choice was left to people: CSEB, terracotta or ceramic tiles
WALLS	AURAM plain blocks 240
RING BEAMS	Composite ring beam with AURAM U blocks 240 and RCC
SPRINGER BEAMS	RCC beams for resting vaults and domes
LINTELS	Composite lintel, single height, with AURAM U blocks 240 and RCC
COLUMNS	Composite pillar with AURAM round hollow blocks 240 and RCC
FLOORS AND ROOFS	- Flat vaults and domes with AURAM blocks 240, laid without support - Precast ferrocement channels
PLASTERS	Stabilised earth plasters for some walls

Fig: 2.6 Main specification of the third building



Fig: 2.7 green street” for motor an apartment



Fig: 2.8 Living room in the third building free vehicles



Fig: 2.9 Bedroom of with a vault

3.2. HUMANSCAPE HABITAT URBAN LIVING:

The “HUMANSCAPES HABITAT- is an applied research and demonstration project of Sustainable and Integrated Urban Living Project” for benchmarking in habitat as a course correction for a sustainable and harmonious model of development which is an imperative need in the present global crisis of energy and climate change. This **mixed-use development of residences, community, and workspace** would be a touchstone for standards for low-embodied energy building.

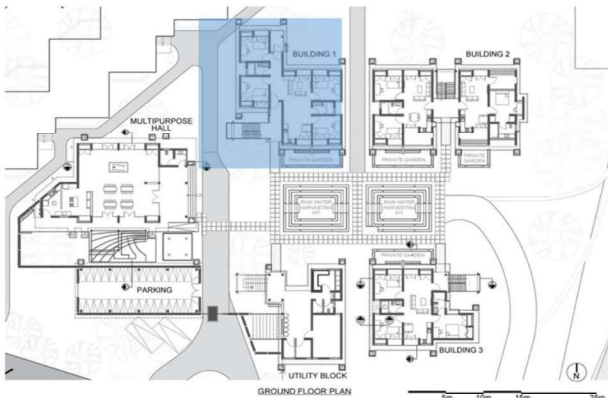


Fig: 2.10 Plan of Humanscape habitat urban living habitat urban living



Fig: 2.11 Exterior view of Humanscape

3.3. HUMANSCAPES HABITAT URBAN LIVING, AUROVILLE:

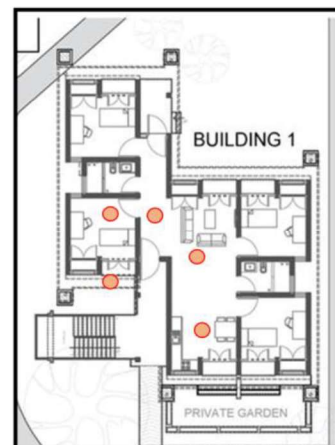
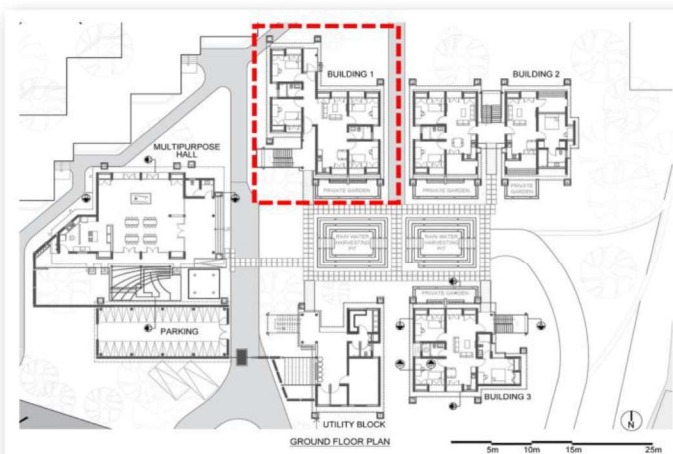
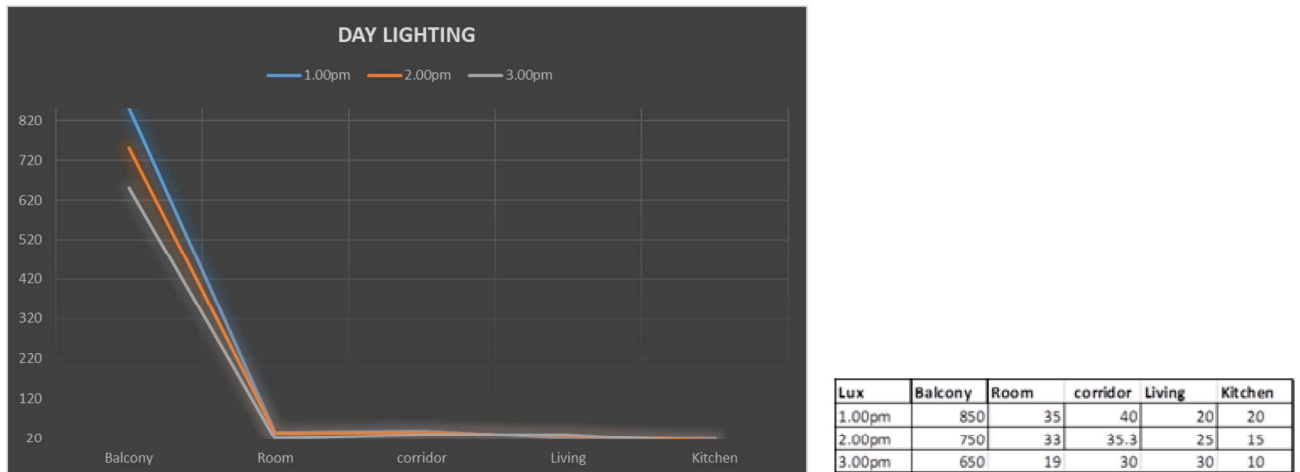


Fig: 2.12 Plan Humanscape Habitat Urban Living, Auroville

3.3.1.DAY LIGHTING:

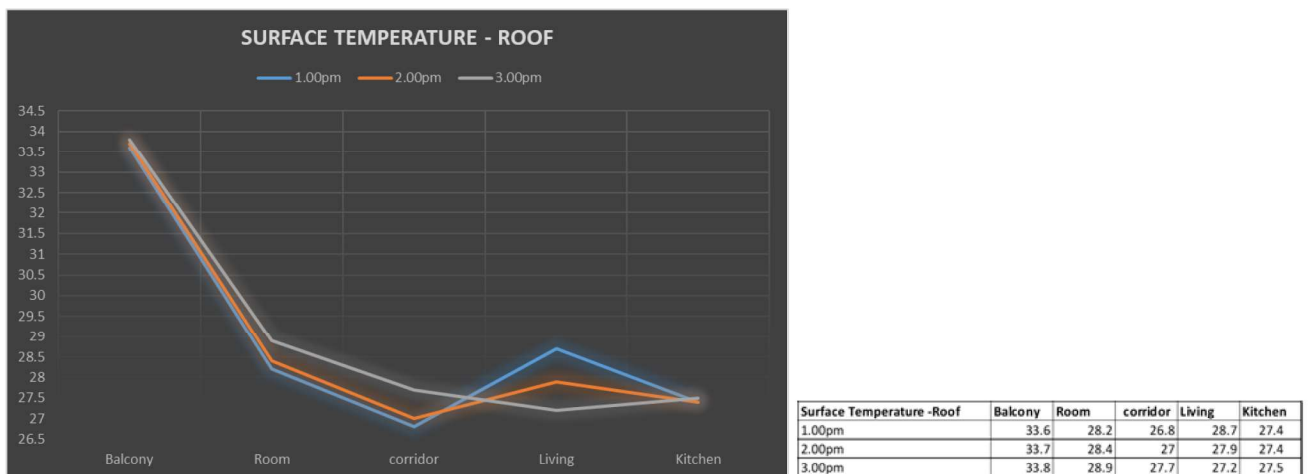
The measurement of the daylighting is calculated by Lux Meter on 12.03.2021.



Graph 2.1: Daylighting using lux meter

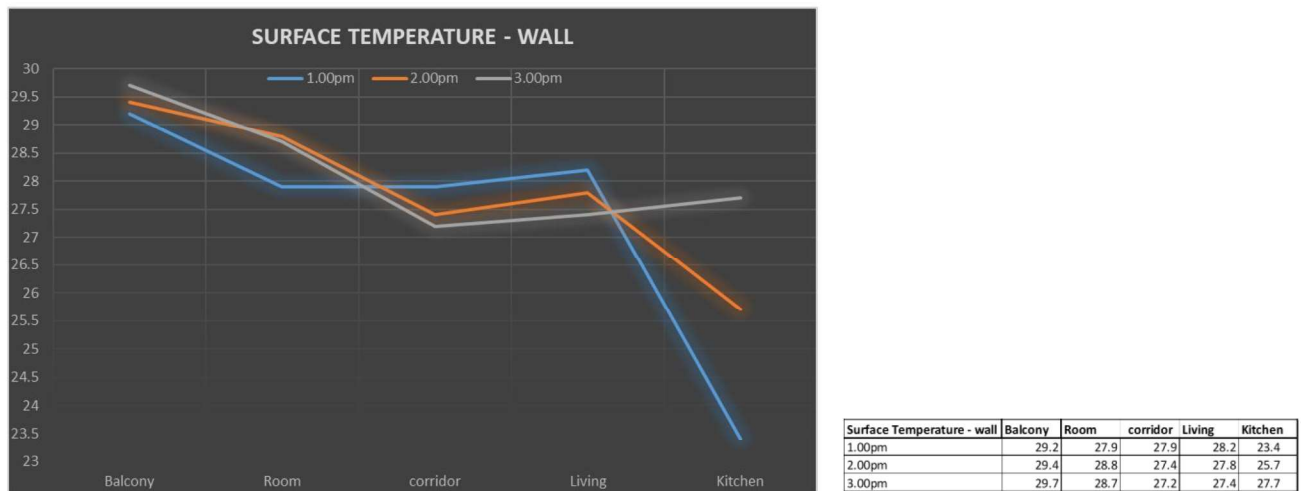
3.3.2. SURFACE TEMPERATURE – ROOF:

The measurement of the surface roof temperature is calculated by Infrared Thermometer on 12.03.2021.



Graph 2.2: The surface roof temperature

3.3.3. SURFACE TEMPERATURE – WALL:



Graph 2.3: the surface wall temperature

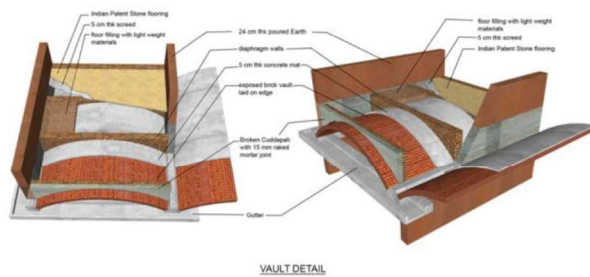
The measurement of the surface wall temperature is calculated by Infrared Thermometer on 12.03.2021.

3.3.4. SURFACE TEMPERATURE – FLOOR:



Graph 2.4: the surface Floor temperature

The measurement of the surface floor temperature is calculated by Infrared Thermometer on 12.03.2021.



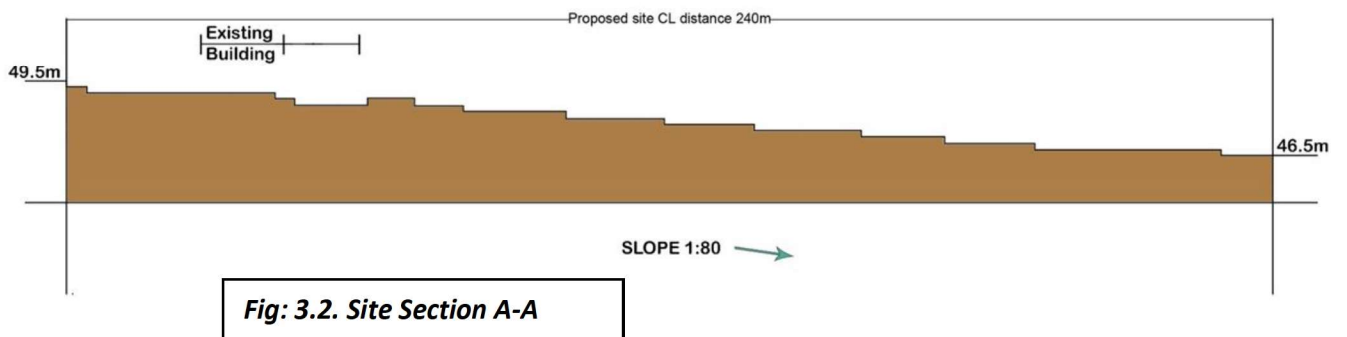
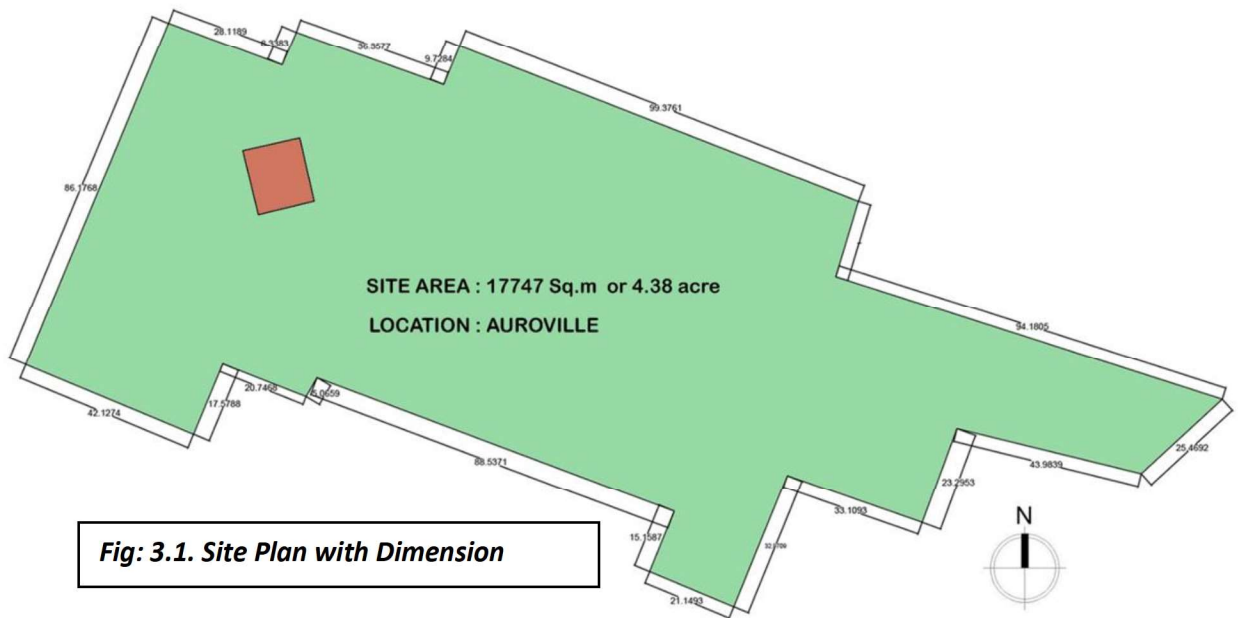
- Concrete slab
- Kadapa stone
- Rammed earth wall

Using local building materials and skills, the residences become a net energy-positive habitat by generating their own energy, using renewable energy. Zero-discharge of water, reduction, and recycling of solid waste, drought-resistant local endemic species landscaping, and growing organic food as a model for urban agriculture would be a hallmark of this project. Reducing point-to-point travel by integrating work and living spaces, using integrated community and IT infrastructure (ICITI), and using clean mobility options like e- vehicles for external contact will be a natural consequence of the campus set-up.

The habitat project has integrated four goals as part of the sustainable human settlement program of development.

- Sustainable built environment to have building envelopes that are solar passive to be climatically suitable built with efficient space usage to reduce the built-up area and low embodied energy building materials with construction techniques that require minimum processing and machinery.
- Integrated environmental planning of water, energy, and waste so Zero-discharge of water, reduction, and recycling of solid waste, water-efficient landscaping using local endemic species, and growing organic food as a model for urban agriculture would be a hallmark of these residences.
- The human ecology, using the principles of the “Cohousing” concept of living, facilitating interaction among neighbors for inclusive social development, economic and environmental benefits. A functional fusion, the living, working, recreational and primary amenities allowing a multiplicity of space usage to reduce the built-up area to enable the inhabitants to interact actively with the farming and productive landscaping, waste recycling, and energy generation as part of the open learning campus.
- Establish a collaborative network of knowledge resources called ‘SustaiNet’, to facilitate further dissemination. This network will enable inter-institutional knowledge sharing and dissemination, a platform for academics, students, and professionals to have an inclusive learning experience during and after completion of the project.

4.0.SITE ANALYSIS:



The site is live proposal from Auroville for co-housing It is warm and humid climate. The existing motorized road towards the site is from the Certitude-Solar kitchen mud road going through Parthana entrance-2 and ending at the mouth of the Line of Progress.

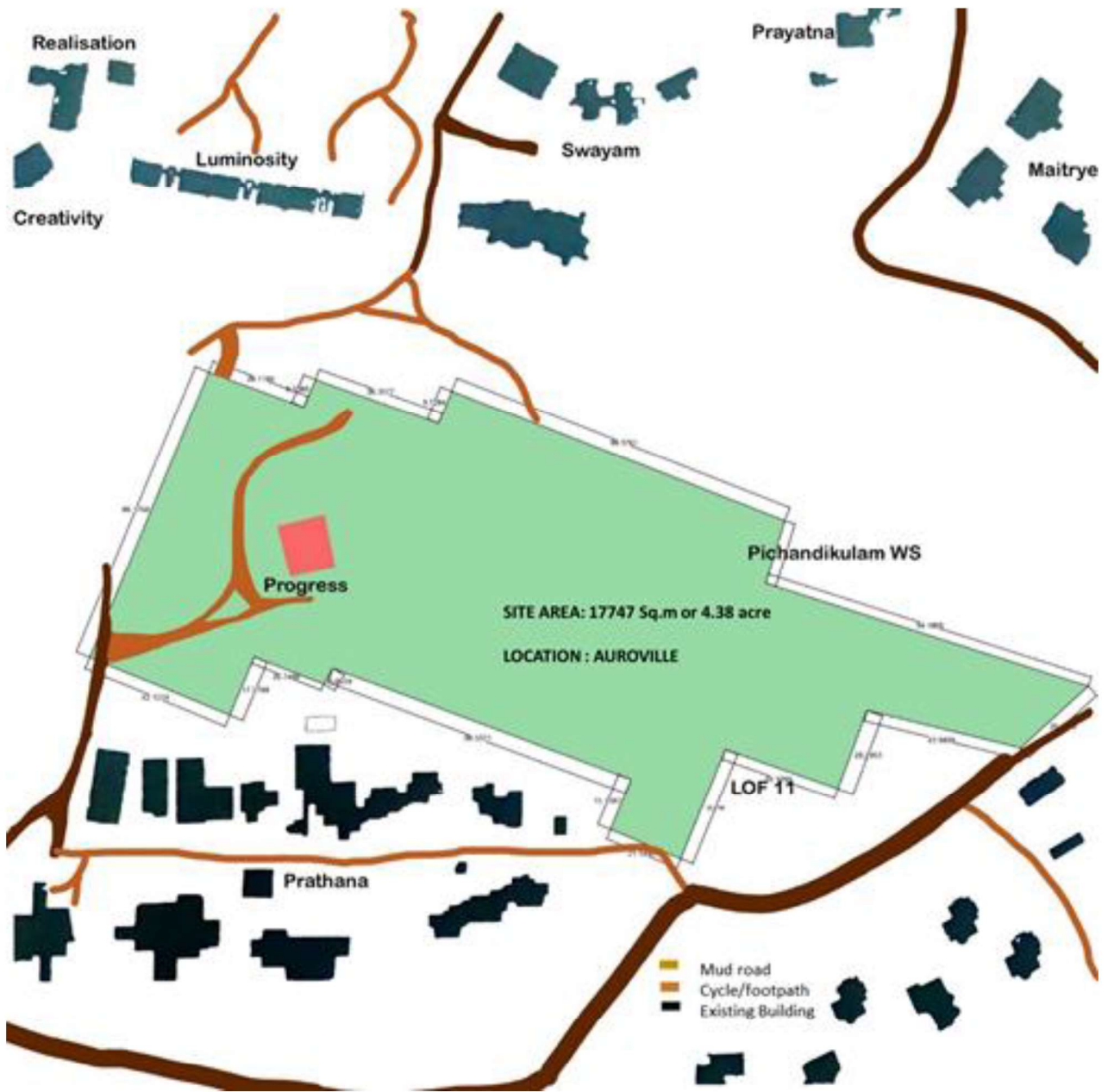


Fig 3.3. SITE PLAN –Existing road and Building

The communities beyond like Luminosity and Swayam have a motorized access from the Vikas Radial, leaving a nonpolluting cycle/ walking track connecting Progress to these communities.

