

# **NATURALLY VENTILATED HIGH RISE RESIDENTIAL BUILDING IN WARM HUMID CLIMATE**

A Thesis

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

by

**CLINTIA KAREN D (39890005)**



**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**



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## DEPARTMENT OF ARCHITECTURE

### BONAFIDE CERTIFICATE

This is to certify that this Report is the bonafide work of **CLINTIA KAREN D (39890005)** who carried out the Thesis entitled "**NATURALLY VENTILATED HIGH RISE RESIDENTIAL BUILDING IN WARM HUMID CLIMATE**" under our supervision from February 2021 to May 2021.

**Internal guide**  
(Ar. SURYA RAJKUMAR)

**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 **CLINTIA KAREN D** hereby declare that the Thesis Report entitled “**NATURALLY VENTILATED HIGH RISE RESIDENTIAL BUILDING IN WARM HUMID CLIMATE**” done by me under the guidance of **Ar. SURYA RAJKUMAR** (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:**

**SIGNATURE OF THE CANDIDATE**

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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.

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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**

Natural ventilation is efficient for passive cooling of buildings, to improve indoor air quality, occupant comfort and consequently, the reduction of the use of electric energy. Hence passive strategies to maintain the indoor thermal comfort using natural ventilation are analysed for a warm humid climate. CFD analysis for evaluating cross ventilation for various iterations to identify the better performing results. Thesis identified results were incorporated in the planning and designing of the high rise residence. Energy analysis and cost analysis to identify the reduction in energy and the cost savings by avoiding air conditioning. Sustainable practices like usage of renewable power, storm water and grey water management and waste management to further reduce the energy consumption and make the design more sustainable.



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# **CHAPTER 1**

## **INTRODUCTION**

### **1.1 INTRODUCTION**

Natural ventilation is one of the most important strategies for the passive cooling in high rise buildings, as it provides thermal comfort and improves the health of users, through internal air renewal. It also reduces the energy consumption, and avoids the use of mechanical ventilation and air conditioning systems. The energy cost of a naturally ventilated building is typically 40% lower than that of air-conditioned building. Since high rise residential buildings contribute to 75% of the energy consumption in the building sector it is necessary to reduce the amount of energy consumption to make it more sustainable. High rise buildings are exposed to maximum solar radiations as they are not completely shaded by the adjacent buildings and vegetation. They also experience high wind speed as the floor height increases hence it is necessary to induce passive strategies for controlled air movement.

Climate plays a major role in increasing the effectiveness of the passive strategies followed in order to improve the natural ventilation. Warm humid climate is considered to be more preferable for the provision of balconies as they are required to have a controlled and consistent air flow pattern.

### **1.2 AIM :**

To design a naturally ventilated high rise residential building in a warm humid climate with strategies to reduce energy consumption.

### **1.3 OBJECTIVES :**

- To design a vertical housing incorporating the various passive strategies and analyzing the effects of the parameters to increase the effect of natural ventilation.
- To observe the variations of wind pressure and wind velocity at different levels in a high rise residential building by evaluating the air flow to achieve the required thermal comfort.
- To create an environment with sufficient daylight and to achieve the required lux level.

## 1.4 SCOPE & LIMITATIONS :

- To plan and design a naturally ventilated and climate responsive high rise residential building with the most effective criteria for orientation, massing, lightwell ratio, window wall ratio and window floor ratio.
- The research is limited to focus mainly on the strategies to improve natural ventilation thereby avoiding the purpose of mechanical systems.
- Climate responsive design strategies to suit only the warm humid climate.

## 1.5 METHODOLOGY :

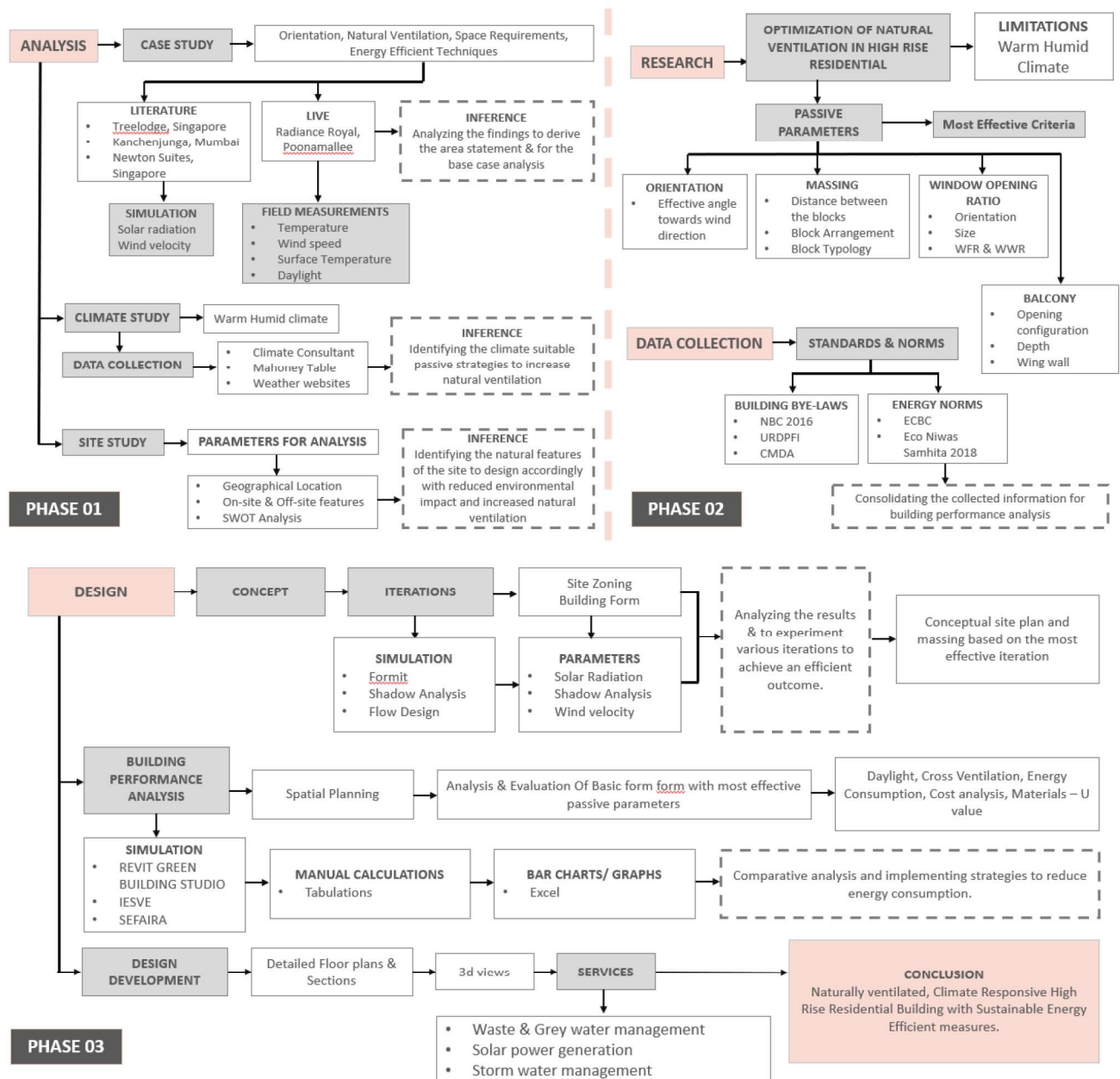


Fig 1.1 Detailed Methodology

## CHAPTER 2

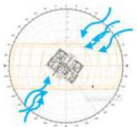
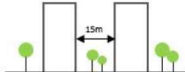
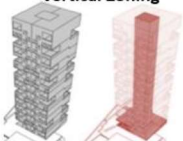
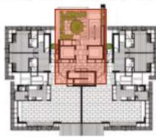
### LITERATURE REVIEW

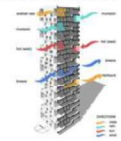
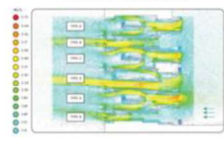
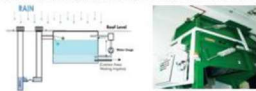
#### 2.1 CASE STUDY :

Literature & Live case studies with **sustainable practices & passive strategies for natural ventilation and to reduce the solar radiations** were selected for analysis based on the **criteria of warm humid climate, similar site area and space requirements**.