The making of this Line of Force will maintain the non-motorized traffic beyond this existing road, and the communication with these communities will remain as such. Internal communication within the entire built mass would be non-motorized as well.

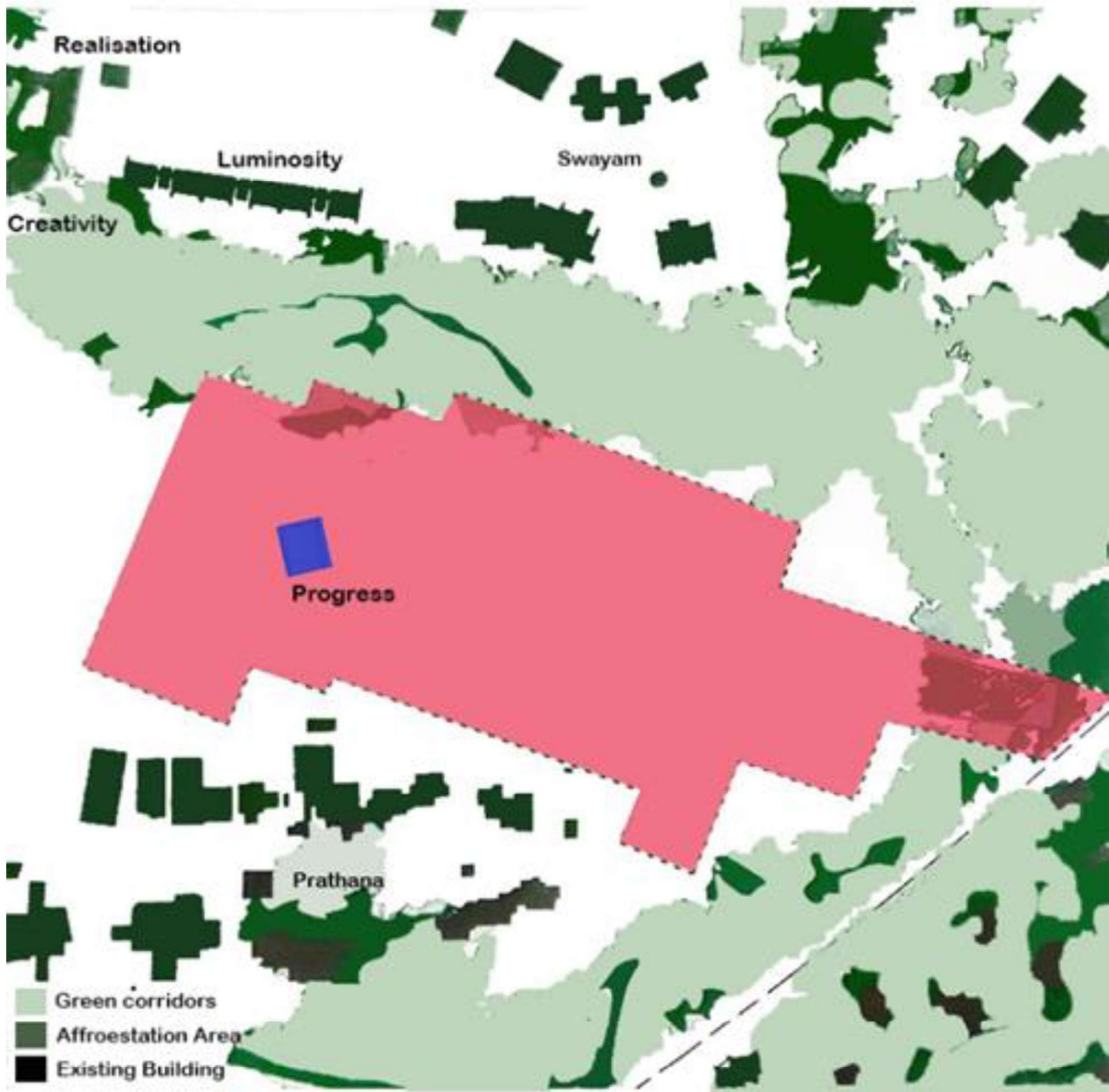


Fig 3.4. Green Corridor Map

Auroville, in 1968 when it was inaugurated, was a barren land with a few existing banyan trees. The soil was untenable and the dusty winds along with strong summer heat created conditions that were foremost to deal with for creating livable conditions.

At present, the afforestation efforts have changed the microclimate of Auroville and as shown in the map, there is a dense forest in large parts of Auroville, besides in the green belt. The Lines of Force are expected to rise higher than the surrounding vegetation with their own green terraces and planters at different levels.

The study area shows a proposed green corridor at the South-East narrow end of the LOP



Fig 3.4. SITE PLAN – Google Map with Contour Reference

Auroville is a plateau with Matrimandir and Peace Area at the center of the city being at the highest level. As one goes away from the center, the land slopes down.

In the study area, the land slopes down with a 2 m drop in around 200m, giving a slope of 1:100 towards South-East.

This drop will be naturally used to direct the surface rain water drainage.

In the detailed design, this drop will give extra height for the spaces to be strategically used to accommodate collective spaces/green spaces as required.

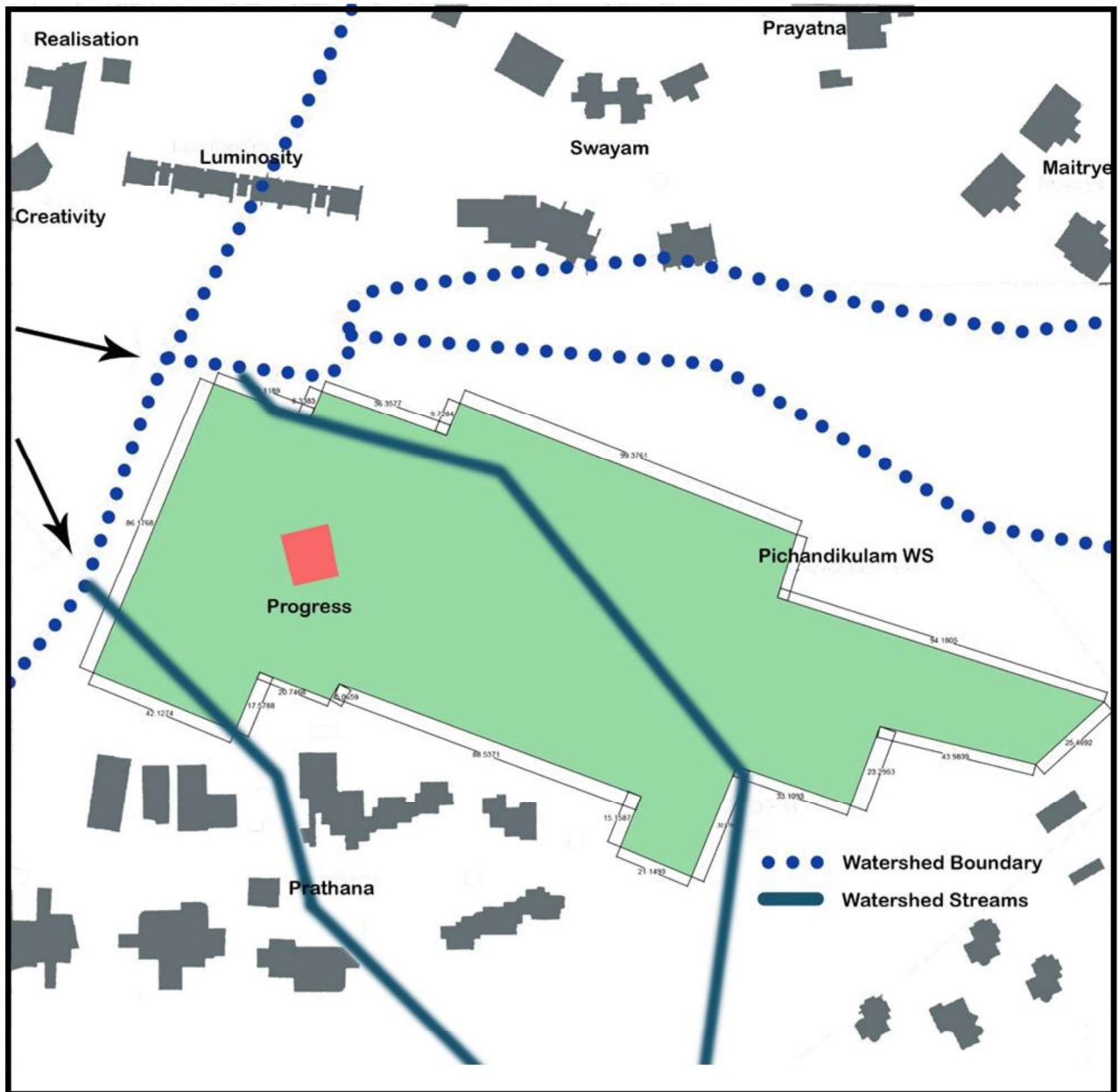
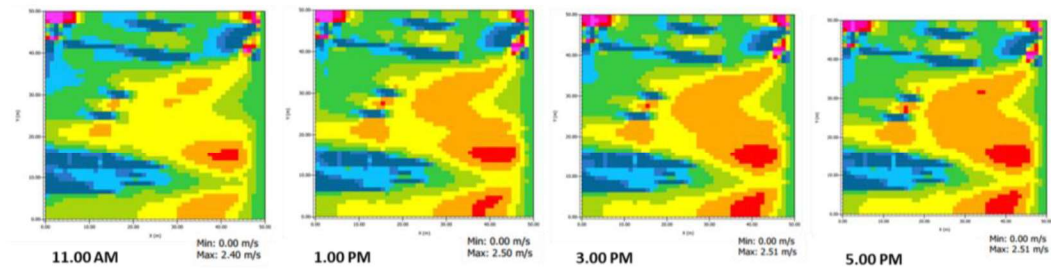


Fig 3.4. Site plan

The purpose of developing a water management system is to reduce the run off and discharge of rainwater out of Auroville and avoid the monsoon floods. To do so, two systems will be combined where by the existing local depression sand canyons are to connect and form a superficial retention water network, while in areas with high percolation levels, water will infiltrate into the soil and reach and refill the underground aquifers, Accordingly, in areas with low percolation water levels, the permeability of the soil must be improved and, if it is not feasible, as in the case of urban areas other solutions will be taken.

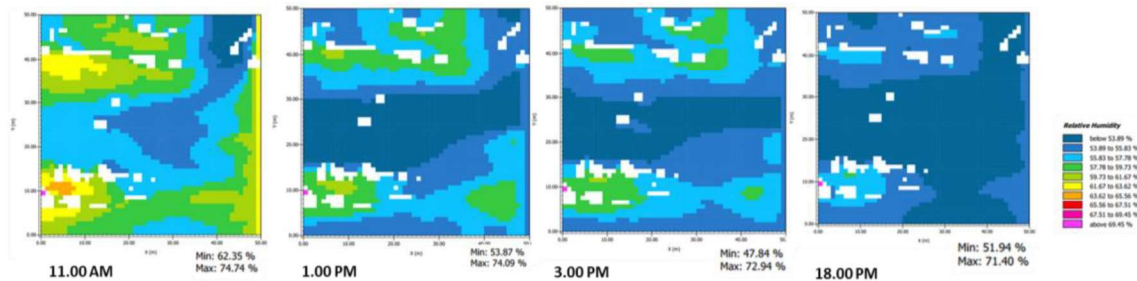
This Simulation of the Envimet is simulated on **11/03/ 2021**

4.1. WIND SPEED (m/s):



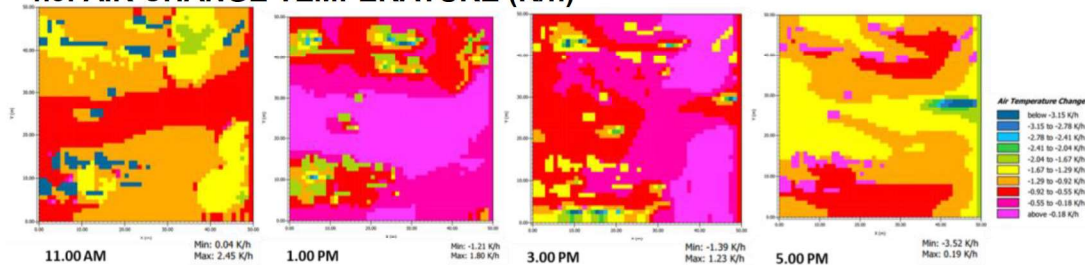
The wind speed at the site area is at an average of **about 1.5 – 1.75 m/s** on the month of January which match the climate consultant. Since the surrounded by maximum of vegetation and exiting building the wind speed is around **0 -3.43 m/s**.

4.2. RELATIVE HUMIDITY (%):



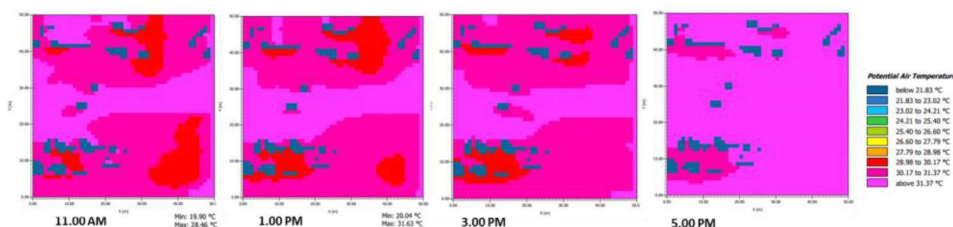
The Maximum humidity falls between 67 – 77% were the average humidity is about 72 %. According to Mahoney's Table calculation most of the month falls under above 70% category

4.3. AIR CHANGE TEMPERATURE (K/h)



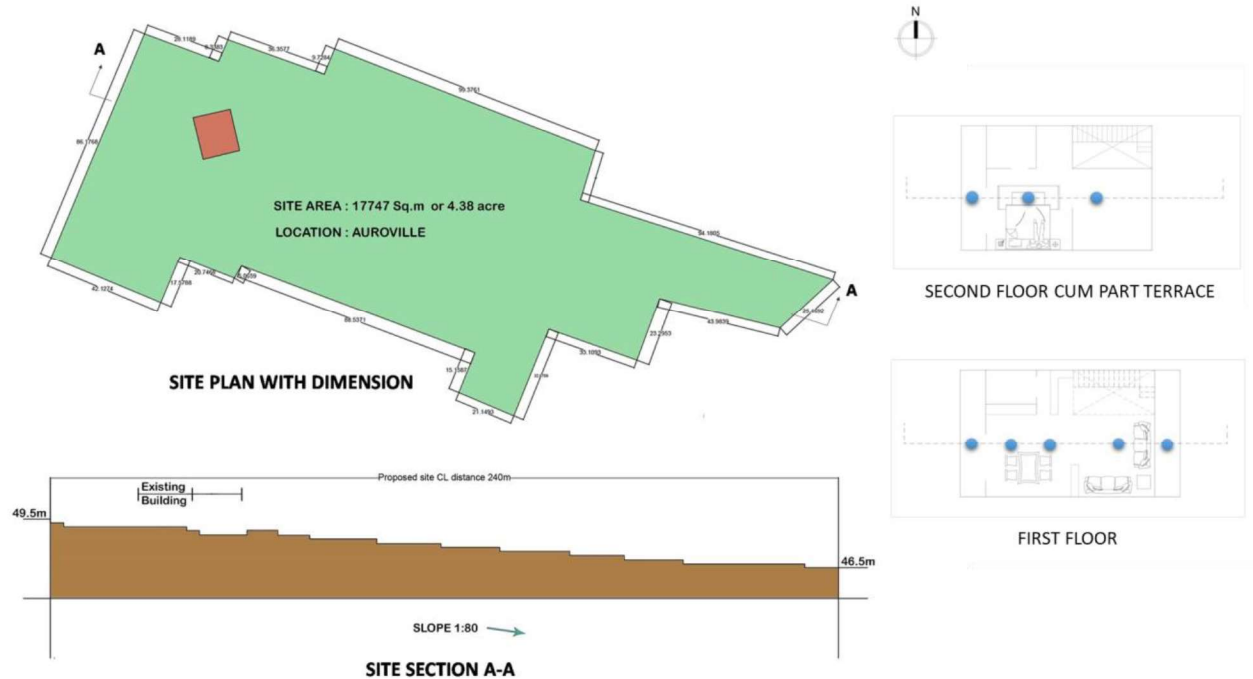
The air temperature change is min 0.01k/h max 2.98k/h, around the site the temperature gradually decreased during night

4.4. POTENTIAL AIR TEMPERATURE (°C):

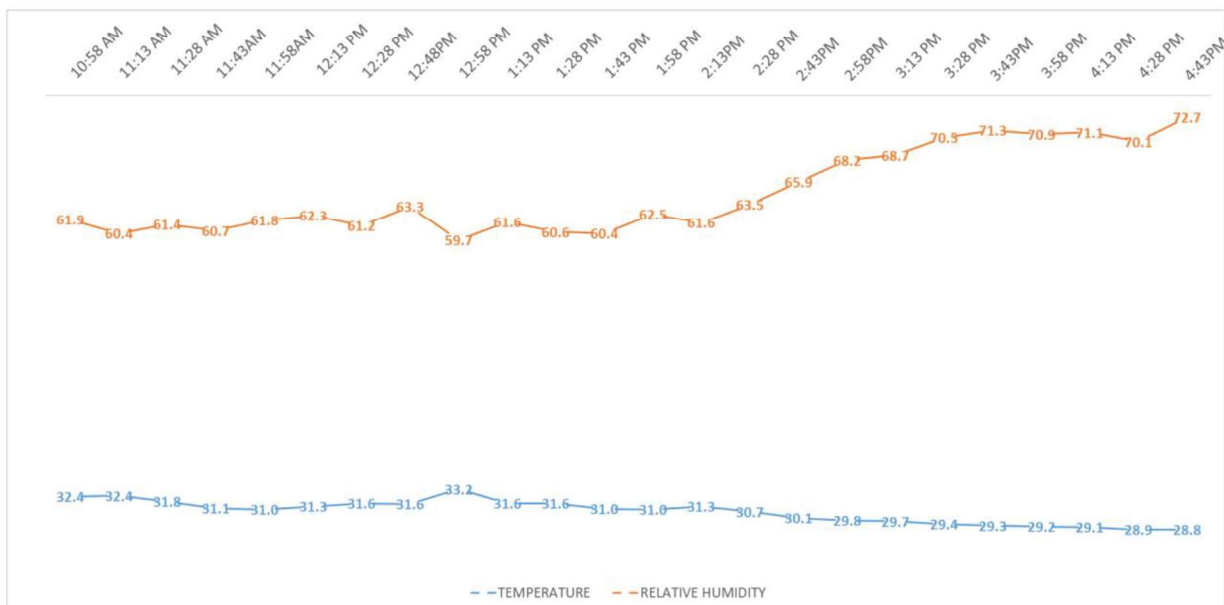


The Potential Air Temperature falls between 32 °C – 20 °C.