- Treelodge, Singapore
- Kanchenjunga, Mumbai
- Newton Suites, Singapore

#### CASE STUDY INFERENCE :

| S.NO | PASSIVE STRATEGIES                                                                                     | CRITERIA                                                                                                                           | INFERENCE                                                                                                                                                                                   |
|------|--------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1.   | Site Plan                                                                                              | Zoning<br>                                        | Site planning by differentiating the <b>semi public, private and service areas</b> for efficient functioning.                                                                               |
| 2.   | Orientation<br>      | Predominant wind Direction & Solar heat Gain<br> | Chennai receives consistent <b>sea breeze from the east</b> throughout the year. Hence it is necessary to orient at an angle to utilize the <b>easterly and south easterly winds</b> .      |
| 3.   | Massing<br>         | Arrangement of blocks<br>                       | <b>Wide spacing between towers</b> with min of 15m to ensure <b>cross air circulation and to create self shading</b> thereby reducing the heat gain.                                        |
| 4.   | Vertical Zoning<br> | Residential units & Service core<br>            | <b>Defining the spaces</b> for the units and the no of required service cores as the norms. Floor plans with more than 4 residential units require <b>2 service cores for easy access</b> . |

| S.NO | PASSIVE STRATEGIES                                                                                         | CRITERIA                                                                                                                      | INFERENCE                                                                                                                                                                                                                                                                                  |
|------|------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 5.   | Natural Ventilation<br> | Cross Ventilation<br>                      | Maintaining the indoor thermal comfort by increasing the natural ventilation. <ul style="list-style-type: none"> <li>• <b>Max openings on the windward and leeward façade</b></li> <li>• <b>Balconies</b></li> <li>• <b>Open spaces</b></li> <li>• <b>Lightwells</b></li> </ul>            |
| 6.   | UHI Effect<br>          | Strategies<br>                             | Necessary strategies to cut down the UHI effect <ul style="list-style-type: none"> <li>• <b>Green Roof</b></li> <li>• <b>Green walls</b></li> <li>• <b>Hybrid planting</b></li> <li>• <b>Cool walls</b></li> </ul>                                                                         |
| 7.   | Shading Elements<br>    | Reduce solar radiations<br>                | <b>Shading elements</b> to reduce the direct solar radiation on the <b>southern and western facades</b> during summers. <ul style="list-style-type: none"> <li>• <b>Balconies</b></li> <li>• <b>Sky gardens</b></li> <li>• <b>Shading Devices</b></li> <li>• <b>Cantilevers</b></li> </ul> |
| 8.   | Services<br>            | Reduce energy usage and save resources<br> | <ul style="list-style-type: none"> <li>• <b>Rain water harvesting</b></li> <li>• <b>Storm water runoff</b></li> <li>• <b>Solar power generation</b></li> <li>• <b>Waste and Grey water recycling</b></li> </ul>                                                                            |



## CHAPTER 3

### ANALYSIS

#### 3.1 CLIMATE ANALYSIS :

Analysis of Warm Humid climate from Climate consultant, Mahoney table and weather websites.

- **Summer months** receive winds majorly from **South-east and South** direction.
- **July to September** receive winds from **South-west monsoon**.
- **October to February** receives winds from **North-east monsoon**.

| PARAMETERS                        | MAHONEY TABLE                                                                                           | CLIMATE CONSULTANT                                                                                  | BAR CHART                         | INFERENCE                                                                                                                                                                                                                        |
|-----------------------------------|---------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------|-----------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>TEMPERATURE</b>                | Max Temperature – April (37 degc)<br>Min Temperature – Jan (21 degc)<br>Average Temperature – 32.2 degc | Max Temperature – May (38 degc)<br>Min Temperature – Jan (20 degc)<br>Average Temperature – 33 degc | <p>Temperature</p>                | <p>The climate of Chennai remains hot and humid for most of the year hence it is necessary to provide <b>proper shading strategies to avoid the heat radiations</b> into the indoor spaces.</p>                                  |
| <b>RAINFALL</b>                   | Max Rainfall – Nov (384mm)<br>Min Rainfall – Feb (1.8 mm)                                               | Max Rainfall – Nov (407.4mm)<br>Min Rainfall – Feb (2.2 mm)                                         | <p>Rainfall (mm)</p>              | <p>The city experiences cyclonic rainfall during the north east monsoons hence precautions have to be taken to <b>avoid storm water runoff</b> and to follow <b>water management strategies</b>.</p>                             |
| PARAMETERS                        | MAHONEY TABLE                                                                                           | CLIMATE CONSULTANT                                                                                  | BAR CHART                         | INFERENCE                                                                                                                                                                                                                        |
| <b>DRY BULB TEMPERATURE (Day)</b> | Max Temperature – May & June (38.2 degc)<br>Min Temperature – Jan (19 degc)                             | Max Temperature – May (39 degc)<br>Min Temperature – Jan (20 degc)                                  | <p>Dry Bulb Temperature (Day)</p> | <p>The air remains very dry and hot during the day and the city experiences high temperatures in most of the months.<br/><b>Shading of western and southern facades</b> is necessary to maintain the indoor thermal comfort.</p> |
| <b>RELATIVE HUMIDITY</b>          | Max Humidity – Nov (Above 70%)<br>Min Humidity – June (50 – 60%)                                        | Max Humidity – Nov (78%)<br>Min Humidity – June (57%)                                               | <p>Humidity</p>                   | <p>Annual average relative humidity is <b>69.8%</b>. High humidity is recorded during winter months. Passive strategies have to be followed for <b>increasing the cross ventilation</b> at every regularly occupied spaces.</p>  |
| <b>WIND VELOCITY</b>              | No data                                                                                                 | Max wind velocity – May (5.8 m/s)<br>Min wind velocity – Oct (3.8 m/s)                              | <p>Wind velocity (m/s)</p>        | <p>Strategies for utilizing the seasonal winds by providing <b>max openings facing the predominant wind directions</b>.</p>                                                                                                      |

Fig 3.1 Inference of Climate analysis

### WIND DIRECTION :

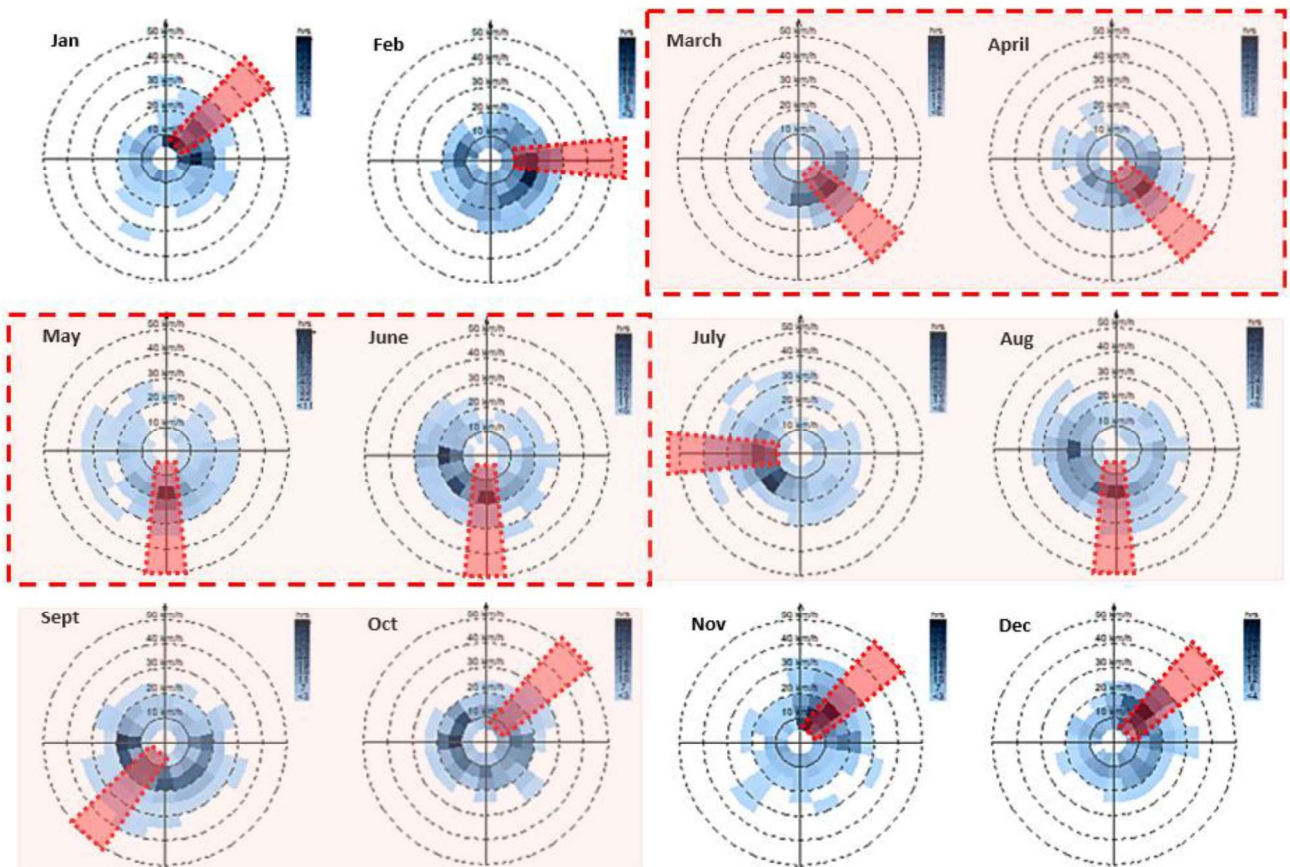
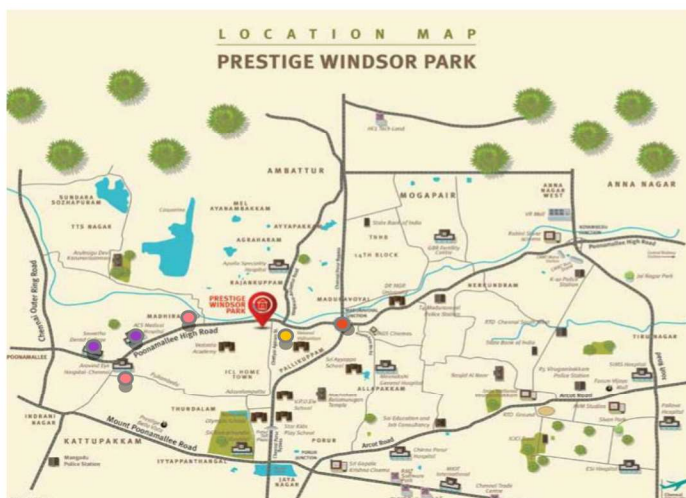


Fig 3.2 Wind Analysis for Chennai

### 3.2 SITE ANALYSIS :

Vanagaram in North east Chennai has evolved into an upmarket residential neighbourhood due to the close proximity to the IT Parks of Ambattur and Poonamallee High road. Nearly 132 upcoming new residential projects at vanagaram.



### LANDMARKS AT CLOSE PROXIMITY

- Vanagaram Bus Stop (500m)
- Madhavayal Flyover (1.12km)
- Aravind Eye hospital (2km)
- ACS Medical College (2.2km)
- Saveetha Dental College (2.2km)

Fig 3.3 Landmarks at close proximity





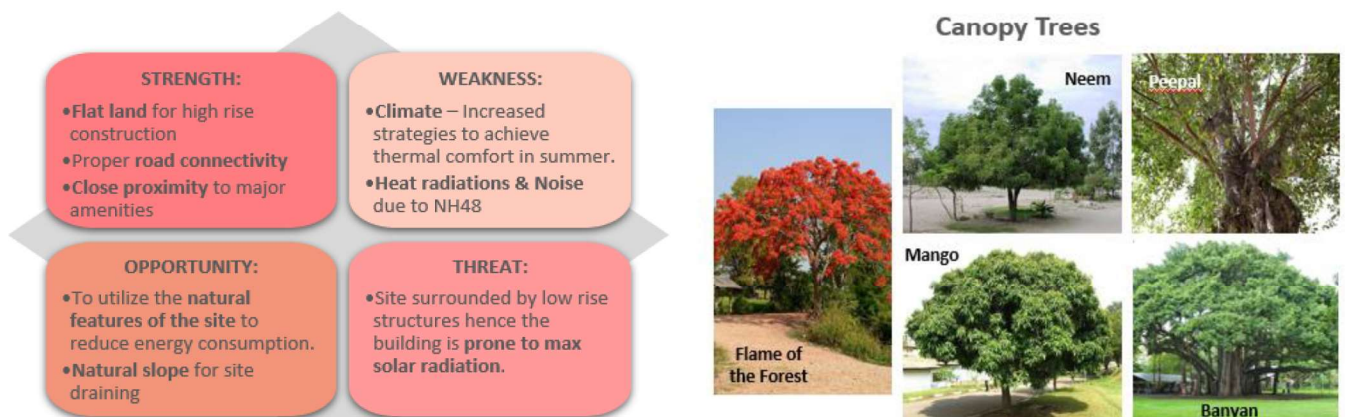
**Fig 3.4 Site Development in 15 years**

The site is a **flat land** with gradual difference in the terrain ranging from **15m elevation in the north** to **13m** at the **center of the site** and **14m** at the **southern end**. The slight variation is noted from the edges of the site to the center in a length of **272m**.



The natural slope of the site can be utilized for **site draining** and **storm water collection**.

**Fig 3.5 Natural Slope of the site**



**Fig 3.6 SWOT analysis and Native Vegetation**



### LEGEND

- Residential (Max ht - G+2)
- Multifamily Housing (G+4)
- Ware house (Gf)
- Institution (G+2)
- Commercial (Max ht - G+2)
- Prestige Windsor Group (5 acres)
- Coovum River (166m from site)
- Secondary road (6m width)
- Primary road  
Poonamallee High Road- NH 48  
(15m width)