4.5. SITE MEASUREMENT:

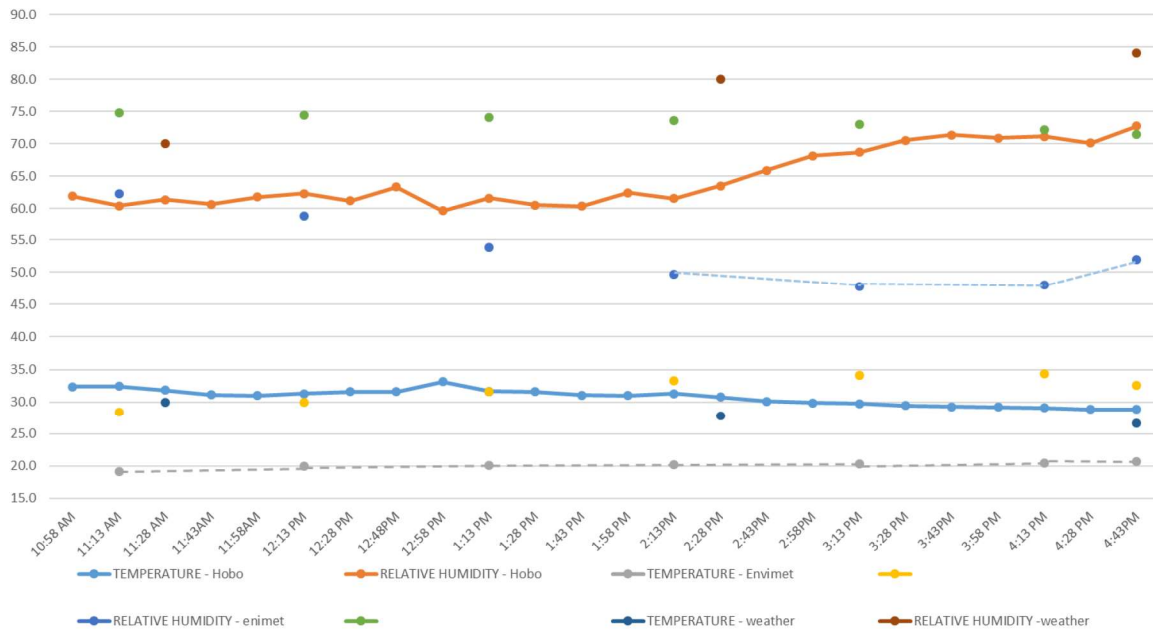


4.6 OUTDOOR TEMPERATURE AND RELATIVE HUMIDITY:



On site recorded outdoor temperature and relative humidity measurement using HOBO software on 11/03/2021 from 10:58 am to 4:43pm

4.7 COMPARATIVE CHART FOR OUTDOOR TEMPERATURE IN SITE:

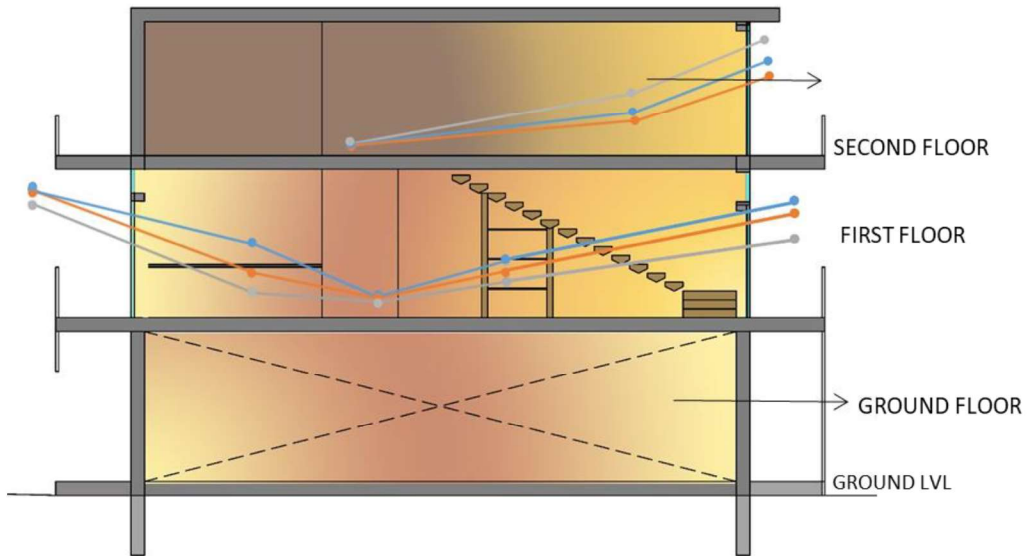


In comparison of onsite recorded outdoor temperature and relative humidity measurement using **HOBO software, envimet and wunderground.**

The relative humidity slightly varies in comparison HOBO and wunderground, where **the relative humidity wunderground is high** and the **temperature of Wunderground is less** on 11/03/2021 from 10:58 am to 4:43pm

The **maximum and minimum relative humidity and air temperature using Envimet falls** in Hobo Software on 11/03/2021 from 10:58 am to 4:43pm

4.8 DAY LIGHTING:



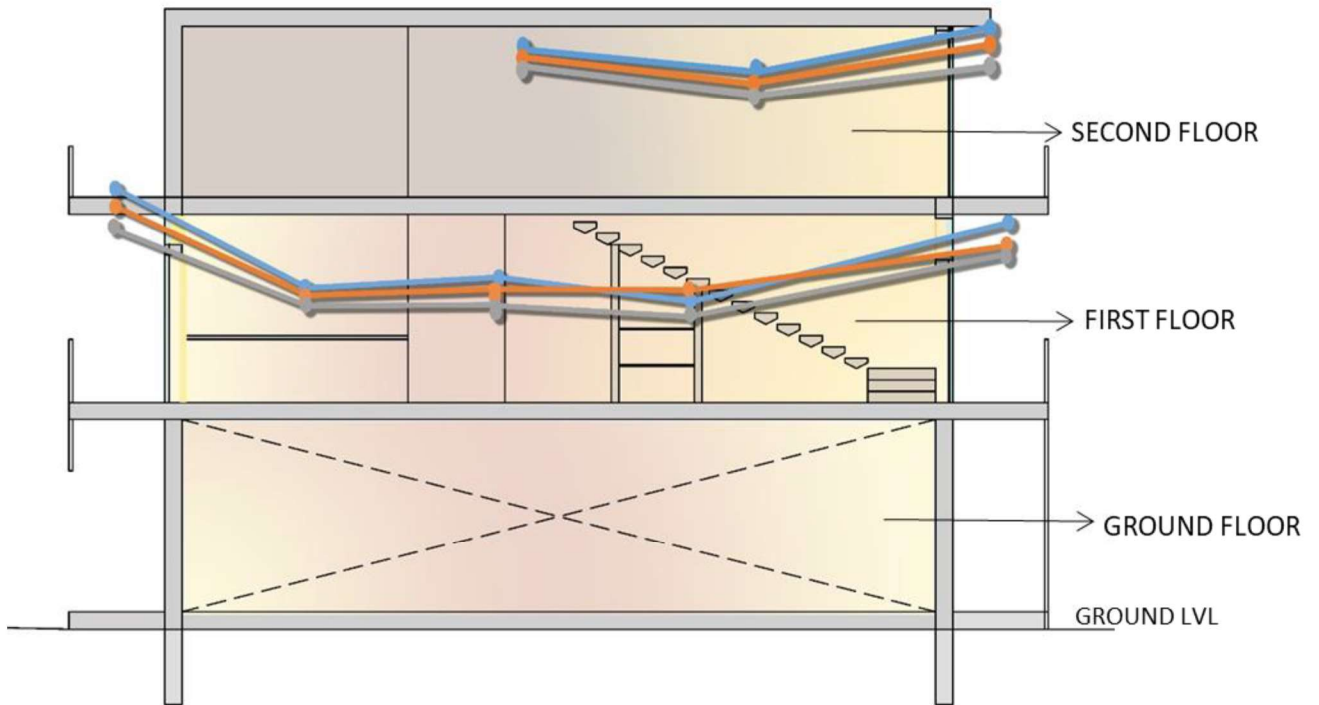
The measurement of the daylighting is calculated by Lux Meter on 11.03.2021.

4.8.1 TABLE FOR DAY LIGHTING:

LUX	Office	Bedroom	Terrace
12:30pm	148	1800	8900
1:30pm	80	1350	7900
2:30pm	220	2800	9900

LUX	Balcony - Entrance	Kitchen	Bath room	Living	Balcony 2
12:30pm	2300	500	50	350	1800
1:30pm	3000	260	45	270	420
2:30pm	2800	100	30	200	375

4.9.1 SURFACE TEMPERATURE - ROOF:



The measurement of the surface roof temperature is calculated by Infrared Thermometer on 11.03.2021.

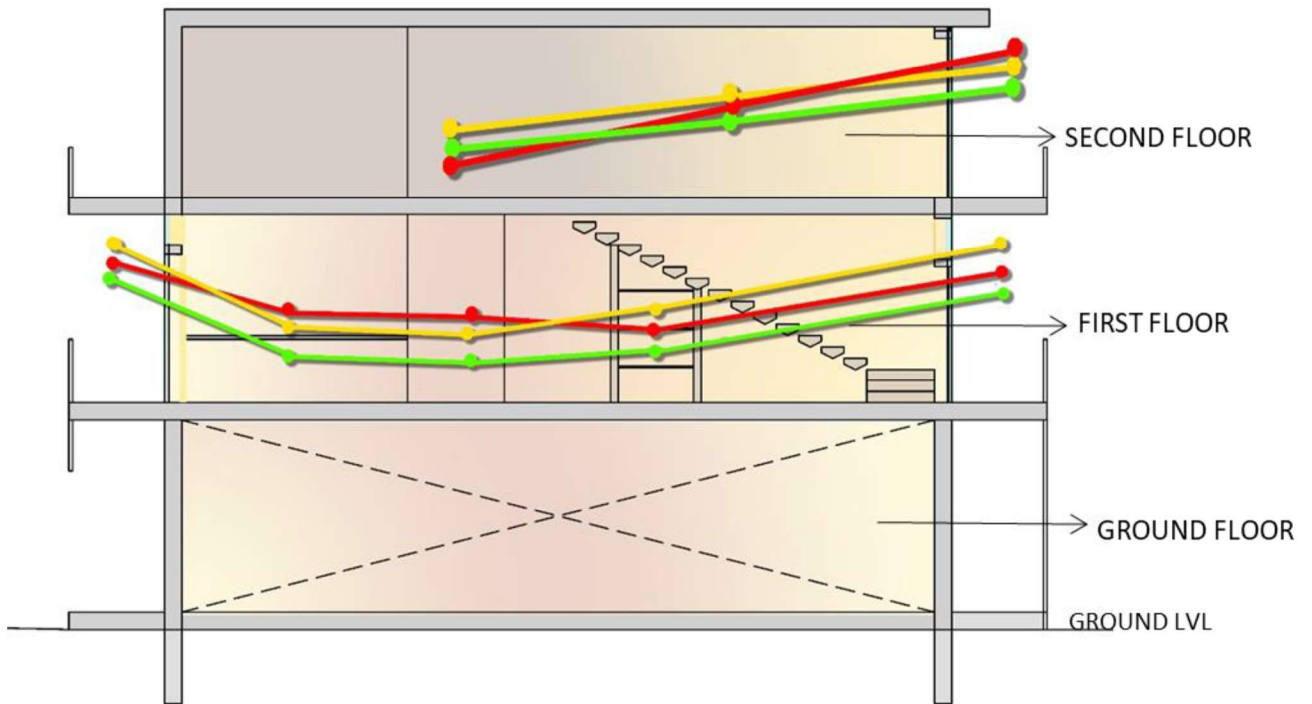
4.9.2. TABLE FOR SURFACE TEMPERATURE:

ROOF surface	Office	Bedroom	Terrace
12:30pm	31.4	30.1	32.7
1:30pm	31	29.5	31.7
2:30pm	30.6	28.8	30.5

Roof surface	Balcony - Entrance	Kitchen	Bath room	Living	Balcony - INNER
12:30pm	33.6	27.8	28	27.1	31
1:30pm	32.4	27.3	27.3	27.7	30.5
2:30pm	31.5	26.9	26.6	26.7	30.3

4.10.1. SURFACE TEMPERATURE – WALL:

The measurement of the surface wall temperature is calculated by Infrared Thermometer on 11.03.2021.



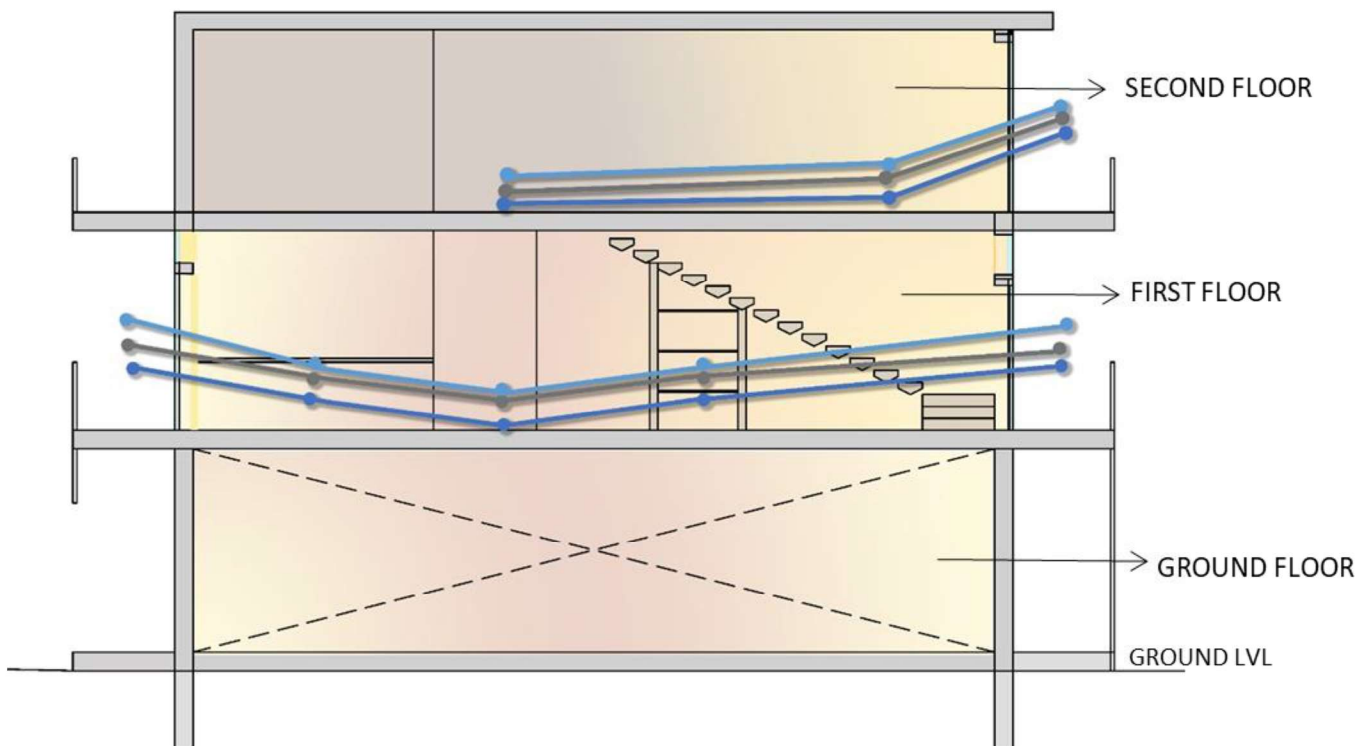
4.10.2. TABLE FOR SURFACE TEMPERATURE:

Wall surface	Office	Bedroom	Terrace
12:30pm	28.8	30.4	32.3
1:30pm	29.7	30.6	31.7
2:30pm	29.3	30.1	31.2

Wall surface	Balcony - Entrance	Kitchen	Bath room	Living	Balcony - INNER
12:30pm	30.3	27.9	27.8	27.5	30.1
1:30pm	31.3	27.5	27.4	28	32.3
2:30pm	30.1	27	26.9	27	29.8

4.11.1. SURFACE TEMPERATURE - FLOOR:

The measurement of the surface floor temperature is calculated by Infrared Thermometer on 11.03.2021.



3.11.2. TABLE FOR SURFACE TEMPERATURE:

Floor surface	Office	Bedroom	Terrace
12:30pm	28.5	28.9	37.3
1:30pm	29.3	30.2	38
2:30pm	30.3	30.9	38.8

Floor surface	Balcony - Enterance	Kitchen	Bath room	Living	Balcony - INNER
12:30pm	33.7	28.3	27.7	28.5	30.8
1:30pm	32.4	28.3	27.3	28.3	29.6
2:30pm	31.4	27.3	26.3	27.3	29

5.0. AREA STATEMENT – CO HOUSING:

Area Calculation							
Spaces	Types of Zone	Occupant Load	No.of occupant	Area Required(sq.m)	No.of units	Timing	Total Area(sq.m)
Single	Private Zone	12.5	24	20	24	24hrs	480
Couple	Private Zone	12.5	24	80	12	24hrs	960
Family A	Private Zone	11.5	36	125	12	24hrs	1500
Multipurpose hall	Public Zone	0.65	90	300	1	24hrs	300
Pavillon	Public Zone	0.65	90	275	1	24hrs	275
Common facilities	Public Zone	11.1	90	2200	1	24hrs	2200
Common Utilities	Public Zone	3.6		50	1	24hrs	50
					Total Area		5765
					Loading 30%		1730
					Total Builtup area		7495

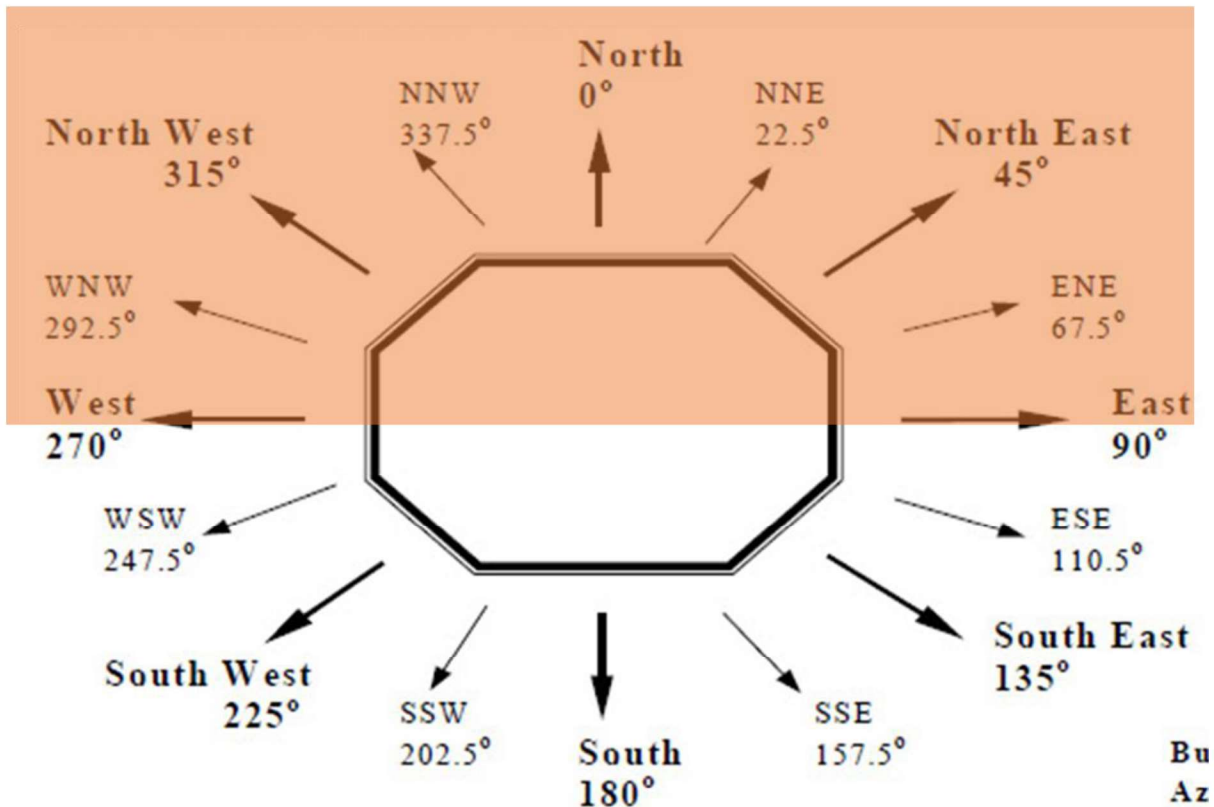
Area	Area Sq.m	Percentage
Total Site Area	17455.829	100%
Total Built up Area	7495	43%
FSI (0.75)	7495	0.43
Height 3.5m	2498.2	14%
Plot Coverage 40%	2498.2	14%
Open Area	9537	55%
Total parking Area	424	2%
Total		100%

Parking Calculation			
Spaces	Area	Bike/ Bicycle	Car
Single	480	10	0
Couple	960	19.2	0
Family A	1500	30	20
Family B	275	5.5	3.666666667
No .of .vehicle		64	24
Parking Area	128.6		295.8333333
Total Parking Area			424.4333333

6.0. ORIENTATION:

In this I have chosen 7 angles for the iteration, Where Orientation is the positioning of a building which helps to reduce heat and increase natural ventilation.