Fig 3.7 Landuse

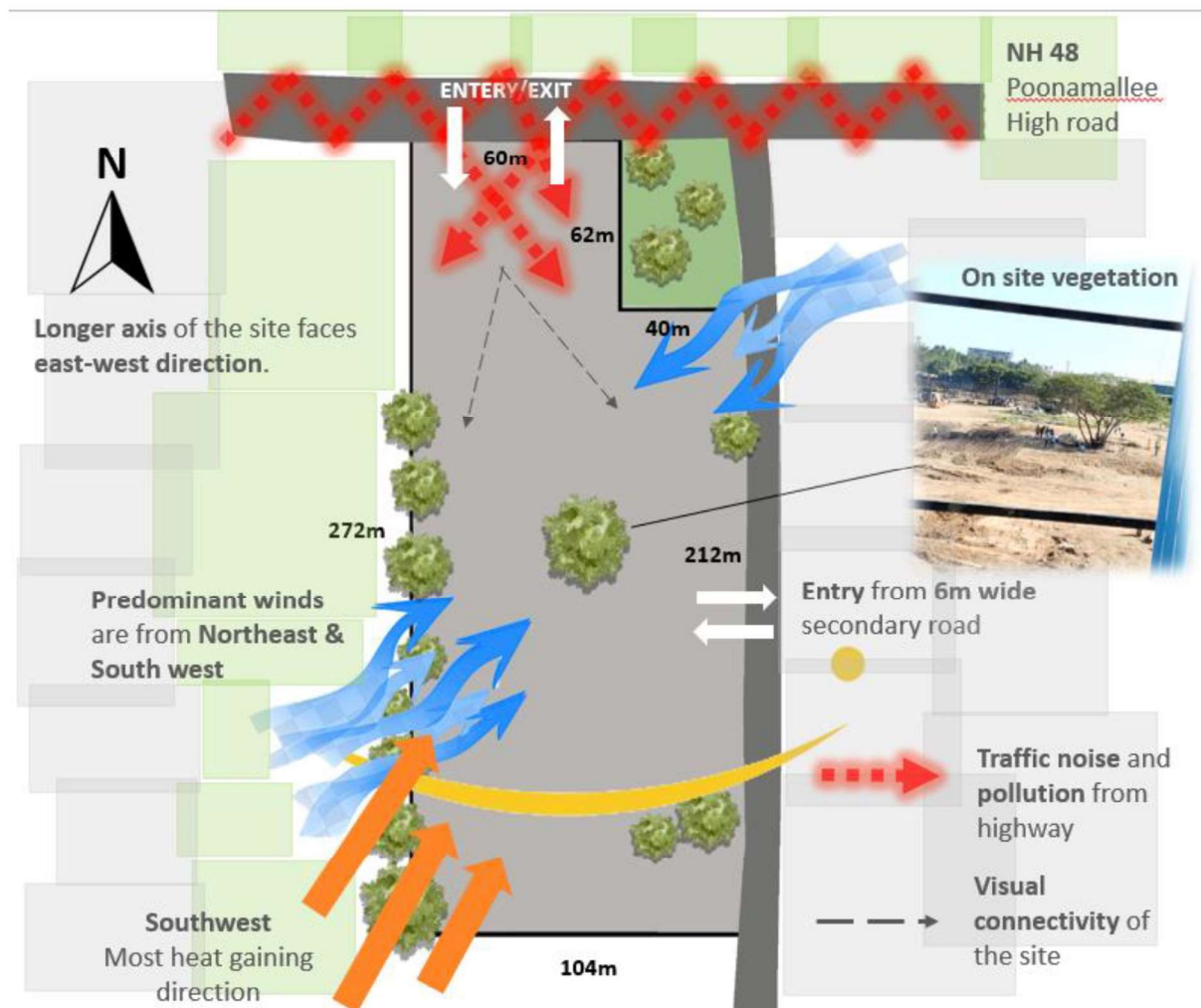


Fig 3.8 Site Analysis

## CHAPTER 4

### ANALYSIS OF PASSIVE PARAMETERS

#### 4.1 ORIENTATION :

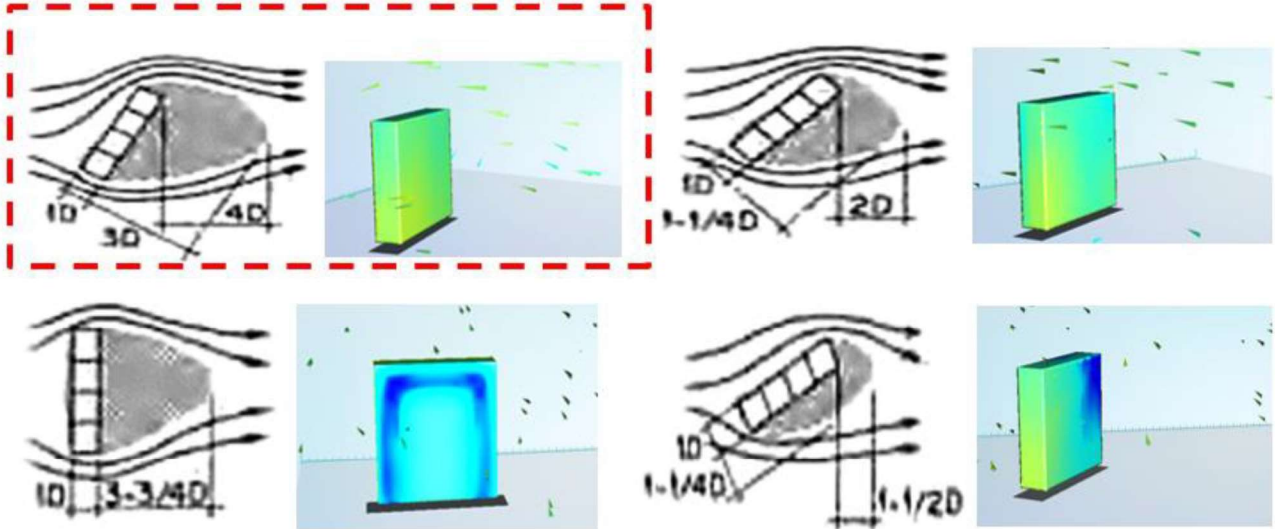


Fig 4.1 Oriented 30 deg, 90deg, 45 deg & 60 deg towards wind direction

| ORIENTATION<br>ANGLE TOWARDS<br>WIND DIRECTION | AIR VELOCITY(m/s)<br>ON THE WINDWARD<br>FACADE | AIR VELOCITY(m/s)<br>ON THE LEEWARD<br>FACADE | INFERENCE                                                                                                                                                                                                 |
|------------------------------------------------|------------------------------------------------|-----------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 90 deg                                         | 13.8                                           | 1.2                                           | The air velocity on the leeward façade of the building has significantly reduced to a great extent.                                                                                                       |
| 30 deg                                         | 13.5                                           | 11.8                                          | Air velocity is almost similar to both facades of the building, the windward and the leeward side. This enhances the cross ventilation as openings on both facades will be exposed to equal air movement. |
| 45 deg                                         | 13                                             | 10.6                                          | Slightly lesser air velocity compared to the 30deg angle, still gives better results compared to the perpendicular wind angle.                                                                            |
| 60 deg                                         | 12.7                                           | 1.5                                           | This orientation does not give uniform and consistent air velocity throughout the building.                                                                                                               |

Table 4.1 Orientation analysis based on wind angle

Orienting the block to **30deg** angle towards the predominant wind direction shows better results in receiving **consistent wind pressure on all facades** compared to the other orientation angles.

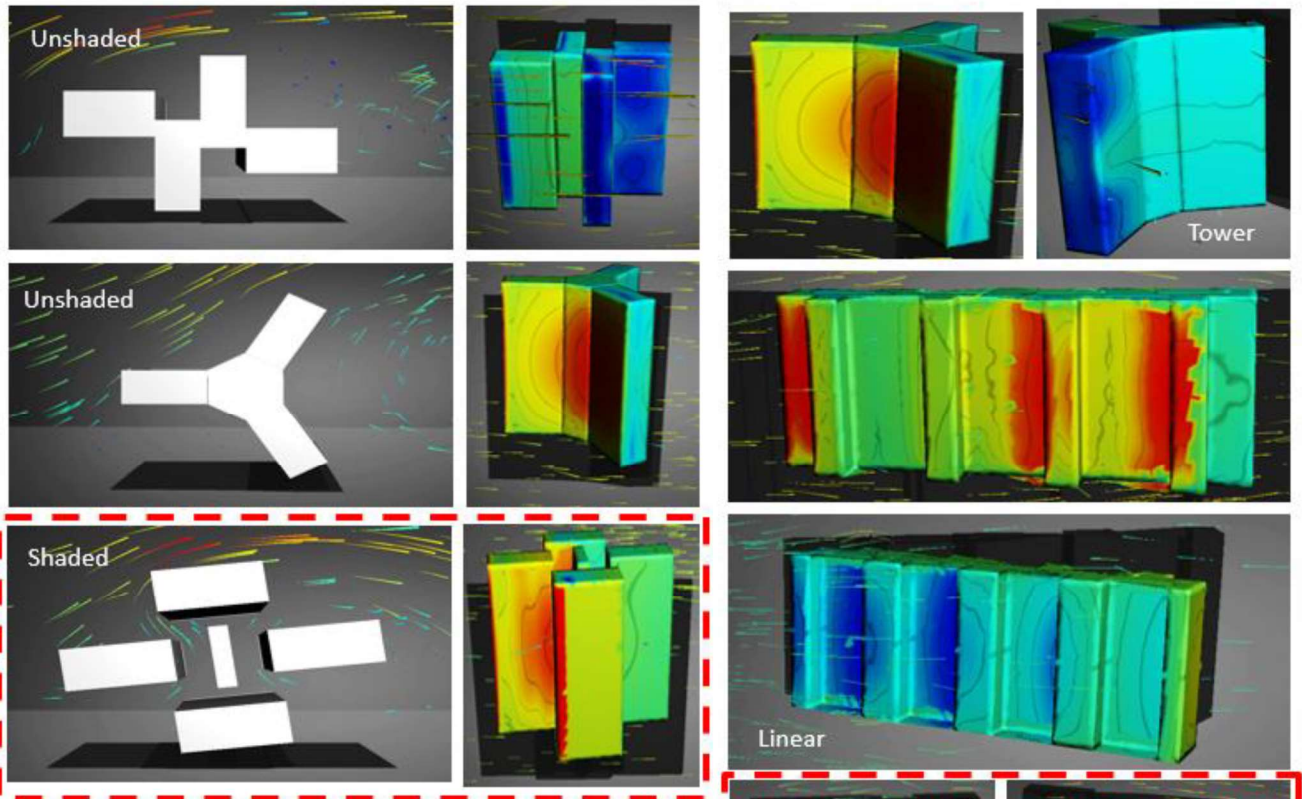
#### References :

##### Research Papers

1. Natural Ventilation Strategies for Residential Buildings in Famagusta Author : Ibrahim Salyani
2. The Effects of Void on Natural Ventilation Performance in Multi-Storey Housing. Author : Fakhriah Muhsin
3. The Potential of Balconies to Induce Wind-Driven Natural Ventilation in Single sided Ventilated High-Rise Apartments. Author : Mohd. Farid Mohamed

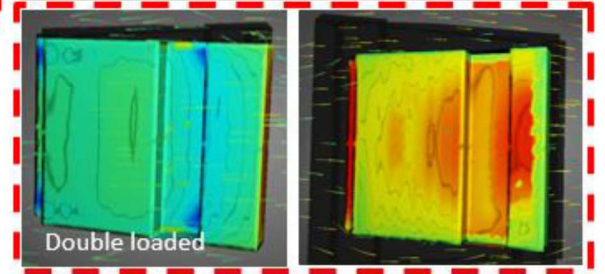


## 4.2 MASSING :



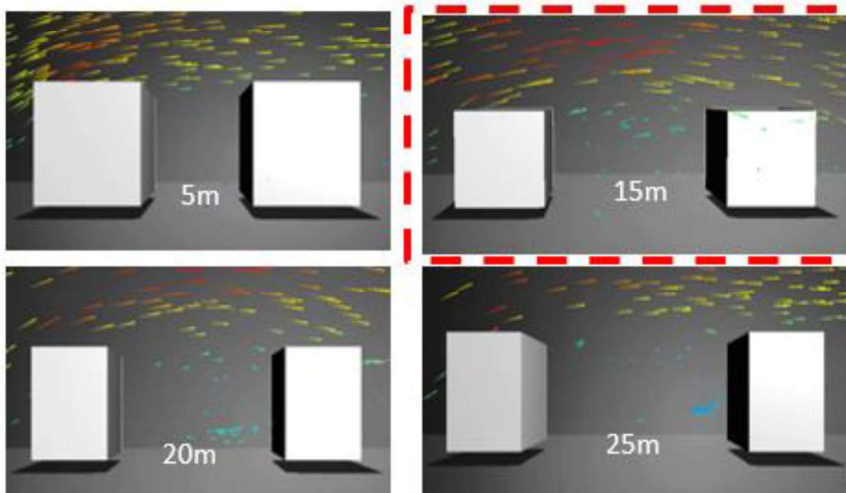
**Fig 4.2 Block Arrangement**

Block arrangement with spacing casts shadow over adjacent blocks reducing heat gain and also increases the wind movement in between the blocks.



**Fig 4.3 Block Typology**

**Double loaded typology receives sufficient air velocity** compared to the other two typologies. Units remain **well shaded from direct solar radiation**.



**Fig 4.4 Distance Between the Blocks**

Proper air circulation is noted at 15m distance between the towers. As the distance between the blocks increases winds start to dissipate.

## References :

### Research Papers

1. Design optimization and field demonstration of natural ventilation for high-rise residential buildings.  
Author : Chaobin Zhoua
2. An Attempt to Design a Naturally Ventilated Tower in Humid Subtropical Climate of the Developing Country. Author : Maha Sohail
3. Design guidelines for energy-efficient multi-storey residential buildings in warm humid climates.

## 4.3 SHADING DEVICE :

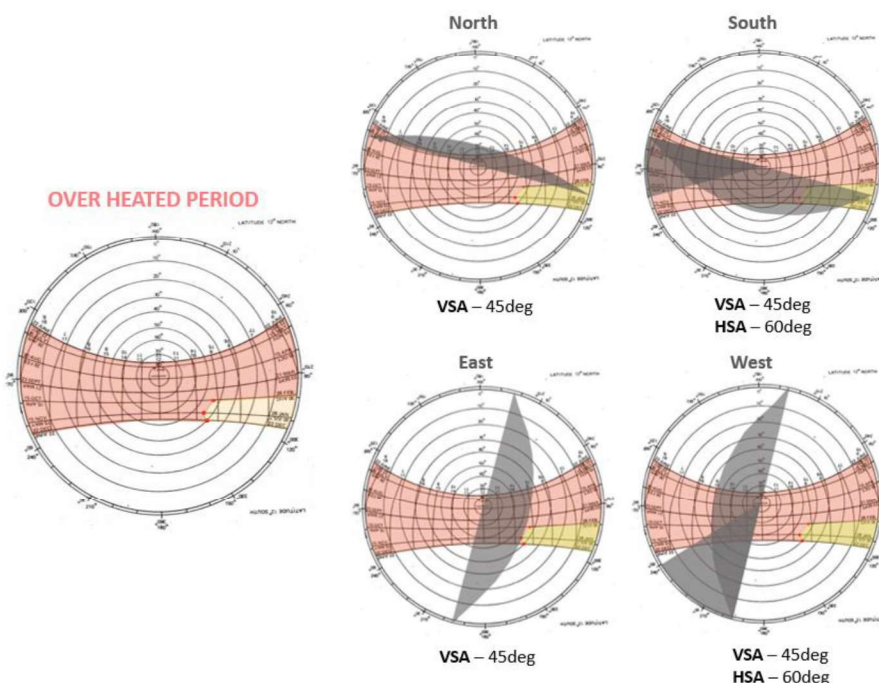
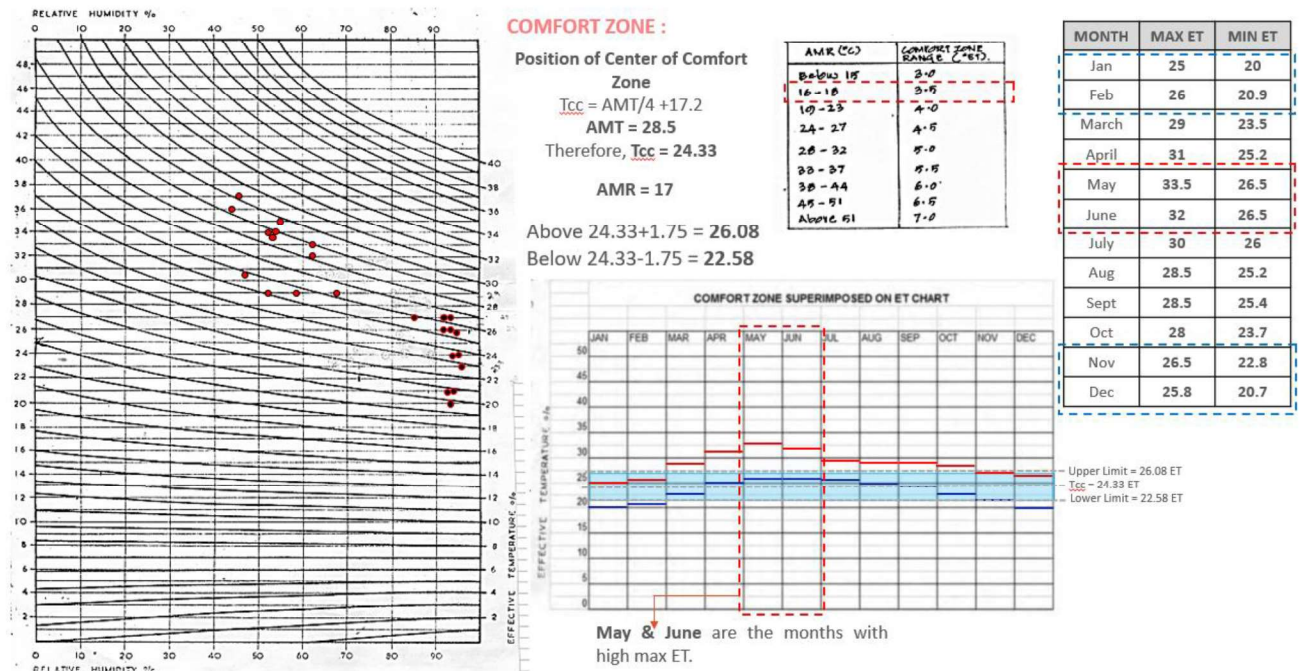
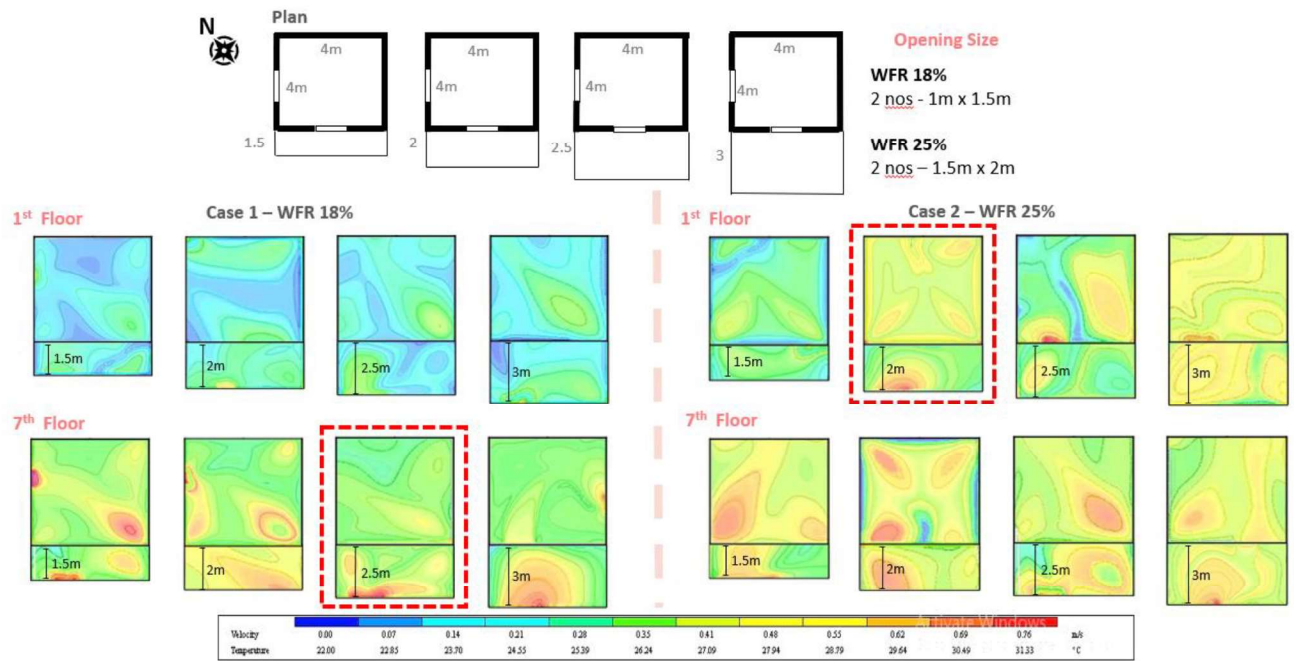


Fig 4.5 Over Heated Period of Chennai

The northern and eastern facades require only the horizontal shading device with VSA as 45 deg to cut down the radiations. The southern and western facades require horizontal and vertical shading device with VSA as 45 deg and HAS as 60 deg.