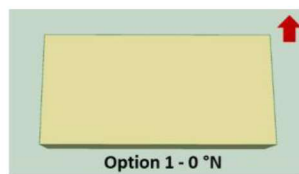
Good orientation can increase **the energy efficiency**



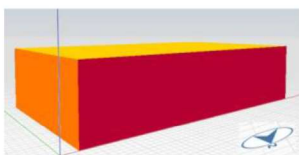
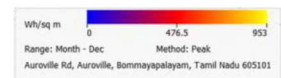
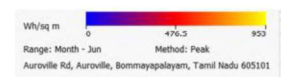
7.0. SOLAR ANALYSIS:

7.0.1. OPTION 1:

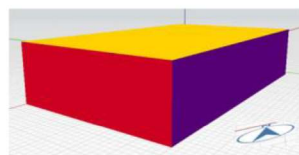
option 1 - 0 °N	wh/sq.m
JUNE	
roof	867.6
longer wall -1	302.3
longer wall -2	72.51
short wall -3	359.6
short wall -4	698



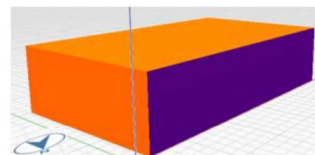
option 1 - 0 °N	wh/sq.m
DECEMBER	
roof	737.4
longer wall -1	55.63
longer wall -2	527.5
short wall -3	332.5
short wall -4	659.1



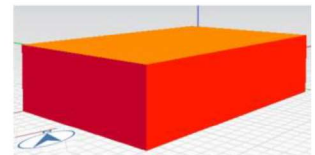
View 1 on June



View 2 on June



View 1 on December

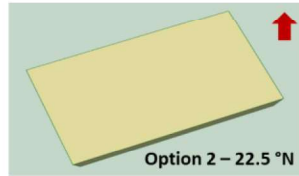


View 2 on December

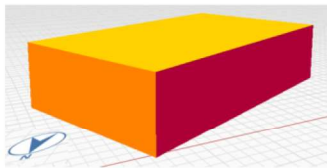
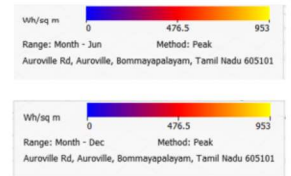


7.0.2. OPTION 2:

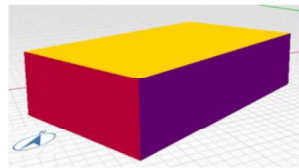
option 2 - 22.5 °NNE	wh/sq.m
JUNE	
roof	867.6
longer wall -1	282
longer wall -2	98.35
short wall -3	293
short wall -4	719



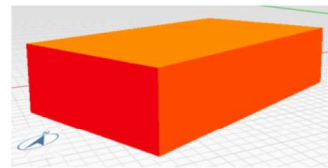
option 2 - 22.5 °NNE	wh/sq.m
DECEMBER	
roof	737.4
longer wall -1	56.59
longer wall -2	612.9
short wall -3	435.9
short wall -4	486.8



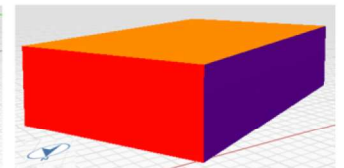
View 1 on June



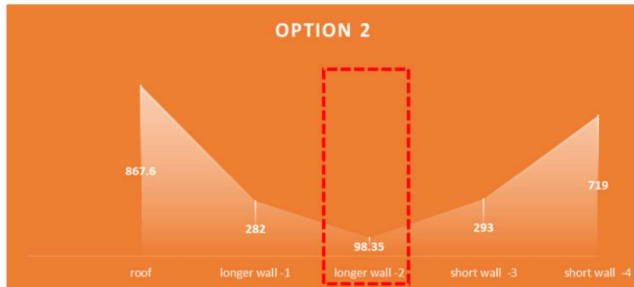
View 2 on June



View 1 on December

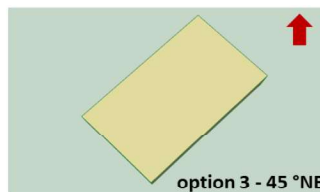


View 2 on December

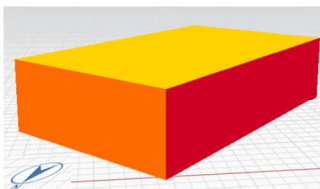
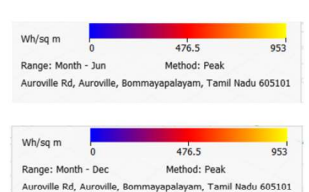


7.0.3. OPTION 3:

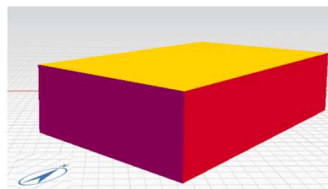
option 3 - 45 °NE	wh/sq.m
JUNE	
roof	867.6
longer wall -1	357.1
longer wall -2	361.7
short wall -3	186.4
short wall -4	673.9



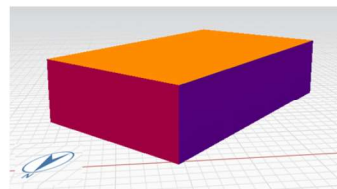
option 3 - 45 °NE	wh/sq.m
DECEMBER	
roof	737.4
longer wall -1	60.15
longer wall -2	707.3
short wall -3	478.9
short wall -4	247.9



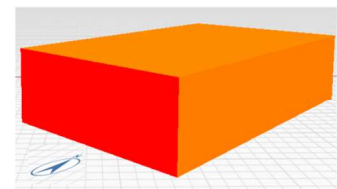
View 1 on June



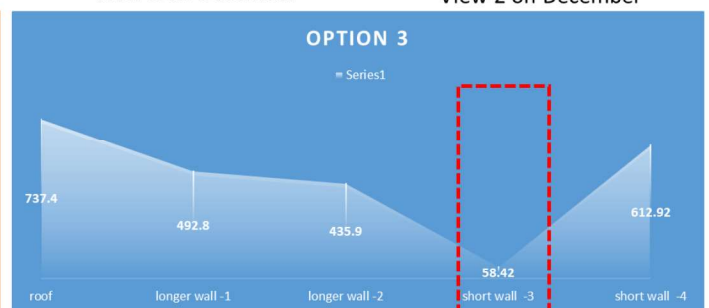
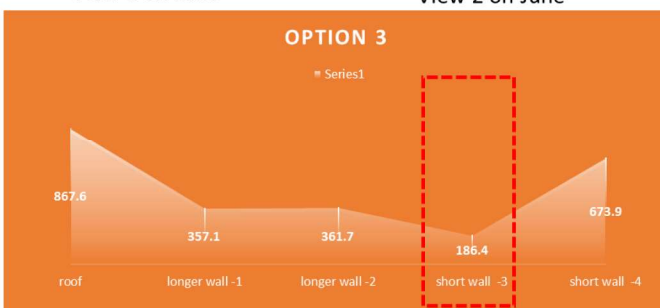
View 2 on June



View 1 on December

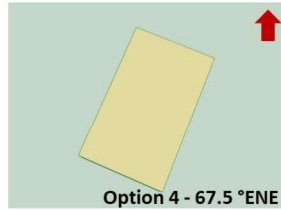


View 2 on December

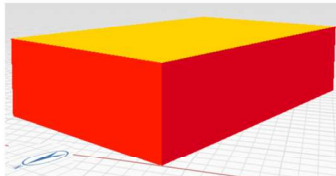
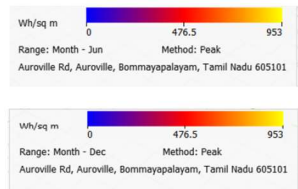


7.0.4. OPTION 4:

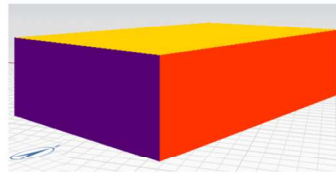
option 4 - 67.5 °ENE	wh/sq.m
roof	867.6
longer wall -1	379.8
longer wall -2	574.2
short wall -3	73.63
short wall -4	529



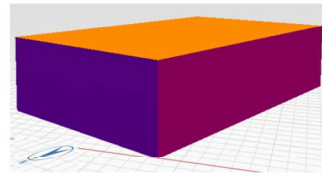
option 4 - 67.5 °ENE	wh/sq.m
DECEMBER	
roof	737.4
longer wall -1	179.8
longer wall -2	728.7
short wall -3	508.9
short wall -4	58.33



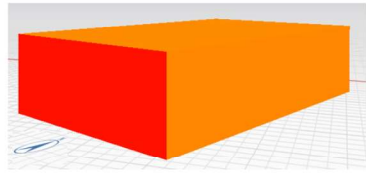
View 1 on June



View 2 on June



View 1 on December

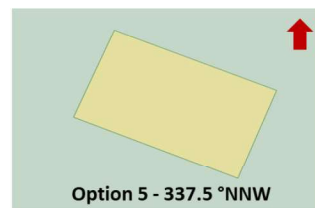


View 2 on December

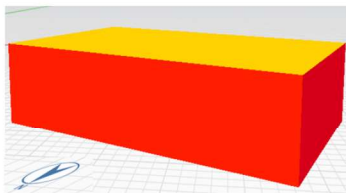
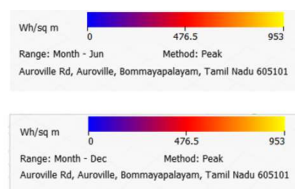


7.0.5. OPTION 5:

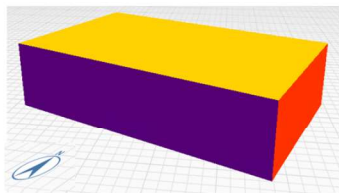
option 5 - 337.5 °NNW	wh/sq.m
roof	867.6
longer wall -1	532.2
longer wall -2	71.72
short wall -3	382.1
short wall -4	571.1



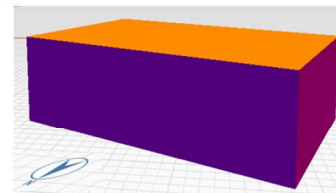
option 5 - 337.5 °NNW	wh/sq.m
DECEMBER	
roof	737.4
longer wall -1	59.3
longer wall -2	511.9
short wall -3	174.9
short wall -4	728.7



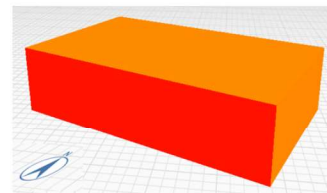
View 1 on June



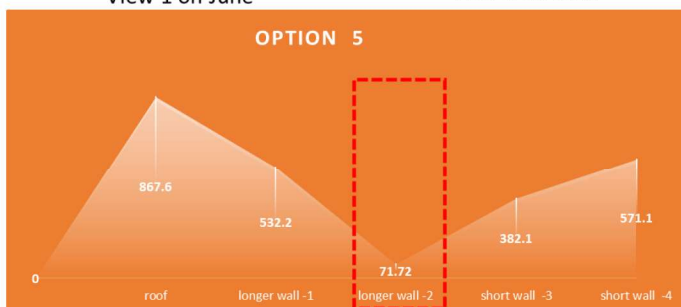
View 2 on June



View 1 on December

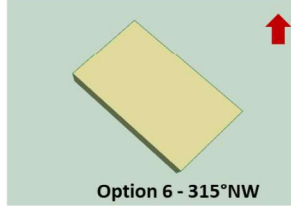


View 2 on December

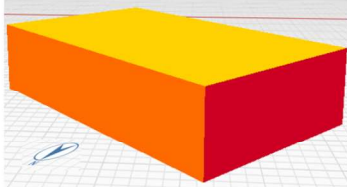
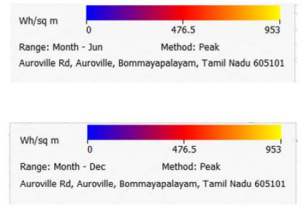


7.0.6. OPTION 6:

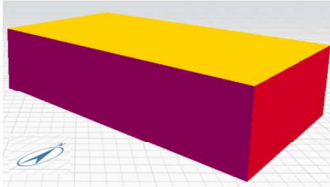
option 6 - 315°NW	wh/sq.m
roof	867.6
longer wall -1	673.5
longer wall -2	186.4
short wall -3	357.1
short wall -4	361.7



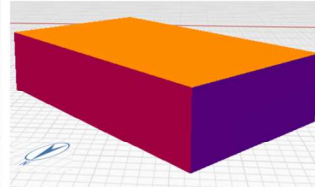
option 6 - 315°NW	wh/sq.m
DECEMBER	
roof	737.4
longer wall -1	247.9
longer wall -2	478.4
short wall -3	60.57
short wall -4	707.3



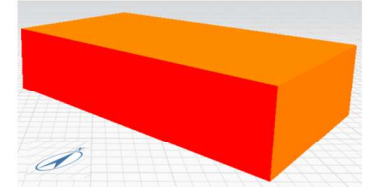
View 1 on June



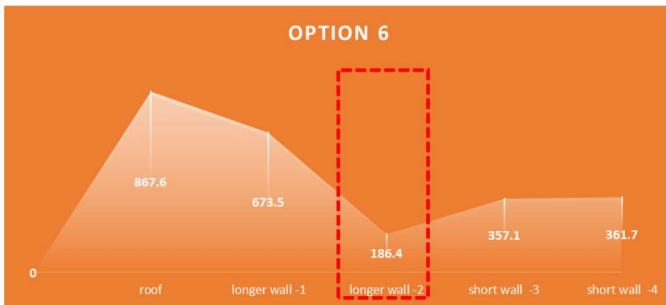
View 2 on June



View 1 on December



View 2 on December

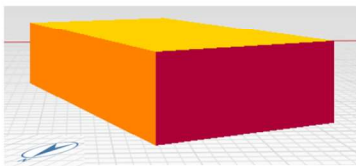
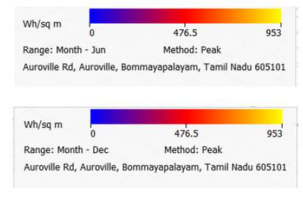


7.0.7. OPTION 7:

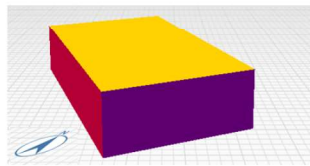
option 7 - 292.5°WNW	wh/sq.m
roof	867.6
longer wall -1	718
longer wall -2	295.2
short wall -3	279.8
short wall -4	92



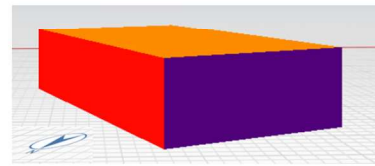
option 7 - 292.5°WNW	wh/sq.m
DECEMBER	
roof	737.4
longer wall -1	492.8
longer wall -2	435.9
short wall -3	58.42
short wall -4	612.92



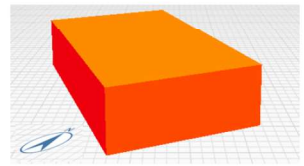
View 1 on June



View 2 on June



View 1 on December



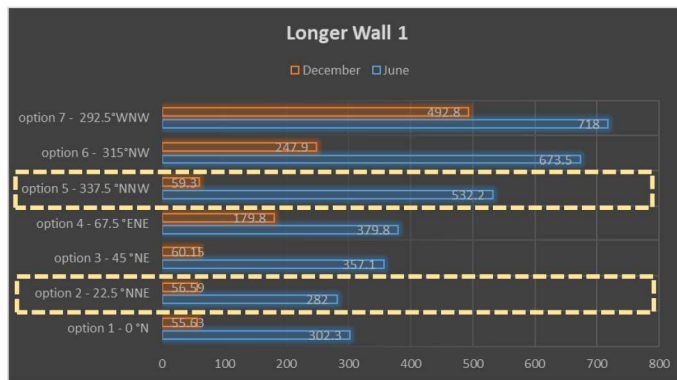
View 2 on December



7.0.8. INFERENCE - SOLAR ANALYSIS:

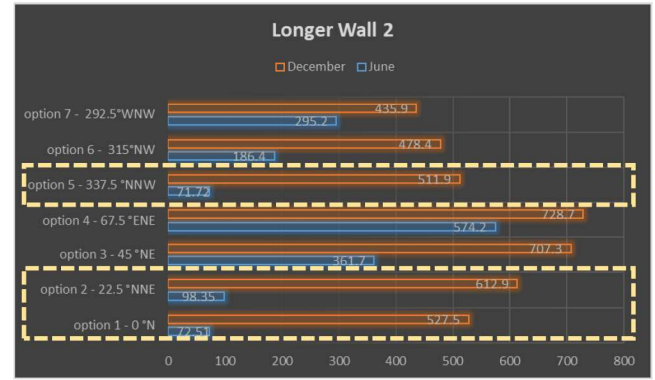
Longer wall -1	June	December
option 1 - 0 °N	302.3	55.63
option 2 - 22.5 °NNE	282	56.59
option 3 - 45 °NE	357.1	60.15
option 4 - 67.5 °ENE	379.8	179.8
option 5 - 337.5 °NNW	532.2	59.3
option 6 - 315°NW	673.5	247.9
option 7 - 292.5°WNW	718	492.8

According to the charts option 2 works more efficiently on longer wall 1



Longer wall -2	June	December
option 1 - 0 °N	72.51	527.5
option 2 - 22.5 °NNE	98.35	612.9
option 3 - 45 °NE	361.7	707.3
option 4 - 67.5 °ENE	574.2	728.7
option 5 - 337.5 °NNW	71.72	511.9
option 6 - 315°NW	186.4	478.4
option 7 - 292.5°WNW	295.2	435.9

According to the charts option 1 ,5 works more efficiently and option 2 works efficiently on longer wall 2



Option 2 and 5 works more efficiently on longer wall 1, 2.

Shorter wall -1	June	December
option 1 - 0 °N	359.6	332.5
option 2 - 22.5 °NNE	293	435.9
option 3 - 45 °NE	186.4	478.9
option 4 - 67.5 °ENE	73.63	508.9
option 5 - 337.5 °NNW	382.1	174.9
option 6 - 315°NW	357.1	60.57
option 7 - 292.5°WNW	279.8	58.42

According to the charts option 3 ,4 works more efficiently and option 2 works efficiently on Shorter wall 1

Shorter wall -2	June	December
option 1 - 0 °N	698	659.1
option 2 - 22.5 °NNE	719	486.8
option 3 - 45 °NE	673.9	247.9
option 4 - 67.5 °ENE	529	58.33
option 5 - 337.5 °NNW	571.1	728.7
option 6 - 315°NW	361.7	707.3
option 7 - 292.5°WNW	92	612.92

According to the charts option7 works more efficiently and option 6 works efficiently on Shorter wall 2



Option 4 and 7 works more efficiently on shorter wall 1, 2.

7.0.9. CONCLUSION:

Even through option 4 and 7 works more efficiently on shorter wall 1, 2.

Longer side of the building is more important, consider the longer wall option 2 and 5 performs better solar analysis considering other analysis like wind analysis, shadow analysis and other factors which perform better will be take.