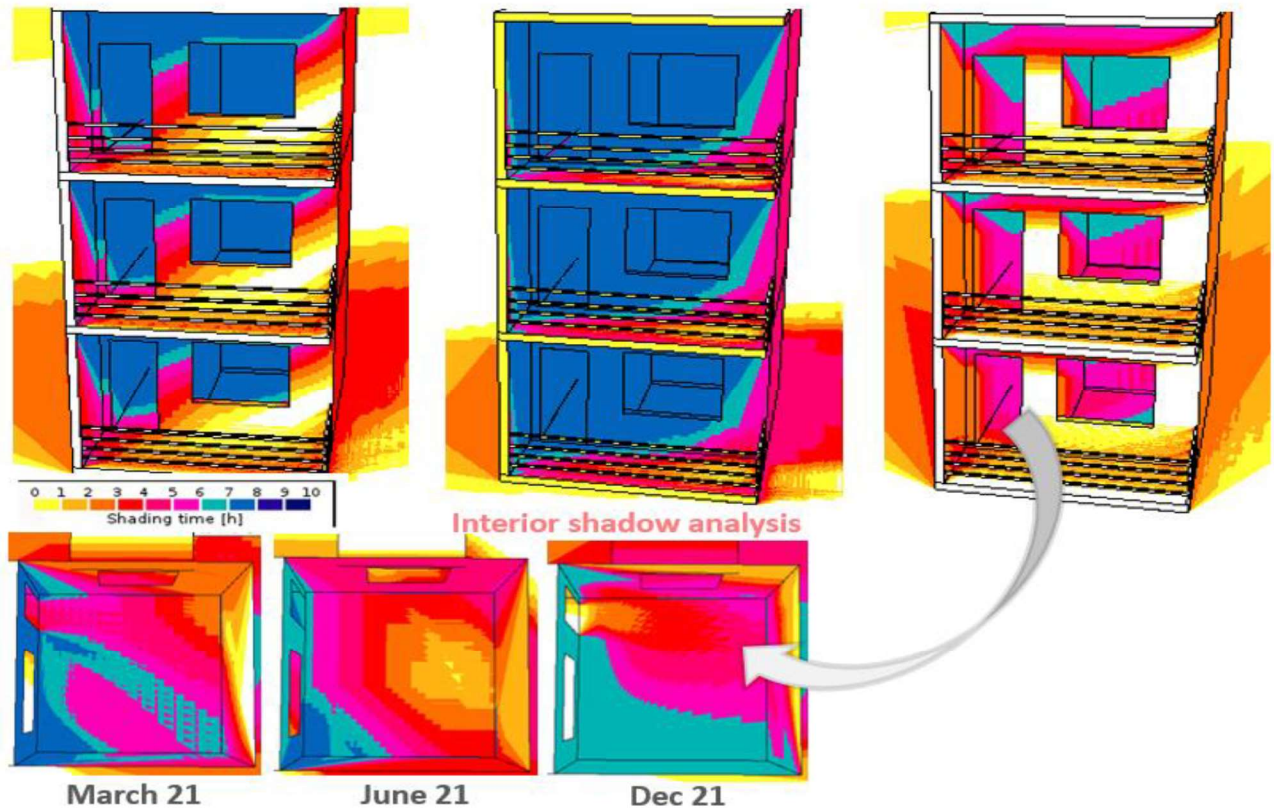


#### 4.4 BALCONY & WINDOW OPENING RATIO :



**Fig 4.6 CFD analysis for South facade**

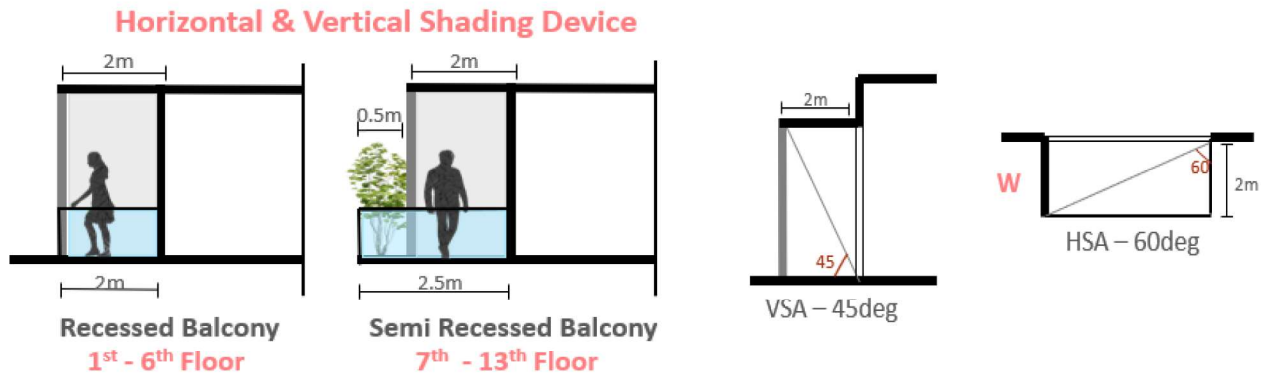
Balcony depth of 2m with WFR 25% performs better at floor levels form 1<sup>st</sup> – 6<sup>th</sup> and depth of 2.5m with WFR 18% is preferable for 7<sup>th</sup> – 13<sup>th</sup> floors as the required wind velocity is achieved within the required temperature range.



**Fig 4.7 Shadow analysis for South facade**



Balcony space remains shaded during Equinox and at Summer Solstice. At Winter Solstice due to low sun angle the balcony is exposed to sun light. Hence the HSA and VSA proves efficient for the southwest façade balconies.



**Fig 4.8 Shading device for South façade**

Vertical fins to cut down the heat from west. Achieved about 60% of shade during Equinox. The remaining 30% will be achieved through adjustable louvers and shade from plants.

| ORIENTATION | FLOOR HT                           | DEPTH (m) | SHADING DEVICE |              | WFR | INFERENCE                                                                                                                                                                   |
|-------------|------------------------------------|-----------|----------------|--------------|-----|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|             |                                    |           | Horizontal (m) | Vertical (m) |     |                                                                                                                                                                             |
| South       | 1 <sup>st</sup> – 6 <sup>th</sup>  | 2         | 2              | 2            | 25% | Indoor air velocity of <b>0.30m/s to 0.48m/s</b> with a indoor air temperature of <b>28degc to 29.6degc</b> is noted which is ideal to maintain the indoor thermal comfort. |
|             | 7 <sup>th</sup> – 13 <sup>th</sup> | 2.5       |                |              | 18% |                                                                                                                                                                             |
| East        | 1 <sup>st</sup> – 6 <sup>th</sup>  | 1.5       | 1.5            | -            | 25% |                                                                                                                                                                             |
|             | 7 <sup>th</sup> – 13 <sup>th</sup> | 2         |                |              | 25% |                                                                                                                                                                             |
| West        | 1 <sup>st</sup> – 6 <sup>th</sup>  | 2         | 2              | 2            | 25% |                                                                                                                                                                             |
|             | 7 <sup>th</sup> – 13 <sup>th</sup> | 2.5       |                |              | 18% |                                                                                                                                                                             |
| North       | 1 <sup>st</sup> – 13 <sup>th</sup> | 1.5       | 1.5            | -            | 25% |                                                                                                                                                                             |
|             |                                    | 1.5       |                |              | 25% |                                                                                                                                                                             |

**Table 4.2 Balcony depth & WFR for different facades**

## CHAPTER 5

### DESIGN

#### 5.1 CONCEPT :

High rise structure surrounded by low rise buildings is constantly exposed to direct solar heat gain hence it is necessary to cut down the heat gain using shading and over shadowing strategies. **Orientation** of the blocks such that one tower **overshadowing** the other during the peak hours of the day to reduce the radiations. **Balconies** proving shade to the floors below. **Shading Fins** to prevent direct heat from the west. **Extended cantilevers** with large VSA to

**reduce the penetration of heat** to the indoor spaces. **Lightwells** with voids and built form to avoid the direct light and induce diffused light and radiations. This also creates over shadowing.



**Fig 5.1 Concept of Shade & Shadow**

### **5.1.1 BIOPHILIC DESIGN :**

Life in a high rise residence is completely devoid of the connect with nature and detached from the natural environment especially as the floor height increases.