8.0. SHADOW ANALYSIS:

8.0.1. OPTION 2 – 22.5 °N:

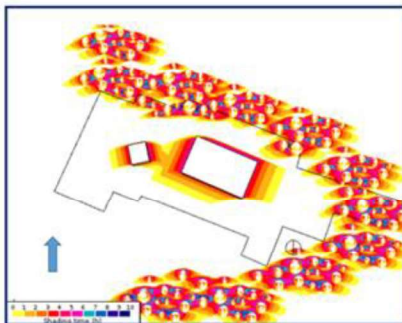


Fig 7.1. Bird eye view

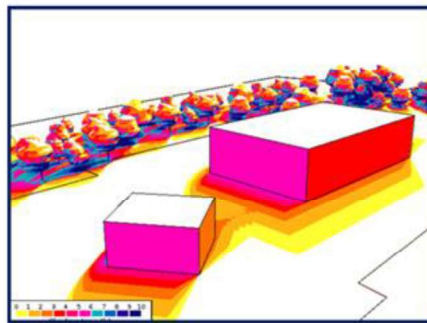


Fig 7.2 View 1 on North east

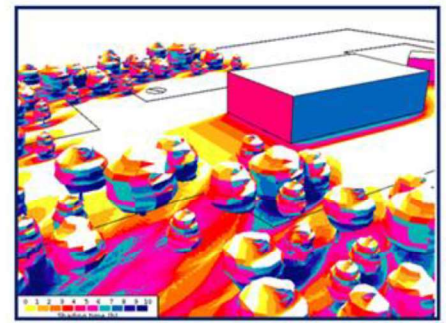


Fig 7.3 View 2 on southwest

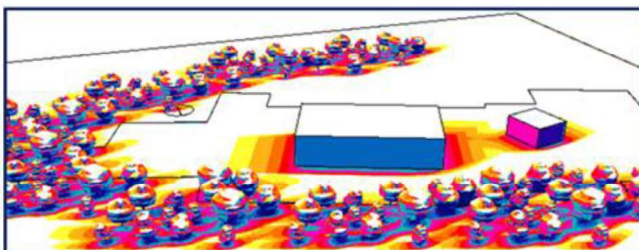


Fig 7.4 View 3

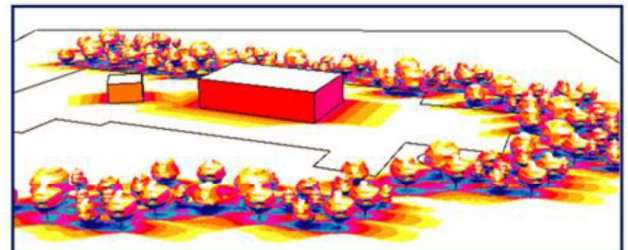


Fig 7.5 View 4

8.0.2. OPTION 5 - 337.5 °NNW

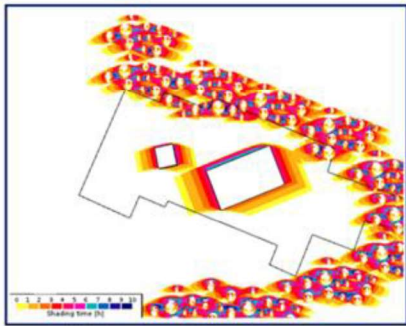


Fig 8.1. Bird eye view

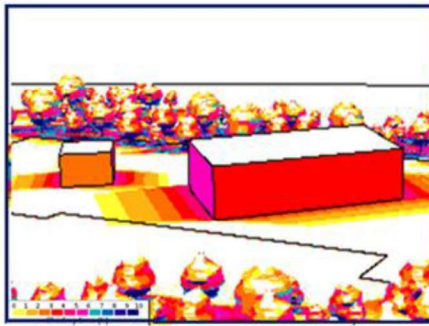


Fig 8.2 View 1 on North east

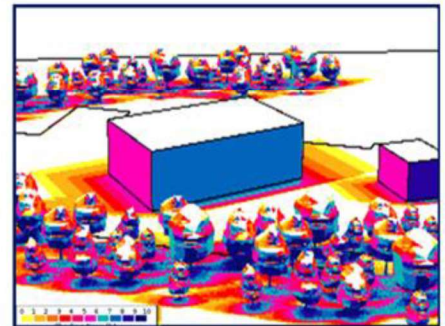


Fig 8.3 View 2 on southwest

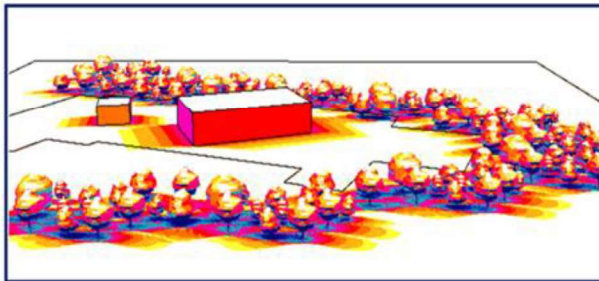


Fig 8.4 View 3

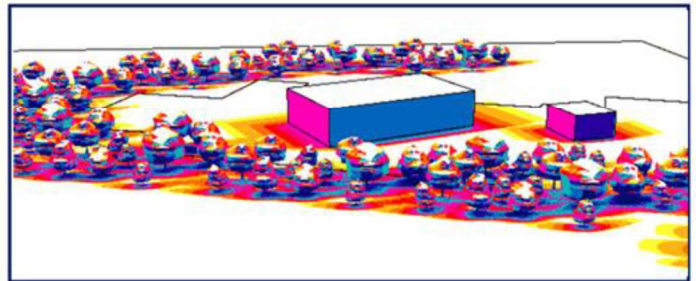


Fig 8.5 View 4

9.0. WIND ANALYSIS:

9.0.1. OPTION 2 – 22.5 °N

In Wind analysis the angle of 22.5 °N air flow increases compared the angle of 337.5 °NNW

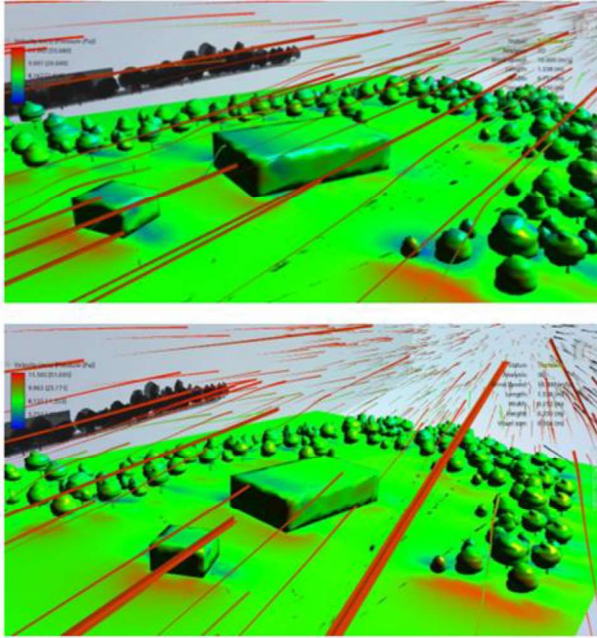


Fig 8.6 Wind Movement on north east

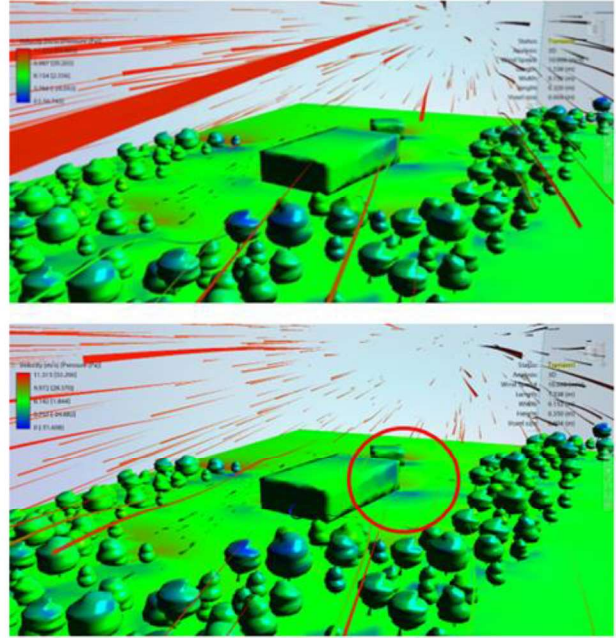


Fig 8.7 Wind Movement on southwest

9.0.2. Option 5 - 337.5 °NNW

In Wind analysis the angle of **337.5 °NNW** air flow is less compared the angle of 22.5 °N

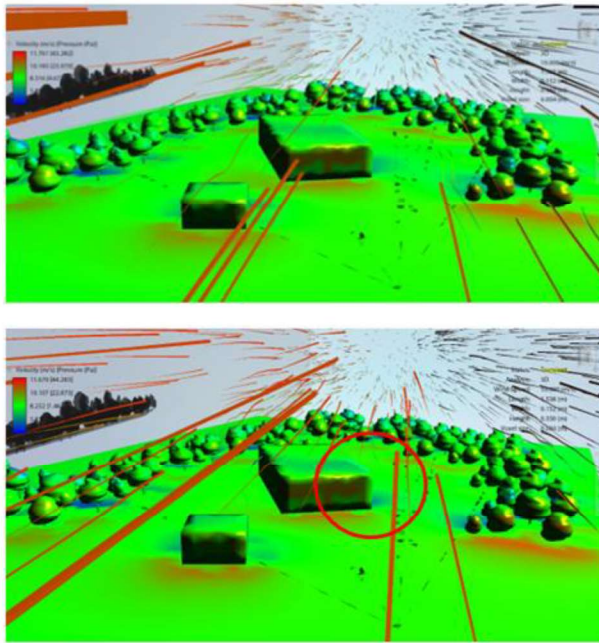


Fig 8.8 Wind Movement on north east

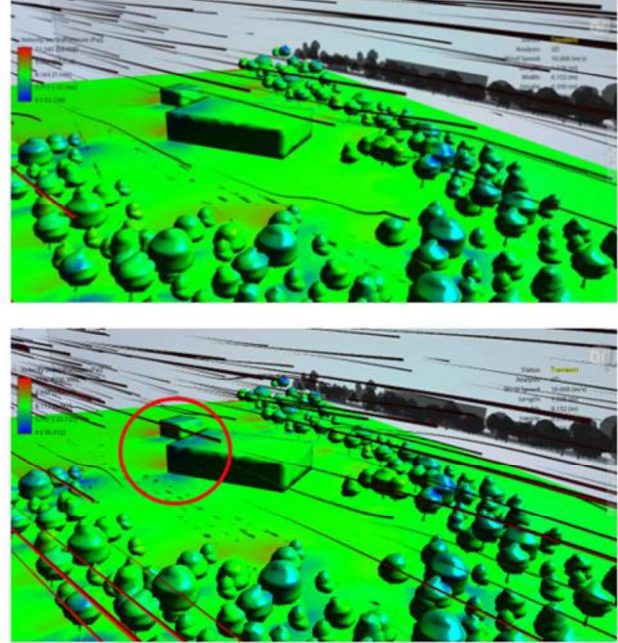


Fig 8.9 Wind Movement on southwest

ANALYSIS	Option 2 – 22.5 °N	Option 5 - 337.5 °NNW
Solar Analysis	option 2 works efficiently on longer wall 1 , 2	option 5 works slightly more efficiently on longer wall 1 , 2
Shadow Analysis	option 2 cast slightly less shadow compared to option 5	Option 5 cast more shadow compared to option 2
Wind Analysis	In Wind analysis the angle of 22.5 °N air flow increases compared the angle of 337.5 °NNW	In Wind analysis the angle of 337.5 °NNW air flow is less compared the angle of 22.5 °N
ORIENTATION	The angle 22.5 °N work better in site where it occupies less space and function better compare to the angle 337.5 °NNW	the angle 337.5 °N not work better in site where it occupies more space compare to the angle 22.5 °N

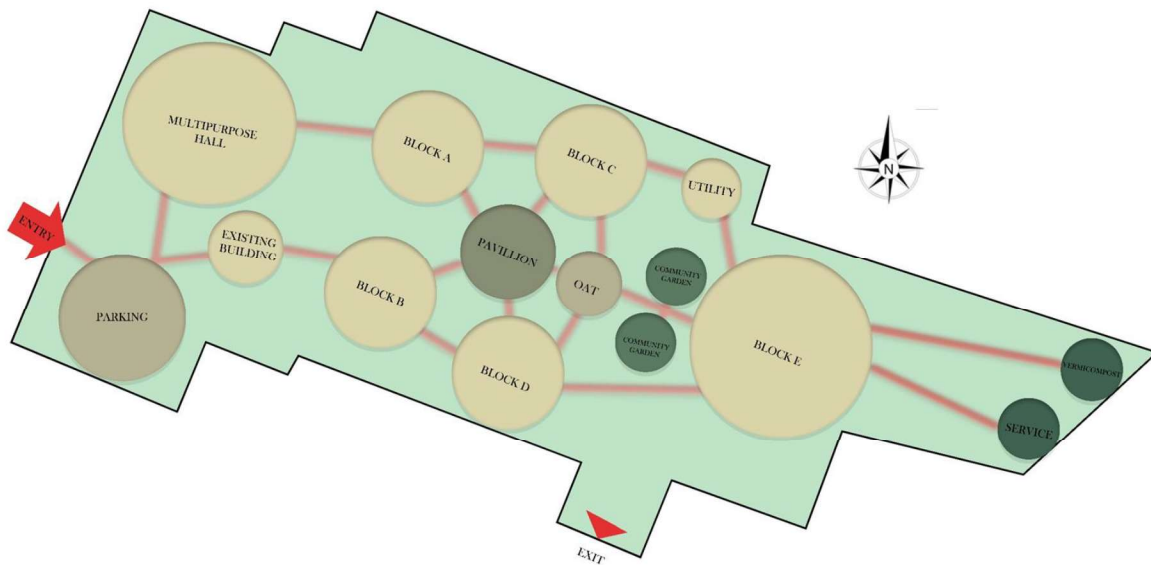
Table 1.1 comparative analysis for both option

9.1. CONCLUSION:

Even though Option 5 – The angle of 337.5 °NNW slightly performs better in solar and shadow analysis consider the wind analysis and orientation **the angle of 22.5 °N was chosen for this site**

10.0. SITE ANALYSIS:

10.0.1. SITE ZONING:



The existing parking and the existing building is retained.

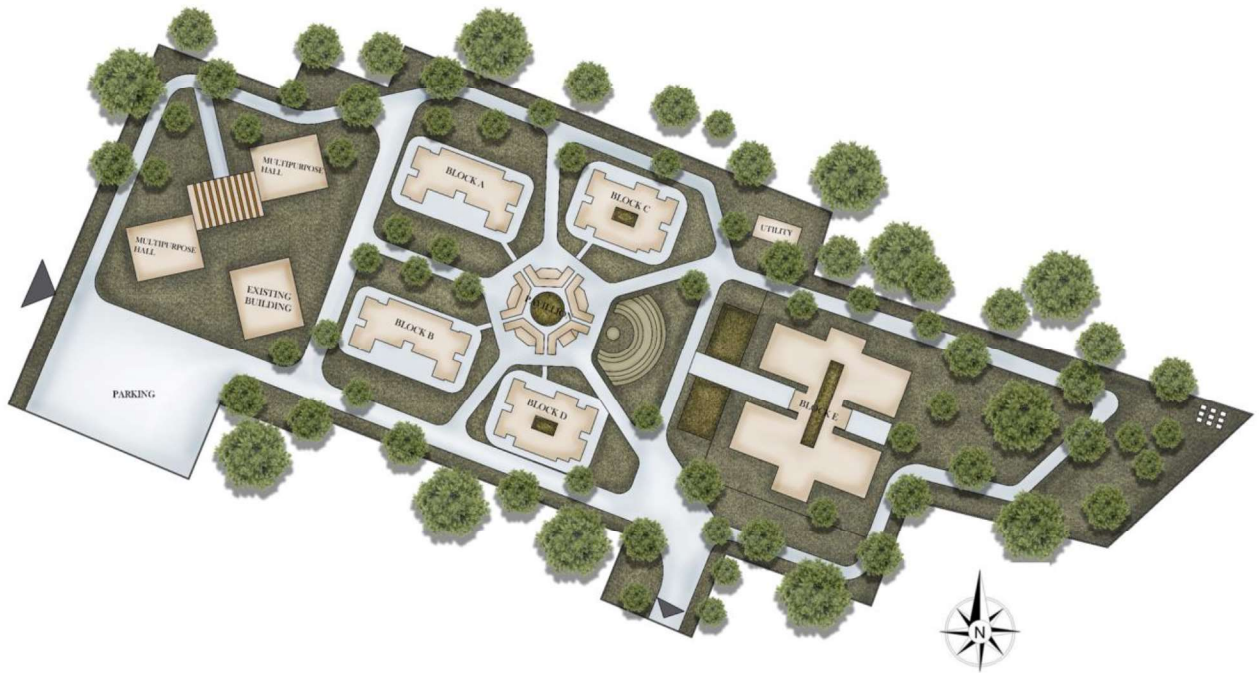
Since the orientation of the existing block is not efficient the orientation is changed to enhance the performance of the new block naturally.

Social interaction is achieved by the use of a pavilion as people at Auroville are more towards social interaction.

This impacts and enhances the vast cultural exchange within various other communities within Auroville.

Existing trees were retained.

10.0.2. SITE PLAN:



10.1. BLOCK A, B:

10.1.1. FLOOR PLANS:



10.2.1. WINDOW FLOOR RATIO – BLOCK A, B:

WINDOW FLOOR RATIO							
Details of exposed door, windows and ventilators							
Opening (Window/door/Ventilator) Name	Opening Width (m)	Opening Height(m)	Opening area (sq.m)	Width of Glass in Opening (m)	Height of Glass in Opening (m)	Glass Area in opening (m2)	Opaque area (m2)
W	1.5	1.5	2.3	1.43	1.43	2.0449	0.2
SD	2.4	2.1	5.0	2.33	2.03	4.7299	0.3101
SD1	3.6	2.1	7.6	3.53	2.03	7.1659	0.3941
D	0.9	2.1	1.9	0	0	0	1.89
D1	0.8	2.1	1.7	0	0	0	1.68
V	0.6	0.6	0.4	0	0	0	0.36

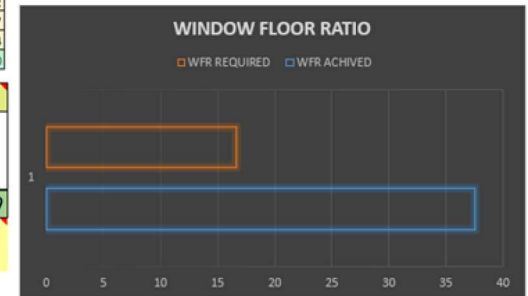
Calculation of total openable window - floor area ratio (WFR _{op})					
Opening (Window/door/Ventilator) Name	Opening area (sq.m)	Openable area for each floor (Sq.m)	Remarks	Nos	Total Openable area (Sq.m)
W	2.3	2.025	90% openable	24	48.6
SD	5.0	4.536	90% openable	12	54.432
SD1	7.6	6.804	90% openable	6	40.824
D	1.9	1.701	90% openable	24	40.82
D1	1.7	1.512	90% openable	6	9.07
V	0.4	0.324	90% openable	6	1.94
Total Openable area (A _{openable})					195.70

TABLE 1 Minimum requirement of window-to-floor area ratio (WFR_{op})

Climatic zone	Minimum WFR _{op} (%)
Composite	12.50
Hot-Dry	10.00
Warm-Humid	16.66
Temperate	12.50
Cold	8.33

Calculate the window operable area to floor area ratio (WFR _{op})			
A (openable)	A (carpet area)	WFR(op) = A (openable)/ A (carpet area)	WFR(op) in %
195.70	522	0.374896552	37.49

Chennai is in Warm and humid climate. As per ECBC standards, the minimum WFR(op) for this climate is 16.66%. Thus, this project complies with the ECBC requirements.



10.2.2. WINDOW WALL RATIO – BLOCK A, B:

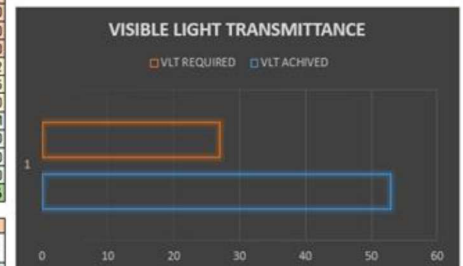
WINDOW WALL RATIO & VISUAL LIGHT TRANSMITTANCE							
Orientation	No. of openings						
	W	SD	SD1	D	D1	V	
North North East - 22.5	1	2	2	0	0	0	0
East South East - 110.5	2	0	0	3	1	0	1
South South West - 202.5	4	2	0	2	0	0	0
West North West - 292.5	2	0	0	3	1	0	1
Total	9	4	2	8	2	0	2

Calculation of window-to-wall ratio (WWR)					
Orientation	Opening Name	Opening Area (Sq.m)	Non-opaque (glass) area in the opening	No. of opening	Total non-opaque (glass) area in Sq.m
North North East - 22.5	W	2.3	2.0	1	2.3
	SD	5.0	4.7	2	10.1
	SD1	7.6	7.2	2	15.1
East South East - 110.5	W	2.3	2.0	2	4.5
	D	1.9	0.0	2	3.8
	D1	1.7	0.0	2	3.4
	V	0.4	0.0	1	0.4
South South West - 202.5	W	2.3	2.0	4	9.0
	SD	5.0	4.7	2	10.1
	D	1.9	0.0	2	3.8
West North West - 292.5	W	2.3	2.0	2	4.5
	D	1.9	0.0	3	5.7
	D1	1.7	0.0	1	1.7
	V	0.4	0.0	1	0.4
Total					74.5

Total Wall Length		Envelope area of the building		
Orientation	Wall length (m)	Orientation	Total Wall length (m)	Envelope area (Sq.m)
North North East - 22.5	24.4	North North East - 22.5	24.4	85.4
East South East - 110.5	11.1	East South East - 110.5	11.1	38.85
South South West - 202.5	24.4	South South West - 202.5	24.4	85.4
West North West - 292.5	11.1	West North West - 292.5	11.1	38.85
Total	71	Total		248.5

Calculation of VLT (Visible Light Transmittance)		
A (non-opaque)	A (envelope)	WWR = A (non-opaque) / A (envelope)
51.6	248.5	0.207507847

As per ECBC, for WWR of 0.03 (range 0-0.30), the minimum required VLT is 0.27 (27%). The glass used in this project has a VLT of 0.53 (53%) (as per certified specification for the product). Thus, this project complies with this requirement. Also, it complies with the recommended value.