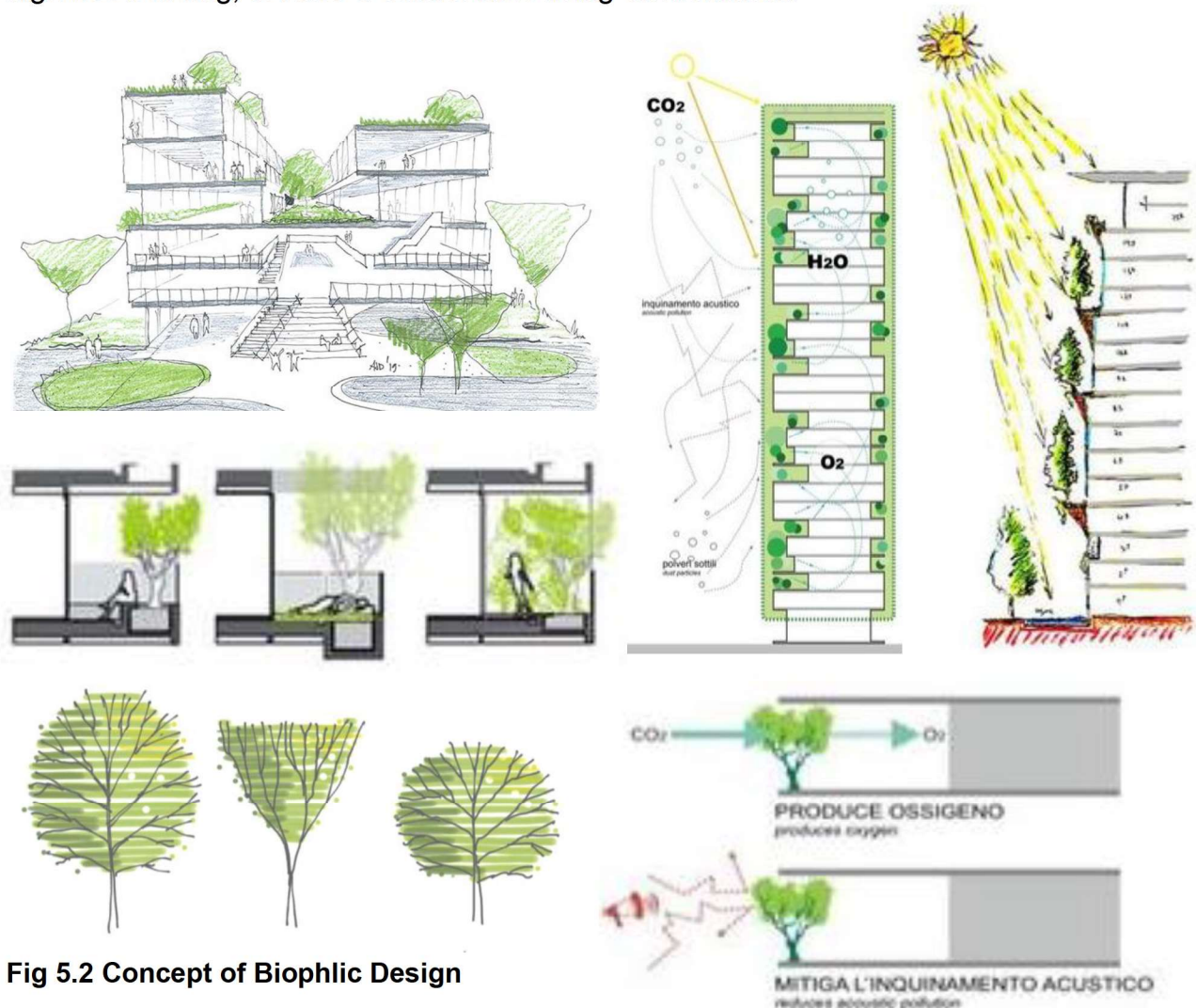


Biophilic concept creates a connectivity to the natural environment even in the higher floors thereby giving the feel of a low rise structure.

**Principles** include

- Access to **natural ventilation and daylight**
- Increased **connection with nature**
- **Views** to green spaces

Plants at the exterior facades reduces the CO<sub>2</sub> content in the air and purifies the air. Reduces the noise level from the outdoor environment entering the indoor spaces. **Green walls shade the indoor spaces** from the direct radiation during the peak hours of the day. Preferable for western facade of the building. Creating private **indoor green spaces** in every residential unit to give the users of the high rise, a feel of **living along with the environment**. Biophilic design acts as a solution to most of the challenges faced by the high rise building, to have a comfortable living environment.



**Fig 5.2 Concept of Biophilic Design**

## 5.2 ZONING :

### ITERATION 1 & 2

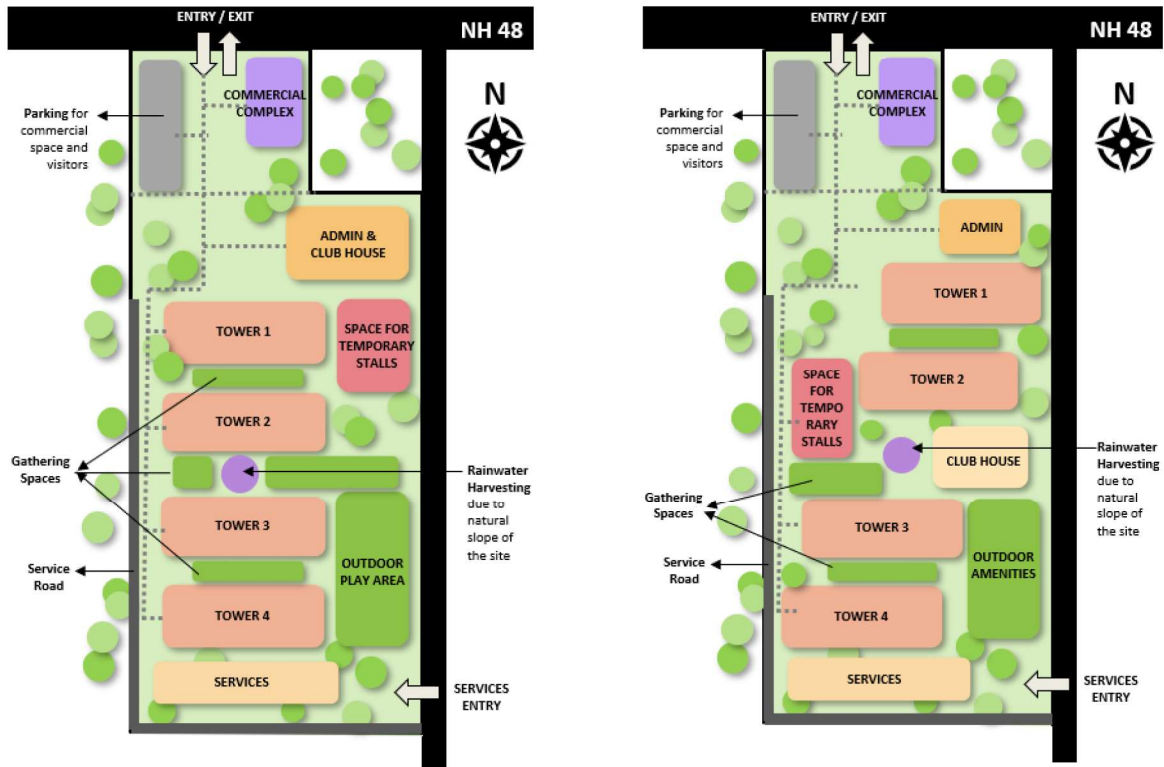


Fig 5.3 Zoning Iterations 1 & 2

Club house and other outdoor gathering spaces are located at the center of the site for easy access from all the towers and to develop social sustainability.

Space for outdoor play area at the south eastern end shaded during the evening hours.

The site is balanced with residential and activity spaces. The central gathering space becomes a space for social sustainability.

### ITERATION 3

**45 deg orientation** occupies more space on site and the space for greenery is reduced on site. **45 deg** orientation of the towers **over shadows the adjoining site area** thereby **reducing the direct radiations** on the ground. **Reduced air velocity** and **inconsistent air pressure** is noted on the **leeward side of the site** as the orientation of the **towers diverts the wind. movement** .