10.2.3. SOLAR HEAT GAIN COEFFICIENT – BLOCK A, B:

SOLAR HEAT GAIN COEFFICIENT										
Calculation of equivalent SHGC of non-opaque openings, for each orientation										
Orientation	Opening name	Width of Glass in Opening (m)	Height of Glass in Opening (m)	No. of openings	Glass Area in opening (m2)	H overhang (m)	V overhang (m)	PF overhang (m)	ESF overhang	SHGC equivalent
North North East - 22.5	W	1.43	1.43	1	2.0449	0.25	1.5	0.17	0.931	0.54
	SD	2.33	2.03	2	9.4598	0.25	1.5	0.17	0.931	0.54
	SD1	3.53	2.03	2	14.3318	0.25	1.5	0.17	0.931	0.54
East South East -110.5	W	1.43	1.43	2	4.0898	0.25	1.5	0.17	0.922	0.53
	D	0	0	2	0	0.25	1.5	0.17	0.922	0.53
	D1	0	0	2	0	0.25	1.5	0.17	0.922	0.53
	V	0	0	1	0	0.25	1.5	0.17	0.922	0.53
South South West - 202.5	W	1.43	1.43	4	8.1796	0.25	1.5	0.17	0.896	0.52
	SD	2.33	2.03	2	9.4598	0.25	1.5	0.17	0.896	0.52
	D	0	0	2	0	0.25	1.5	0.17	0.896	0.52
West North West - 292.5	W	1.43	1.43	2	4.0898	0.25	1.5	0.17	0.922	0.53
	D	0	0	3	0	0.25	1.5	0.17	0.922	0.53
	D1	0	0	1	0	0.25	1.5	0.17	0.922	0.53
	V	0	0	1	0	0.25	1.5	0.17	0.922	0.53
Solar control glass - 6mm - aura - clear		U-Value : 5.7 W/(m2.k)								
		SHGC - 0.58. 58% of solar heat transmitted								
		VT- 0.53. 53% of VLT								
The glass chosen has SHGC value of 0.27. All windows in this project has SHGC value lesser than the given SHGC value and so performs better										

Glass Details		Light Factors			Energy Factors		
Product Name	Shade	Transmission	Reflection		SF	SC	U-Value
		%	External	Internal	%		W/m ² .K
Solar Control Glass - 6 mm							
Spring	Clear	65	21	24	69	0.79	5.7
Nimbus	Clear	54	21	14	59	0.68	5.4
Aura	Clear	53	25	21	58	0.67	5.7
Nectar	Clear	37	22	16	45	0.52	5.3

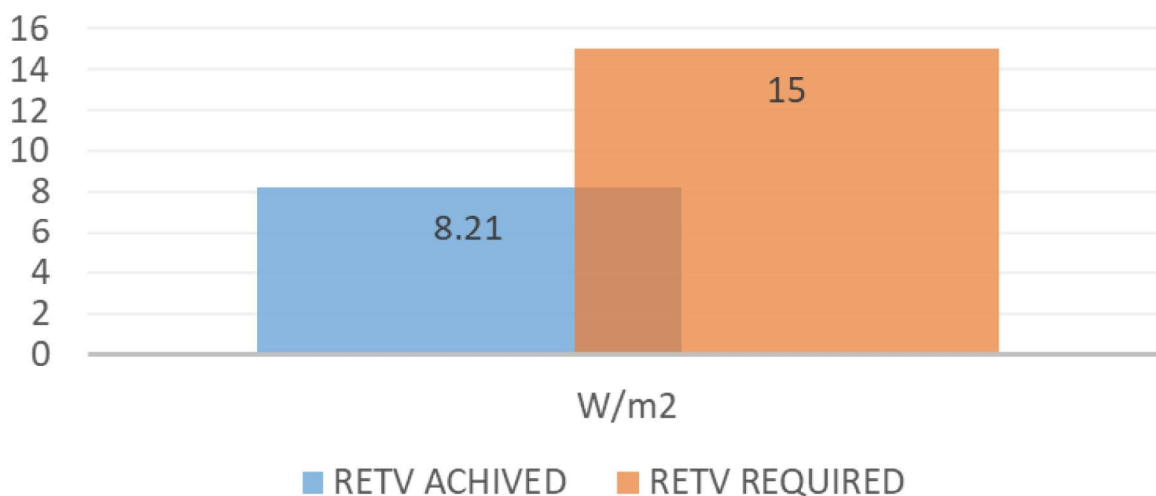
10.2.4. RESIDENTIAL ENVELOPE TRANSMITTANCE VALUE:

Residential Envelope Transmittance Value					
Calculation of 3 terms of RETV formula					
Calculation of Term-I					
Orientation	Component	(a) Area (m ²)	(b) U value (W/m ² .K)	(c) Orientation factor	(a) X (b) X (c)
North North East - 22.5	Opaque area 1 (earth wall)	83.2	0.9	0.66	49.32
	Opaque area 2 (timber window frame - teak)	0.2	2.1	0.66	0.28
	Opaque area 1 (earth wall)	75.3	0.9	0.66	44.67
	Opaque area 2 (timber window frame - teak)	0.6	2.1	0.66	0.86
East South East - 110.5	Opaque area 1 (earth wall)	70.3	0.9	0.66	41.68
	Opaque area 2 (timber window frame - teak)	0.8	2.1	0.66	1.09
	Opaque area 1 (earth wall)	34.4	0.9	1.16	35.71
	Opaque area 2 (timber window frame - teak)	0.5	2.1	1.16	1.21
South South West - 202.5	Opaque area 1 (earth wall)	76.6	0.9	0.97	66.60
	Opaque area 2 (timber window frame - teak)	0.6	2.1	0.97	1.26
	Opaque area 1 (earth wall)	75.3	0.9	0.97	65.48
	Opaque area 2 (timber window frame - teak)	0.6	2.1	0.97	1.26
West North West - 292.5	Opaque area 1 (earth wall)	34.4	0.9	1.16	35.74
	Opaque area 2 (timber window frame - teak)	0.4	2.1	1.16	1.00
Term-I total					346.15

Calculation of Term-II					
Orientation	Component	(a) Area (m ²)	(b) U value (W/m ² .K)	(c) Orientation factor	(a) X (b) X (c)
North North East - 22.5	Non-Opaque (glass) area	2.0	5.7	0.66	7.68
	Non-Opaque (glass) area	9.5	5.7	0.66	35.53
	Non-Opaque (glass) area	14.3	5.7	0.66	53.83
East South East - 110.5	Non-Opaque (glass) area	4.0	5.7	1.16	26.33
South South West - 202.5	Non-Opaque (glass) area	8.2	5.7	0.97	45.04
	Non-Opaque (glass) area	9.5	5.6	0.97	51.17
West North West - 292.5	Non-Opaque (glass) area	4.1	5.7	1.16	26.95
Term-II total					246.54

Calculation of Term-III					
Orientation	Component	(a) Glass Area (m ²)	(b) Equivalent SHGC	(c) Orientation factor	(a) X (b) X (c)
North North East - 22.5	W	2.0449	0.54	0.66	0.73
	SD	9.4598	0.54	0.66	3.37
	SDI	14.3318	0.54	0.66	5.10
East South East - 110.5	W	4.0898	0.53	1.16	2.53
South South West - 202.5	W	8.1796	0.52	0.97	4.11
	SD	9.4598	0.52	0.97	4.75
West North West - 292.5	W	4.0898	0.53	1.16	2.53
Term-II total					23.10

10.2.5. RESIDENTIAL ENVELOPE TRANSMITTANCE:



Achieved RETV IS **8.115 W/m²** This is less than the maximum RETV of **15 W/m²**. Hence it complies with this requirement.

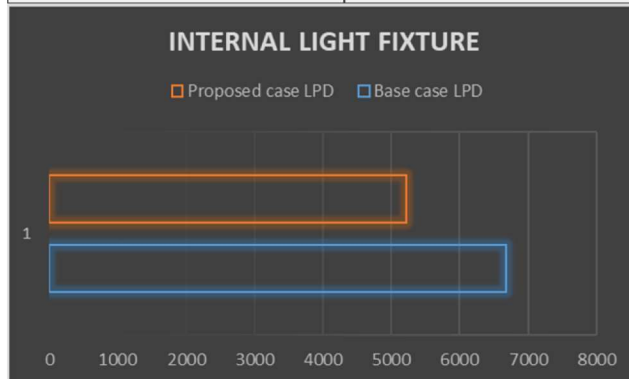
10.2.6. INTERNAL LIGHT FIXTURE:

Internal Light Fixture - COUPLE (Base Case LPD)					
Typology (LIG)	Area (Sq.m)	Timing(Hrs)	Base Case LPD	Watt	Energy (Annual)Kwh
Living and entrance	180	6	5	900	1971
Kitchen and dining	120	5	5	600	1095
Bedroom Area	240	8	5	1200	3504
Toilet Area	30	2	5	150	109.5
					6679.5

Internal Light Fixture LIG (Proposed Case LPD)											
Typology (COUPLE)	Area (Sq.m)	Lux Required	Lumens	Efficacy	Watt	LPD	Proposed Fixture (W)	No of Fixture	Timing (Hrs)	Total Watt	Energy (Annual)
Living and entrance	180	300	54000	81	666.67	3.70	12	56	6	666.666667	1460
Kitchen and dining	120	300	36000	81	444.44	3.70	12	37	7	444.444444	1135.555556
Bedroom	240	300	72000	81	888.89	3.70	12	74	8	888.888889	2595.555556
Toilet	30	100	3000	81	37.04	1.23	12	3	2	37.03703704	27.03703704
											5218.148148

Comparing internal light fixture to the Base LPD. The Proposed LPD **Saves 26%**.

Internal Light Fixture COUPLE (Saving)				
	Energy (Annual)	Rate of unit Rs	Total Amount	Percentage
Base Case	6679.5	6	\$ 40,077.00	100%
Proposed Case	5218.148148	6	\$ 31,308.89	78%
		Saving Annual	\$ 8,768.11	22%



Appliance	Watt	Timing (Hrs)	No of Items	Total Watt	Energy (Annual)
T.v	120	6	2	240	525.6
Fan	36	18	6	216	1419.12
Kitchen Fan	150	6	2	300	657
Mixer	750	1	2	1500	547.5
					3149.22

Solar Panel		
Energy (Annual) Kwh	Solar Panel (Kw)	Area (Sq.m)
8367.368148	5.731074074	53.24167815
10% extra added	0.573107407	5.324167815
Proposed Solar Panel	6.304181481	58.56584596
Solar Panel (w)	6304.181481	
No.of.solar panel		16

Cost Calculation		
Electric Current	\$ 50,204.21	Rupees
Solar Panel	\$ 208,037.99	Rupees
Return On Investment	4.14	Years

10.2.7. CROSS VENTILATION:

Cross Ventilation - BLOCK A B				
Regularly Occupied Spaces	Total Floor Area (Carpet) (Sq.M)	Window/Door type	Satisfies Cross Ventilation Criteria	Area Which Satisfies Cross Ventilation Criteria
Living,Dining and Kitchen 1	42.00	W,SD1	Yes	42.00
Bedroom 1	18.00	W,D,SD2	Yes	18.00
Living,Dining and Kitchen 2	42.00	W,SD1	Yes	42.00
Bedroom 2	18.00	W,D,SD2	Yes	18.00

Total Floor Area	120.00
Floor area achieving Cross Ventilation	120.00
	100%

10.2.8. EXTERIOR CONNECTIVITY:

EXTERIOR CONNECTIVITY - BLOCK A B							
Regularly Occupied Spaces	Total Floor Area (Carpet) (Sq.m)	Window/Door type	Direct line of sight	Obstruction of views (8m)	Access either to sky or flora & fauna or both.	Eligible	Meets the requirement
Living,Dining and Kitchen 1	42.00	W,SD1	YES	No	YES	YES	42.00
Bedroom 1	18.00	W,D,SD2	YES	No	YES	YES	18.00
Living,Dining and Kitchen 2	42.00	W,SD1	YES	No	YES	YES	42.00
Bedroom 2	18.00	W,D,SD2	YES	No	YES	YES	18.00
Total Floor Area							120.00
Floor area achieving Exterior connectivity							120.00
							100%

10.2.9. DAYLIGHT:

DAYLIGHT - BLOCK A B							
Regular Occupied	Floor area (sq.m)	Window area	VLT	Constant	Glazing Factor Required	Achieved Y/N	Area Meeting
Living,Dining and Kitchen1	42.00	9.59	0.7	0.2	3.195	2	42.00
Bedroom 1	18.00	6.56	0.7	0.2	5.103	1	18.00
Living,Dining and Kitchen	42.00	9.59	0.7	0.2	3.195	2	42.00
Bedroom 1	18.00	6.56	0.7	0.2	5.103	1	18.00
Total Floor Area							120.00
Floor area achieving daylight							120.00
							100%

10.2.10. TIME LAG FOR THE DIFFERENT OF SUSTAINABLE ROOF:

Thermal lag can be used to ease our internal and external diurnal temperature variation .in above give table inverted mud pod roof works effectively for 9 hours to reduce internal and external temperature.

10.2.11. TIME LAG:

S.No	Roof Description	Time Lag in hrs
1	Reinforced slab	5
2	Filler Slab Roof	2
3	Madras Terrace Roof	7
4	Thatch roof	4
5	Inverted Mud Pots roof	9

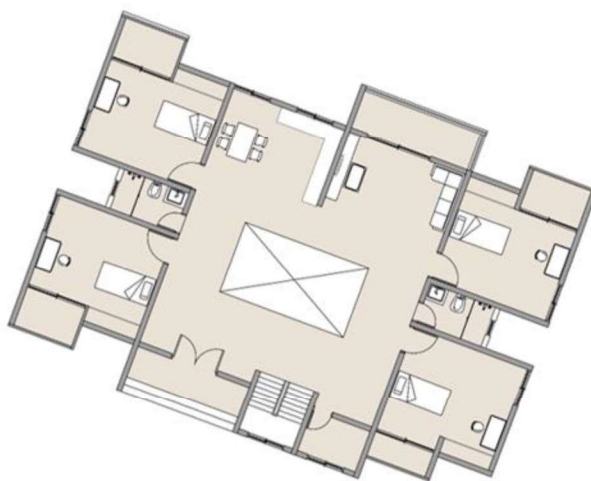
THERMAL TRANSMITTANCE OF ROOF			
Roof construction details			
Material layer	Thickness, t (m)	Thermal conductivity, k (W/m.K)	Thermal resistance of material, $R=t/k$ ($m^2 \cdot K/W$)
Terracotta tile with lime mortar	0.05	0.398	0.13
lime concrete (brick jelly)	0.05	0.43	0.12
Brick with lime mortar	0.3	0.664	0.45
Sum of all material thermal resistance			0.69

Total thermal resistance			
	Roof		
R _{si} (m ² .K/W)	0.17	Standard from ECBC	
R _{se} (m ² .K/W)	0.04		
R _f = R _{si} +R _{se} +R ₁ +R ₂ +R ₃ +... = 0.17+0.04+0.46 =0.90m ² .K/W			

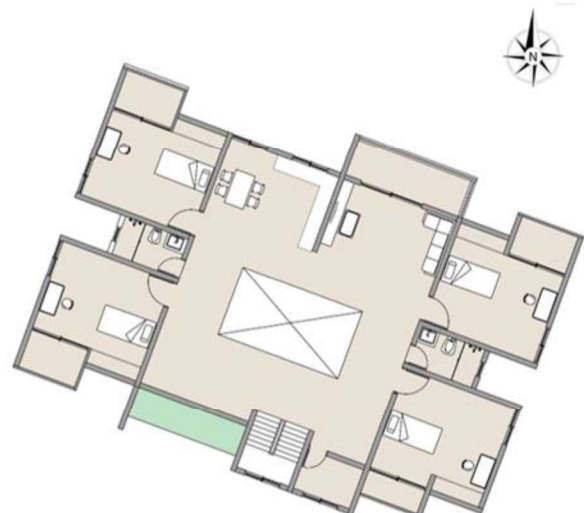
Thermal transmittance of roof
$U_{roof} = 1/R_f = 1.1065 \text{ w/m}^2\text{K}$
<i>This is less than the maximum U_{roof} value of $1.2 \text{ w/m}^2\text{K}$. Hence it complies with this requirement.</i>

11.0. BLOCK C, D:

11.1.1. FLOOR PLANS:



BLOCK C, D – GROUND FLOOR



BLOCK C, D – FIRST FLOOR AND SECOND FLOOR

11.2.1. WINDOW FLOOR RATIO – BLOCK C, D:

WINDOW FLOOR RATIO							
Details of exposed door, windows and ventilators							
Opening (Window/door/Ventilator) Name	Opening Width (m)	Opening Height(m)	Opening area (sq.m)	Width of Glass in Opening (m)	Height of Glass in Opening (m)	Glass Area in opening (m2)	Opaque area (m2)
W	1.5	1.5	2.3	1.43	1.43	2.0449	0.2
SD	2.4	2.1	5.0	2.33	2.03	4.7299	0.3101
SD1	3.6	2.1	7.6	3.53	2.03	7.1659	0.3941
D	0.9	2.1	1.9	0	0	0	1.89
D1	0.8	2.1	1.7	0	0	0	1.68
V	0.6	0.6	0.4	0	0	0	0.36

Calculation of total openable window - floor area ratio (WFR _{op})					
Opening (Window/door/Ventilator) Name	Opening area (sq.m)	Openable area for each floor (Sq.m)	Remarks	Nos	Total Openable area (Sq.m)
W	2.3	2.025	90% openable	24	48.6
SD	5.0	4.536	90% openable	12	54.432
SD1	7.6	6.804	90% openable	6	40.824
D	1.9	1.701	90% openable	18	30.62
D1	1.7	1.512	90% openable	9	13.61
V	0.4	0.324	90% openable	6	1.94
Total Openable area (A _{openable})					190.03

TABLE 1 Minimum requirement of window-to-floor area ratio (WFR_{op})

Climatic zone	Minimum WFR _{op} (%)
Composite	12.50
Hot Dry	10.00
Warm Humid	16.66
Temperate	12.50
Cold	8.33

Calculate the window operable area to floor area ratio (WFR _{op})			
A (openable)	A (carpet area)	WFR _{op} = A (openable)/ A (carpet area)	WFR _{op} in %
190.03	582	0.326505155	32.65
Chennai is in Warm and humid climate. As per ECBC standards, the minimum WFR _{op} for this climate is 16.66%. Ths, this project complies with the ECBC requirements.			



11.2.2. WINDOW WALL RATIO – BLOCK C, D:

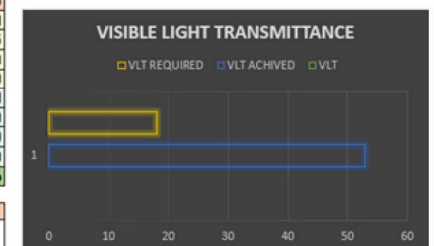
WINDOW WALL RATIO & VISUAL LIGHT TRANSMITTANCE						
Orientation	W	No. of openings				
		SD	SD1	D	D1	V
North North East - 22.5	2	2	1	0	0	0
East South East - 110.5	2	0	0	2	1	1
South South West - 202.5	2	2	0	2	1	0
West North West - 292.5	2	0	0	2	1	1
Total	8	4	1	6	3	2

Calculation of window-to-wall ratio (WWR)						
Orientation	Opening Name	Opening Area (Sq.m)	Non-opaque (glass) area in the opening	No. of opening	Total opening in Sq.m	Total non-opaque (glass) area in Sq.m
North North East - 22.5	W	2.3	2.0	2	4.5	4.1
	SD	5.0	4.7	2	10.1	9.5
	SD1	7.6	7.2	1	7.6	7.2
East South East - 110.5	W	2.3	2.0	2	4.5	4.0
	D	1.9	0.0	2	3.8	0.0
	D1	1.7	0.0	1	1.7	0.0
	V	0.4	0.0	1	0.4	0.0
South South West - 202.5	W	2.3	2.0	2	4.5	4.1
	SD	5.0	4.7	2	10.1	9.5
	D	1.9	0.0	2	3.8	0.0
	D1	1.7	0.0	1	1.7	0.0
West North West - 292.5	W	2.3	2.0	2	4.5	4.1
	D	1.9	0.0	2	3.8	0.0
	D1	1.7	0.0	1	1.7	0.0
	V	0.4	0.0	1	0.4	0.0
Total					62.8	42.4

Total Wall Length	
Orientation	Wall length (m)
North North East - 22.5	19.67
East South East - 110.5	12.94
South South West - 202.5	19.67
West North West - 292.5	12.94
Total	65.22

Envelope area of the building			
Orientation	Total Wall length (m)	Total Wall height (m)	Envelope area (Sq.m)
North North East - 22.5	19.67	3.5	68.845
East South East - 110.5	12.94	3.5	45.29
South South West - 202.5	19.67	3.5	68.845
West North West - 292.5	12.94	3.5	45.29
Total			228.27

Calculation of VLT (Visible Light Transmittance)		
A (non-opaque)	A (envelope)	WWR = A (non-opaque) / A (envelope)
42.4	228.27	0.185547378
As per ECBC, for WWR of 0.03 (range 0-0.30), the minimum required VLT is 0.18 (18%). The glass used in this project has a VLT of 0.53(53%) (as per certified specification for the product). Thus, this project complies with this requirement. Also, it complies with the recommended value.		



11.2.3. SOLAR HEAT GAIN COEFFICIENT – BLOCK C, D:

SOALR HEAT GAIN COEFFICIENT									
Calculation of equivalent SHGC of non-opaque openings, for each orientation									
Orientation	Opening name	Width of Glass in Opening (m)	Height of Glass in Opening (m)	No. of openings	Glass Area in opening (m ²)	H overhang (m)	V overhang (m)	PF overhang (m)	SHGC equivalent
North North East - 22.5	W	1.43	1.43	2	4.0898	0.25	1.5	0.17	0.54
	SD	2.33	2.03	2	9.4598	0.25	2.1	0.12	0.54
	SD1	3.53	2.03	1	7.1659	0.25	2.1	0.12	0.54
East South East -110.5	W	1.43	1.43	2	4.0898	0.25	1.5	0.17	0.53
	D	0	0	2	0	0.25	2.1	0.12	0.53
	D1	0	0	1	0	0.25	2.1	0.12	0.53
	V	0	0	1	0	0.25	0.6	0.42	0.49
South South West - 202.5	W	1.43	1.43	2	4.0898	0.25	1.5	0.17	0.47
	SD	2.33	0	2	0	0.25	2.1	0.12	0.47
	D	0	0	2	0	0.25	2.1	0.12	0.06
	D1	0	0	1	0	0.25	2.1	0.12	0.47
West North West - 292.5	W	1.43	1.43	2	4.0898	0.25	1.5	0.17	0.49
	D	0	0	2	0	0.25	2.1	0.12	0.49
	D1	0	0	1	0	0.25	2.1	0.12	0.49
	V	0	0	1	0	0.25	0.6	0.42	0.38

Solar control glass - 6mm - aura - clear	U-Value : 5.7 W/(m ² .K)	
	SHGC - 0.58. 58% of solar heat transmitted	
	VT- 0.53. 53% of VLT	

The glass choosen has SHGC value of 0.27. All windows in this project has SHGC value lesser than the given SHGC value and so performs better

Glass Details		Light Factors			Energy Factors		
Product Name	Shade	Transmission	Reflection		SF	SC	U-Value
			External	Internal			
		%	%	%	%		
Solar Control Glass – 6 mm							
Spring	Clear	65	21	24	69	0.79	5.7
Nimbus	Clear	54	21	14	59	0.68	5.4
Aura	Clear	53	25	21	58	0.67	5.7
Nectar	Clear	37	22	16	45	0.52	5.3

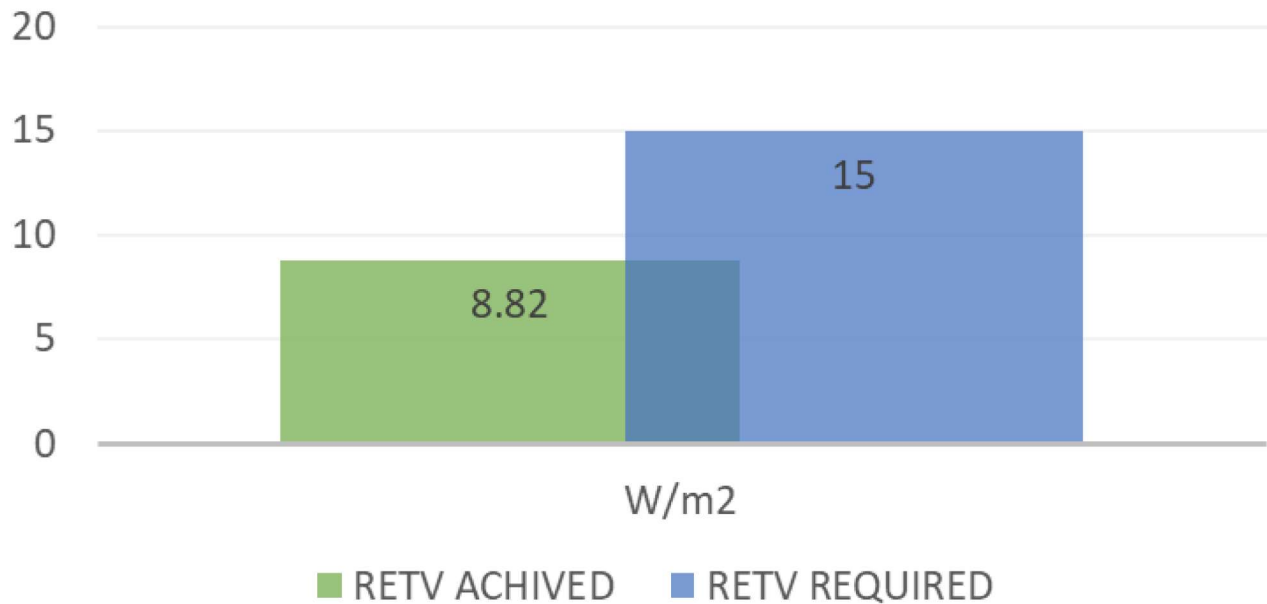
11.2.4. RESIDENTIAL ENVELOPE TRANSMITTANCE – BLOCK – C , D:

Calculation of 3 terms of RETV formula					
Calculation of Term-I					
Orientation	Component	(a) Area (m ²)	(b) U value (W/m ² .K)	(c) Orientation factor	(a) X (b) X (c)
North North East - 22.5	Opaque area 1 (earth wall)	64.3	0.9	0.66	38.16
	Opaque area 2 (timber window frame - teak)	0.4	2.1	0.66	0.57
	Opaque area 1 (earth wall)	58.8	0.9	0.66	34.85
	Opaque area 2 (timber window frame - teak)	0.6	2.1	0.66	0.86
East South East -110.5	Opaque area 1 (earth wall)	61.3	0.9	0.66	36.35
	Opaque area 2 (timber window frame - teak)	0.4	2.1	0.66	0.55
	Opaque area 1 (earth wall)	40.8	0.9	1.16	42.40
	Opaque area 2 (timber window frame - teak)	0.5	2.1	1.16	1.21
South South West - 202.5	Opaque area 1 (earth wall)	64.1	0.9	0.97	55.76
	Opaque area 2 (timber window frame - teak)	0.6	2.1	0.97	1.26
	Opaque area 1 (earth wall)	58.8	0.9	0.97	51.09
	Opaque area 2 (timber window frame - teak)	0.6	2.1	0.97	1.26
West North West - 292.5	Opaque area 1 (earth wall)	40.8	0.9	1.16	42.44
	Opaque area 2 (timber window frame - teak)	0.4	2.1	1.16	1.00
Term-I total					307.75

Calculation of Term-II					
Orientation	Component	(a) Area (m ²)	(b) U value (W/m ² .K)	(c) Orientation factor	(a) X (b) X (c)
North North East - 22.5	Non-Opaque (glass) area	4.1	5.7	0.66	15.36
	Non-Opaque (glass) area	9.5	5.7	0.66	35.53
	Non-Opaque (glass) area	7.2	5.7	0.66	26.92
East South East -110.5	Non-Opaque (glass) area	4.0	5.7	1.16	26.33
	Non-Opaque (glass) area	4.1	5.7	0.97	22.52
South South West - 202.5	Non-Opaque (glass) area	9.5	5.6	0.97	51.17
	Non-Opaque (glass) area	4.1	5.7	1.16	26.95
Term-II total					204.79

Calculation of Term-III					
Orientation	Component	(a) Glass Area (m ²)	(b) Equivalent SHGC	(c) Orientation factor	(a) X (b) X (c)
North North East - 22.5	W	2.0449	0.54	0.66	0.73
	SD	9.4598	0.54	0.66	3.37
	SD1	14.3318	0.54	0.66	5.10
East South East -110.5	W	4.0898	0.53	1.16	2.53
South South West - 202.5	W	8.1796	0.52	0.97	4.11
	SD	9.4598	0.52	0.97	4.75
West North West - 292.5	W	4.0898	0.53	1.16	2.53
Term-II total					23.10

11.2.5. RESIDENTIAL ENVELOPE TRANSMITTANCE:



Achieved RETV IS **8.82 W/m²** This is less than the maximum RETV of **15 W/m²**. Hence it complies with this requirement.

11.2.6. INTERNAL LIGHT FIXTURE:

Internal Light Fixture - SINGLE (Base Case LPD)					
Typology (SINGLE)	Area (Sq.m)	Timing(Hrs)	Base Case LPD	Watt	Energy (Annual)Kwh
COMMON AREA	240	6	5	1200	2628
Stair & Eletrical room	30	1	5	150	54.75
Bedroom Area	240	8	5	1200	3504
Toilet Area	30	2	5	150	109.5
					6296.25

Internal Light Fixture LIG (Proposed Case LPD)										
Typology (SINGLE)	Area (Sq.m)	Lux Required	Lumens	Efficacy	Watt	LPD	Proposed Fixture (W)	No of Fixture	Timing (Hrs)	Total Watt
Living and entrance	240	300	72000	81	888.89	3.70	12	74	6	888.888889
Kitchen and dining	30	300	9000	81	111.11	3.70	12	9	7	111.111111
Bedroom	240	300	72000	81	888.89	3.70	12	74	8	888.888889
Toilet	30	100	3000	81	37.04	1.23	12	3	2	37.03703704
										4853.148148

Comparing internal light fixture to the Base LPD. The Proposed LPD **Saves 26%**.

Internal Light Fixture SINGLE (Saving)				
	Energy (Annual)	Rate of unit Rs	Total Amount	Percentage
Base Case	6296.25	6	\$ 37,777.50	100%
Proposed Case	4853.148148	6	\$ 29,118.89	77%
		Saving Annual	\$ 8,658.61	23%



Internal Equipment BLOCK C ,D					
Appliance	Watt	Timing (Hrs)	No of Items	Total Watt	Energy (Annual)
T.v	120	6	2	240	525.6
Fan	36	18	6	216	1419.12
Kitchen Fan	150	6	2	300	657
Mixer	750	1	2	1500	547.5
					3149.22

Solar Panel		
Energy (Annual)	Solar Panel (Kw)	Area (Sq.m)
8002.368148	5.481074074	50.91917815
10% extra added	0.548107407	5.091917815
Proposed Solar Panel	6.029181481	56.01109596
Solar Panel (w)	6029.181481	
No.of.solar panel		15

Cost Calculation		
Electric Current	\$ 48,014.21	Rupees
Solar Panel	\$ 198,962.99	Rupees
Return On Investment	4.14	Years

11.2.7. CROSS VENTILATION:

Cross Ventilation - BLOCK C D				
Regularly Occupied Spaces	Total Floor Area (Carpet) (Sq.M)	Window/Door type	Satisfies Cross Ventilation Criteria	Area Which Satisfies Cross Ventilation Criteria
Living,Dining and Kitchen 1	78.00	W,W,D,SD1	Yes	78.00
Bedroom 1	18.00	W,,D,SD	Yes	18.00

Total Floor Area	96.00
Floor area achieving Cross Ventilation	96.00
	100%

11.2.8. EXTERIOR CONNECTIVITY:

EXTERIOR CONNECTIVITY - BLOCK C D							
Regularly Occupied Spaces	Total Floor Area (Carpet) (Sq.m)	Window/Door type	Direct line of sight	Obstruction of views (8m)	Access either to sky or flora & fauna or both.	Eligible	Meets the requirement
Living,Dining and Kitchen 1	78.00	W,W,D,SD1	YES	No	YES	YES	78.00
Bedroom 1	18.00	W,,D,SD	YES	No	YES	YES	18.00

Total Floor Area	96.00
Floor area achieving Cross Ventilation	96.00
	100%

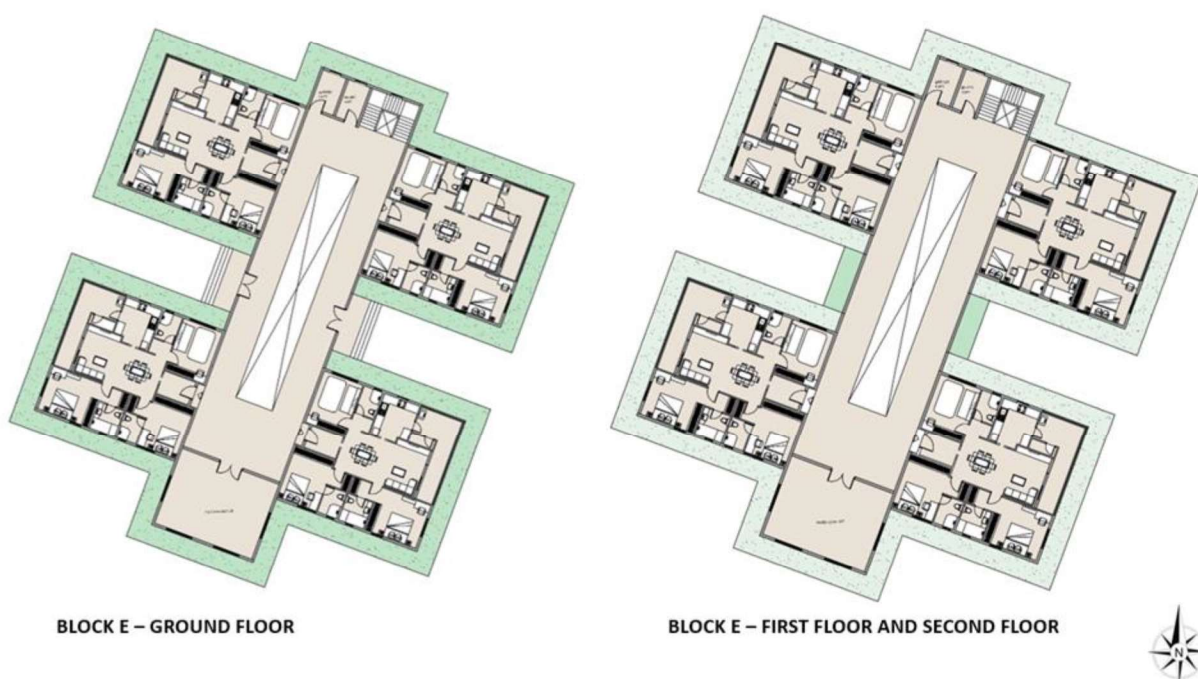
11.2.9. DAYLIGHT:

DAYLIGHT - BLOCK C D							
Regular Occupied	Floor area (sq.m)	Window area	VLT	Constant	Glazing Factor Required	Achieved Y/N	Area Meeting
Living,Dining and Kitchen1	78.00	13.50	0.7	0.2	2.423077	2	78.00
Bedroom 1	18.00	8.45	0.7	0.2	6.573	1	18.00

Total Floor Area	96.00
Floor area achieving daylight	96.00
	100%

12.0. BLOCK E:

12.1.1. FLOOR PLANS:



12.2.1. WINDOW FLOOR RATIO – BLOCK E:

WINDOW FLOOR RATIO							
Details of exposed door, windows and ventilators							
Opening (Window/door/Ventilator) Name	Opening Width (m)	Opening Height(m)	Opening area (sq.m)	Width of Glass in Opening (m)	Height of Glass in Opening (m)	Glass Area in opening (m2)	Opaque area (m2)
W	1.5	1.5	2.3	1.43	1.43	2.0449	0.2
W1	0.9	1.5	1.4	0.83	1.43	1.1869	0.2
W2	2	1.5	3.0	1.93	1.43	2.7599	0.2
SD	2.4	2.1	5.0	2.33	2.03	4.7299	0.3101
SD1	3.6	2.1	7.6	3.53	2.03	7.1659	0.3941
D	0.9	2.1	1.9	0	0	0	1.89
D1	0.8	2.1	1.7	0	0	0	1.68
V	0.6	0.6	0.4	0	0	0	0.36

Calculation of total openable window - floor area ratio (WFR _{op})					
Opening (Window/door/Ventilator) Name	Opening area (sq.m)	Openable area for each floor (Sq.m)	Remarks	Nos	Total Openable area (Sq.m)
W	2.3	2.025	90% openable	24	48.6
W1	1.4	1.215	90% openable	33	40.095
W2	3.0	2.7	90% openable	24	64.8
SD	5.0	4.536	90% openable	12	54.432
SD1	7.6	6.804	90% openable	0	0
D	1.9	1.701	90% openable	84	142.88
D1	1.7	1.512	90% openable	48	72.58
V	0.4	0.324	90% openable	36	11.66
Total Openable area (A _{openable})					435.05

Calculate the window operable area to floor area ratio (WFR_{op})

A (openable)	A (carpet area)	WFR(op) = A (openable)/ A (carpet area)	WFR(op) in %
435.05	2025	0.21484	21.48

Chennai is in Warm and humid climate. As per ECBC standards, the minimum WFR(op) for this climate is 16.66%. This project complies with the ECBC requirements.

TABLE 1 Minimum requirement of window-to-floor area ratio (WFR_{op})

Climatic zone	Minimum WFR _{op} (%)
Composite	12.50
Hot-Dry	10.00
Warm-Humid	16.66
Temperate	12.50
Cold	8.33



12.2.2. WINDOW WALL RATIO – BLOCK E:

WINDOW WALL RATIO & VISUAL LIGHT TRANSMITTANCE										
Naaf openings										
Orientation	W	W1	W2	SD	SD1	D	D1	V		
North North East - 22.5	0	4	4	0	0	2	2	4		
East South East - 110.5	4	1	0	2	0	4	4	0		
South South West - 202.5	4	4	2	2	0	10	4	0		
West North West - 292.5	4	1	2	2	0	4	4	8		
Total	12			8	0	20	14	12		

Calculation of window-to-wall ratio (WWR)

Orientation	Opening Name	Opening Area (Sq.m)	Non-opaque (glass) area in the opening	No. of opening	Total opening in Sq.m	Total non-opaque (glass) area in Sq.m
North North East - 22.5	W1	1.4	1.2	6	8.1	7.1
	W2	3.0	2.8	4	12.0	11.0
	D	1.9	0.0	2	3.8	0.0
	D1	1.7	0.0	2	3.4	0.0
	V	0.4	0.0	4	1.4	0.0
East South East - 110.5	W	2.3	2.0	2	4.5	4.0
	W1	1.4	1.2	2	2.7	2.4
	SD	5.0	4.7	2	10.1	9.4
	D	1.9	0.0	2	3.8	0.0
	D1	1.7	0.0	2	3.4	0.0
South South West - 202.5	W	2.3	2.0	4	9.0	8.2
	W1	1.4	1.2	2	2.8	2.4
	W2	3.0	2.8	2	6.0	5.5
	SD	5.0	4.7	2	10.1	9.4
	V	0.4	0.0	1	0.4	0.0
West North West - 292.5	W	2.3	2.0	2	4.5	4.1
	W1	1.4	1.2	3	4.2	3.6
	W2	3.0	2.8	1	3.0	2.8
	SD	5.0	4.7	1	5.0	4.7
	Total				98.1	74.6

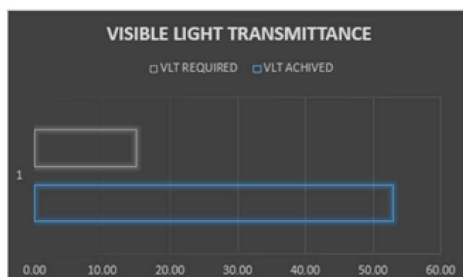
Total Wall Length	
Orientation	Wall length (m)
North North East - 22.5	37.79
East South East - 110.5	31.6
South South West - 202.5	37.79
West North West - 292.5	31.6
Total	138.78

Envelope area of the building		
Orientation	Total Wall length (m)	Envelope area (Sq.m)
North North East - 22.5	37.79	3.5
East South East - 110.5	31.6	3.5
South South West - 202.5	37.79	3.5
West North West - 292.5	31.6	3.5
Total		485.73

Calculation of VLT (Visible Light Transmittance)

A (non-opaque)	A (envelope)	WWR = A (non-opaque) / A (envelope)
74.6	485.73	0.153503798

As per ECBC, for WWR of 0.03 (range 0-0.30), the minimum required VLT is 0.153 (15%). The glass used in this project has a VLT of 0.53 (58%) (as per certified specification for the product). Thus, this project complies with this requirement. Also, it complies with the recommended value.



12.2.3. SOLAR HEAT GAIN COEFFICIENT:

SOLAR HEAT GAIN COEFFICIENT										
Calculation of equivalent SHGC of non-opaque openings, for each orientation										
Orientation	Opening name	Width of Glass in Opening (m)	Height of Glass in Opening (m)	No. of openings	Glass Area in opening (m2)	H overhang (m)	V overhang (m)	PF overhang (m)	ESF overhang	SHGC equivalent
North North East - 22.5	W1	1.43	1.43	6	12.2694	0.25	1.5	0.17	0.931	0.54
	W2	0.83	1.43	4	4.7476	0.25	1.5	0.17	0.931	0.54
East South East - 110.5	W	1.43	1.43	2	4.0898	0.25	1.5	0.17	0.922	0.53
	W1	0.83	1.43	2	2.3738	0.25	1.5	0.17	0.922	0.53
South South West - 202.5	SD	2.33	1.43	2	6.6638	0.25	1.5	0.17	0.922	0.53
	W	1.43	1.43	4	8.1796	0.25	1.5	0.17	0.896	0.52
West North West - 292.5	W1	1.43	1.43	2	4.0898	0.25	1.5	0.17	0.896	0.52
	W2	0.83	1.43	2	2.3738	0.25	1.5	0.17	0.896	0.52
	SD	2.33	1.43	2	6.6638	0.25	1.5	0.17	0.896	0.52
	W	1.43	1.43	2	4.0898	0.25	1.5	0.17	0.922	0.53
	W1	1.43	1.43	3	6.1347	0.25	1.5	0.17	0.922	0.53
	W2	0.83	1.43	1	1.1869	0.25	1.5	0.17	0.922	0.53
	SD	2.33	1.43	1	3.3319	0.25	1.5	0.17	0.922	0.53

Solar control glass - 6mm - aura - clear	U-Value : 5.7 W/(m2.k)								
	SHGC - 0.58, 58% of solar heat transmitted								
	VT- 0.53, 53% of VLT								
The glass chosen has SHGC value of 0.27. All windows in this project has SHGC value lesser than the given SHGC value and so performs better									

Glass Details		Light Factors			Energy Factors		
Product Name	Shade	Transmission	Reflection		SF	SC	U-Value
			External	Internal			
		%	%	%	%		W/m²K

Solar Control Glass - 6 mm

Spring	Clear	65	21	24	69	0.79	5.7
Nimbus	Clear	54	21	14	59	0.68	5.4
Aura	Clear	53	25	21	58	0.67	5.7
Nectar	Clear	37	22	16	45	0.52	5.3

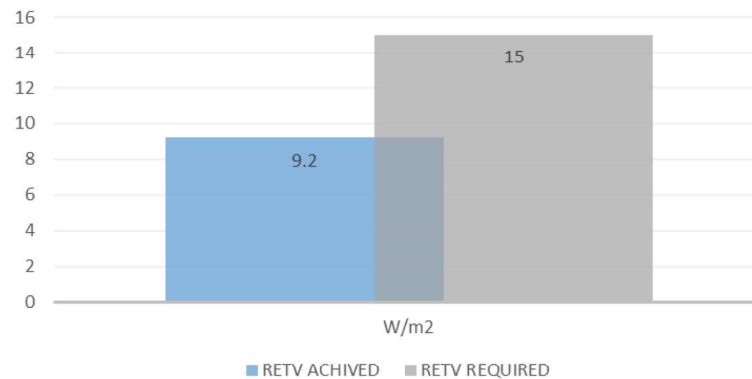
12.2.4. RESIDENTIAL ENVELOPE TRANSMITTANCE – BLOCK - E:

Calculation of 3 terms of RETV formula						
Calculation of Term-I						
Orientation	Component	(a) Area (m²)	(b) U value (W/m² .K)	(c) Orientation factor	(a) X (b) X (c)	
North North East - 22.5	Opaque area 1 (earth wall)	124.2	0.9	0.66	73.64	
	Opaque area 2 (timber window frame - teak)	1.0	2.1	0.66	1.41	
	Opaque area 1 (earth wall)	120.3	0.9	0.66	71.3291715	
	Opaque area 2 (timber window frame - teak)	1.0	2.1	0.66	1.3839	
East South East -110.5	Opaque area 1 (earth wall)	106.1	0.9	1.16	110.29095	
	Opaque area 2 (timber window frame - teak)	0.5	2.1	1.16	1.21275	
	Opaque area 1 (earth wall)	107.9	0.9	1.16	112.16205	
	Opaque area 2 (timber window frame - teak)	0.3	2.1	1.16	0.82467	
	Opaque area 1 (earth wall)	100.5	0.9	1.16	104.49054	
	Opaque area 2 (timber window frame - teak)	0.6	2.1	1.16	1.55232	
South South West - 202.5	Opaque area 1 (earth wall)	123.3	0.9	0.97	107.166591	
	Opaque area 2 (timber window frame - teak)	0.8	2.1	0.97	1.66426344	
	Opaque area 1 (earth wall)	129.5	0.9	0.97	112.556871	
	Opaque area 2 (timber window frame - teak)	0.4	2.1	0.97	0.8682408	
	Opaque area 1 (earth wall)	126.3	0.9	0.97	109.774791	
	Opaque area 2 (timber window frame - teak)	0.5	2.1	0.97	1.0143	
West North West - 292.5	Opaque area 1 (earth wall)	122.2	0.9	0.97	106.227639	
	Opaque area 2 (timber window frame - teak)	0.6	2.1	0.97	1.298304	
	Opaque area 1 (earth wall)	106.1	0.9	1.16	110.38644	
	Opaque area 2 (timber window frame - teak)	0.4	2.1	1.16	0.99580152	
	Opaque area 1 (earth wall)	106.4	0.9	1.16	110.69856	
	Opaque area 2 (timber window frame - teak)	0.6	2.1	1.16	1.45656	
	Opaque area 1 (earth wall)	107.6	0.9	1.16	111.94704	
	Opaque area 2 (timber window frame - teak)	0.2	2.1	1.16	0.48552	
	Opaque area 1 (earth wall)	105.6	0.9	1.16	109.824624	
	Opaque area 2 (timber window frame - teak)	0.3	2.1	1.16	0.825384	
Term-I total					1365.49	

Calculation of Term-II						
Orientation	Component	(a) Area (m²)	(b) U value (W/m² .K)	(c) Orientation factor	(a) X (b) X (c)	
North North East - 22.5	Non-Opaque (glass) area	7.1	5.7	0.66	26.59	
	Non-Opaque (glass) area	11.0	5.7	0.66	41.32	
East South East -110.5	Non-Opaque (glass) area	4.0	5.7	1.16	26.33	
	Non-Opaque (glass) area	2.4	5.7	1.16	15.54	
South South West - 202.5	Non-Opaque (glass) area	9.4	5.7	1.16	62.15	
	Non-Opaque (glass) area	8.2	5.7	0.97	45.04	
	Non-Opaque (glass) area	2.4	5.7	0.97	13.06	
	Non-Opaque (glass) area	5.5	5.7	0.97	30.28	
West North West - 292.5	Non-Opaque (glass) area	9.4	5.6	0.97	51.07	
	Non-Opaque (glass) area	4.1	5.7	1.16	26.95	
	Non-Opaque (glass) area	3.6	5.7	1.16	23.72	
	Non-Opaque (glass) area	2.8	5.7	1.16	18.45	
	Non-Opaque (glass) area	4.7	5.7	1.16	30.97	
Term-II total					411.47	

Calculation of Term-III						
Orientation	Component	(a) Glass Area (m²)	(b) Equivalent SHGC	(c) Orientation factor	(a) X (b) X (c)	
North North East - 22.5	W1	12.2694	0.54	0.66	4.366026973	
	W2	4.7476	0.54	0.66	1.689418363	
East South East -110.5	W	4.0898	0.53	1.16	2.526055972	
	W1	2.3738	0.53	1.16	1.466172348	
South South West - 202.5	SD	6.6638	0.53	1.16	4.11588141	
	W	8.1796	0.52	0.97	4.106248194	
	W1	4.0898	0.52	0.97	2.053124097	
	W2	2.3738	0.52	0.97	1.191673427	
West North West - 292.5	SD	6.6638	0.52	0.97	3.345300102	
	W	4.0898	0.53	1.16	2.528243034	
	W1	6.1347	0.53	1.16	3.792364551	
	W2	1.1869	0.53	1.16	0.73372088	
	SD	3.3319	0.53	1.16	2.059722472	
Term-III total					33.97	

12.2.5. RESIDENTIAL ENVELOPE TRANSMITTANCE:



Achieved RETV IS **9.2 W/m2** This is less than the maximum RETV of **15 W/m2**. Hence it complies with this requirement

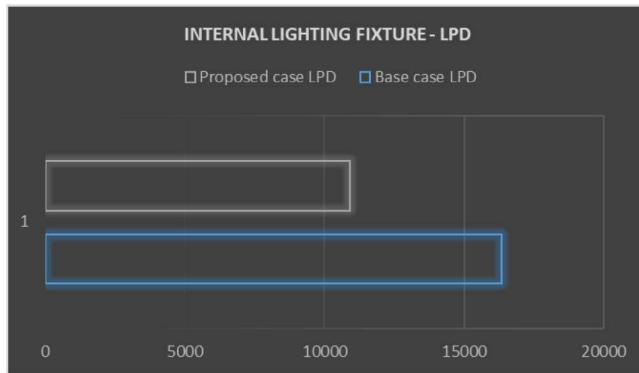
12.2.6. INTERNAL LIGHT FIXTURE:

Internal Light Fixture - Family (Base Case LPD)					
Typology (Family)	Area (Sq.m)	Timing(Hrs)	Base Case LPD	Watt	Energy (Annual)Kwh
Living and entrance	336	6	5	1680	3679.2
Kitchen	120	5	5	600	1095
Bedroom Area	540	8	5	2700	7884
Toilet Area	144	2	5	720	525.6
Common area	495	2	5	2475	1806.75
Staircase & Eletrical room	75	2	5	375	273.75
Multipurpose hall	150	4	5	750	1095
					16359.3

Internal Light Fixture (Proposed Case LPD)										
Typology (Family)	Area (Sq.m)	Lux Required	Lumens	Efficacy	Watt	LPD	Proposed Fixture (W)	No of Fixture	Timing (Hrs)	Energy (Annual)
Living and entrance	336	300	100800	81	1244.44	3.70	12	104	6	2725.333333
Kitchen	120	300	36000	81	444.44	3.70	12	37	5	811.1111111
Bedroom Area	540	300	162000	81	2000.00	3.70	12	167	8	5840
Toilet Area	144	100	54000	81	666.67	1.23	10	67	2	486.6666667
Common area	495	120	17280	81	213.33	1.48	11	19	2	155.7333333
Staircase & Eletrical room	75	100	7500	81	92.59	1.23	11	8	2	67.59259259
Multipurpose hall	150	300	45000	81	555.56	3.70	12	46	4	10897.54815

Comparing internal light fixture to the Base LPD. The Proposed LPD **Saves 26%**.

Internal Light Fixture Family (Saving)				
	Energy (Annual)	Rate of unit Rs	Total Amount	Percentage
Base Case	16359.3	6	\$ 98,155.80	100%
Proposed Case	10897.54815	6	\$ 65,385.29	66.61%
		Saving Annual	\$ 32,770.51	33%



Internal Equipment Family					
Appliance	Watt	Timing (Hrs)	No of Items	Total Watt	Energy (Annual)
T.v	120	6	24	2880	6307.2
Fan	36	18	48	1728	11352.96
Kitchen Fan	150	6	12	1800	3942
Mixer	750	1	12	9000	3285
					24887.16

Solar Panel		
Energy (Annual)	Solar Panel (Kw)	Area (Sq.m)
35784.70815	24.51007407	227.6985881
10% extra added	2.451007407	22.76985881
Proposed Solar Panel	26.96108148	250.468447
Solar Panel (w)	26961.08148	
No.of.solar panel		67

Cost Calculation		
Electric Current	\$ 214,708.25	Rupees
Solar Panel	\$ 889,715.69	Rupees
Return On Investment	4.14	Years

12.2.7. CROSS VENTILATION:

Cross Ventilation - BLOCK E				
Regularly Occupied Spaces	Total Floor Area (Carpet) (Sq.M)	Window/Door type	Satisfies Cross Ventilation Criteria	Area Which Satisfies Cross Ventilation Criteria
Living	26.00	SD ,MD	Yes	26.00
Kitchen	10.00	W1 , D	Yes	10.00
Master Bedroom	17.00	W,W1,D	Yes	17.00
Bedroom	15.00	W,D	Yes	15.00
Ch. Bedroom	13.00	W2,D,SD1	Yes	13.00
Multipurpose hall	50.00	W2,W2,W2,D	Yes	50.00

Total Floor Area	131.00
Floor area achieving Cross Ventilation	131.00
	100%

12.2.8. EXTERIOR CONNECTIVITY:

EXTERIOR CONNECTIVITY - BLOCK E							
Regularly Occupied Spaces	Total Floor Area (Carpet) (Sq.m)	Window/Door type	Direct line of sight	Obstruction of views (8m)	Access either to sky or flora & fauna or both	Eligible	Meets the requirement
Living	26.00	SD ,MD	YES	No	YES	YES	26.00
Kitchen	10.00	W1 , D	YES	No	YES	YES	10.00
Master Bedroom	17.00	W,W1,D	YES	No	YES	YES	17.00
Bedroom	15.00	W,D	YES	No	YES	YES	15.00
Ch. Bedroom	13.00	W2,D,SD1	YES	No	YES	YES	13.00
Multipurpose hall	50.00	W2,W2,W2,D	YES	No	YES	YES	50.00

Total Floor Area	131.00
Floor area achieving Exterior connectivity	131.00
	100%

12.2.9. DAYLIGHT:

DAYLIGHT - BLOCK E							
Regular Occupied	Floor area (sq.m)	Window area	VLT	Constant	Glazing Factor Required	Achieved Y/N	Area Meeting
Living	26.00	6.43	0.7	0.2	3.460154	1	26.00
Kitchen	10.00	3.24	0.7	0.2	4.536	2	10.00
Master Bedroom	17.00	5.27	0.7	0.2	4.335882	1	17.00
Bedroom	15.00	3.92	0.7	0.2	3.654	1	15.00
Ch. Bedroom	13.00	6.57	0.7	0.2	7.075385	1	13.00

Total Floor Area	81.00
Floor area achieving daylight	81.00
	100%

13.0. RAINFALL RUNOFF CALCULATION:

ACE RESIDENTIAL SECTOR 150- SITE RAINFALL CALCULATION				
Run-off Calculation				
S.No.	Zone	Area (sq.m.)	Run-off Coefficient	Impervious Area (sq. m.)
1	Cemented Roof	2945.00	0.80	2356.0
2	Vegetation Open Area (Inside, Outside and Utility area)	11310.83	0.20	2262.2
3	Hardscape (Pathways/Driveways)	3700.00	0.95	3515.0
Net Impervious Area				8133.2
Rainfall Intensity (m/day) considering 14% of average peak rainfall (4 point)				0.060
Total Run-off Volume (Cu.m.)				491.12

Year	Peak Month Rainfall	Peak Rainfall (mm)
2014	OCT	384
2015	NOV	807.6
2016	AUG	188
2017	NOV	437
2018	NOV	340

Last 5 years average daily rainfall (mm)	431.32
--	--------

Area cu.m	Liters
1	1000
491.12	491119.5902

BLOCK A , B	REQUIRED	ACHIVED
Wall floor ratio	16.60%	37.49%
Wall window ratio	Visual light transmittance 27%	Visual light transmittance 53%
Residential Envelope Transmittance Value	15 W/m2	8 W/m2
Solar heat coefficient	According to IGBC Required : GLAZING : SHGC - 0.5 UVALUE :5.7W/M2k Max point : 2 points	According to IGBC Achived : GLAZING : SHGC - 0.5 UVALUE :5.7W/m2K Max point : 2 points
Internal light fixture	BASE CASE LPD:6679 Max point : 2 points	BASE CASE LPD:5218 Achived point : 1 points
Solar panel	No.of .solar panel:16	Return on Investment: 4.14 year
Cross ventilation	Percentage achived:25% achived points: 4	Percentage achived:100% achived points: 4
Exterior connectivity	Percentage achived:50% achived points:2	Percentage achived:100% achived points:2
Daylight	Percentage achived:75% achived points:2	Percentage achived:100% achived points:2
RAINFALL RUNOFF CALCULATION	Max point : 4 points	Max point : 4 points
Water Efficient Plumbing Fixtures	Baseline consumption :9225 Max point : 6 points	Proposed consumption :5670 Max point : 6 points
Enhanced Energy Performance	Max point : 7 points	Achived point : 7 points
Minimum Energy Performance	Max points :2 points	Achived point : 2 points

BLOCK C , D	REQUIRED	ACHIVED
Wall floor ratio	16.60%	32.65%
Wall window ratio	Visual light transmittance 27%	Visual light transmittance 53%
Residential Envelope Transmittance Value	15 W/m2	8 W/m2
Solar heat coefficient	According to IGBC Required : GLAZING: SHGC - 0.5 UVALUE :5.7W/M2k Max point : 2 points	According to IGBC Achived : GLAZING : SHGC - 0.5 UVALUE :5.7W/m2K Max point : 2 points
Internal light fixture	BASE CASE LPD:6296 Max point : 2 points	BASE CASE LPD:4853 Achived point : 1 points
Solar panel	No.of .solar panel:15	Return on Investment: 4.14 year
Cross ventilation	Percentage achived:25% achived points: 4	Percentage achived:100% achived points: 4
Exterior connectivity	Percentage achived:50% achived points:2	Percentage achived:100% achived points:2
Daylight	Percentage achived:75% achived points:2	Percentage achived:100% achived points:2
RAINFALL RUNOFF CALCULATION	Max point : 4 points	Max point : 4 points
Water Efficient Plumbing Fixtures	Baseline consumption :9225 Max point : 6 points	Proposed consumption :5670 Max point : 6 points
Enhanced Energy Performance	Max point : 7 points	Achived point : 7 points
Minimum Energy Performance	Max points :2 points	Achived point : 2 points

BLOCK E	REQUIRED	ACHIVED
Wall floor ratio	16.60%	21.89%
Wall window ratio	Visual light transmittance 27%	Visual light transmittance 53%
Solar heat coefficient	According to IGBC Required : GLAZING : SHGC - 0.5 UVALUE :5.7W/m2K	According to IGBC Achived : GLAZING : SHGC - 0.5 UVALUE :5.7W/m2K
Residential Envelope Transmittance Value	15 W/m2	8 W/m2
Internal light fixture	BASE CASE LPD:16359 Max point : 2 points	BASE CASE LPD:10897 Achived point : 1 points
Solar panel	No.of .solar panel:67	Return on Investment: 4.14 year
Cross ventilation	Percentage achived:25% achived points: 4	Percentage achived:100% achived points: 4
Exterior connectivity	Percentage achived:50% achived points:2	Percentage achived:100% achived points:2
Daylight	Percentage achived:75% achived points:2	Percentage achived:100% achived points:2
RAINFALL RUNOFF CALCULATION	Max point : 4 points	Max point : 4 points
Water Efficient Plumbing Fixtures	Baseline consumption :9225 Max point : 6 points	Proposed consumption :5670 Max point : 6 points
Enhanced Energy Performance	Max point : 7 points	Achived point : 7 points
Minimum Energy Performance	Max points :2 points	Achived point : 2 points

14.0. CONCLUSION:

In my prethesis, I have done a research based on a performance of thermal comfort in comparing earth architecture and conventional buildings.

Following thesis, I have proved that through the earth architecture and passive strategies, co-living can be enhanced and Such a way, the **COMPUTATION SIMULATION, IGBC and ECBC calculations** are done and justified.

REFERENCES

- 1) Attia, S. (2018). *Regenerative and positive impact architecture: Learning from case studies*. Springer International Publishing.
- 2) Brown, M., Haselsteiner, E., Apró, D., Kopeva, D., Luca, E., Pulkkinen, K. L., & Rizvanolli, B. V. (2018). *RESTORE—Sustainability, restorative to regenerative: An exploration in progressing a paradigm shift in built environmental thinking, from sustainability to restorative e sustainability and on to regenerative sustainability (COST Action CA16114 Report)*.
- 3) Carragher, V., & Peters, M. (2018). *Engaging an ecovillage and measuring its ecological footprint*. *Local Environment*, 23(8), 861-878.
- 4) Giratalla, W. (2010). *Assessing the environmental practices and impacts of intentional communities: an ecological footprint comparison of an ecovillage and cohousing community in southwestern British Columbia (Doctoral dissertation, University of British Columbia)*.
- 5) Khoja, A., & Waheeb, S. (2020). *Vernomimicry: Bridging the Gap between Nature and Sustainable Architecture*. *Journal of Sustainable Development*, 13(1).