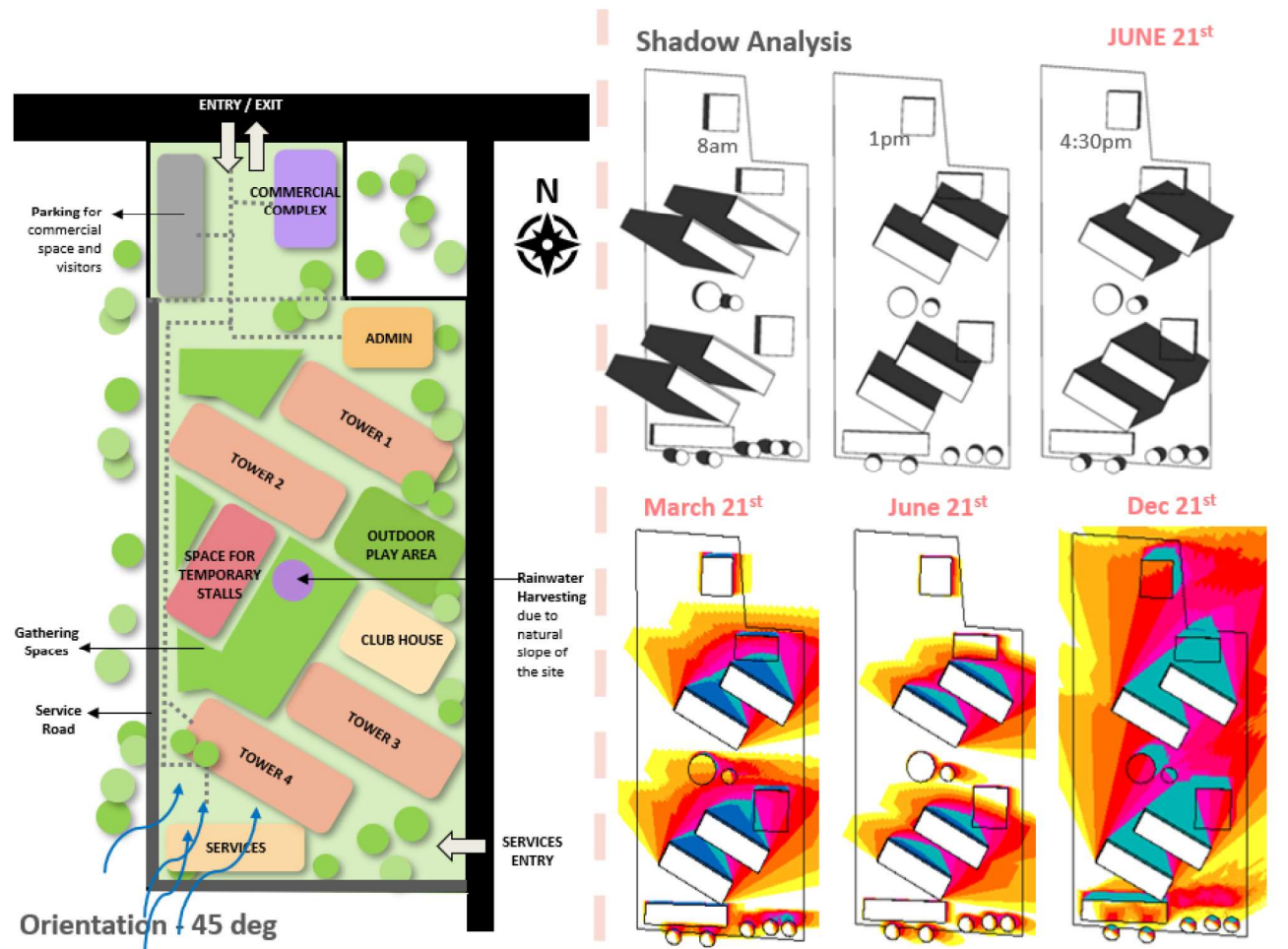


Fig 5.4 Zoning Iterations 3

## ITERATION 4

**30 deg** orientation of the towers over shadows about 3/4<sup>th</sup> of the adjoining site area at summer solstice thereby reducing the direct radiations on the ground.

**Uniform distribution of wind velocity** throughout the site. 30deg orientation facilitates wind movement in between the blocks and throughout the site.

**30 deg orientation** has space for efficient space planning with increased green spaces and proper air velocity and reduced radiations.

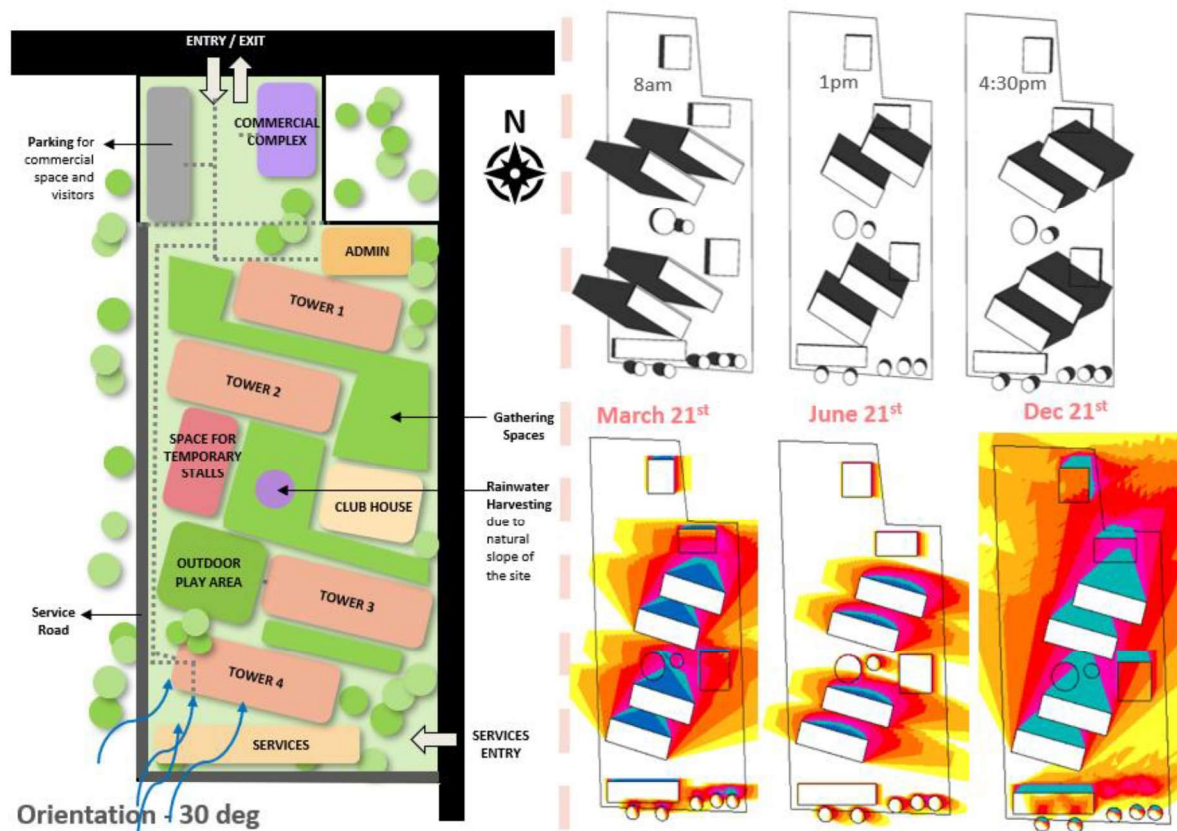


Fig 5.5 Zoning Iterations 4

## 5.4 MASSING :

### ITERATION 1

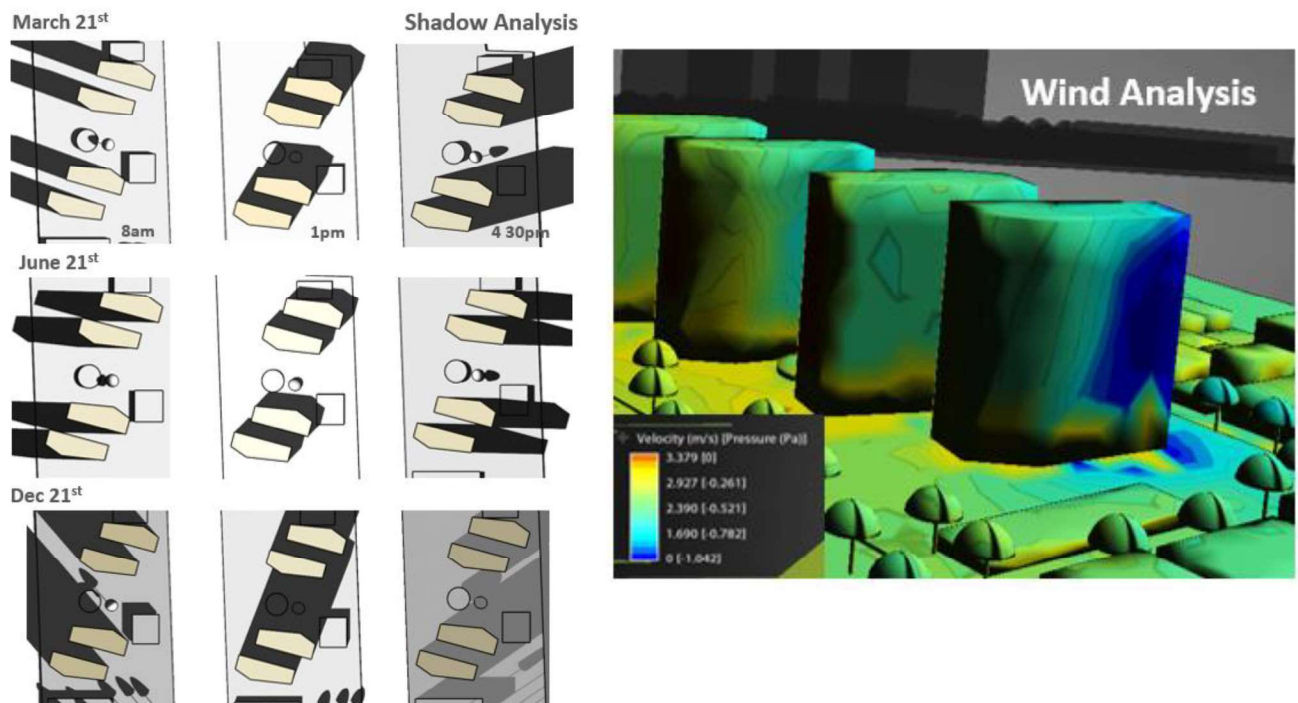
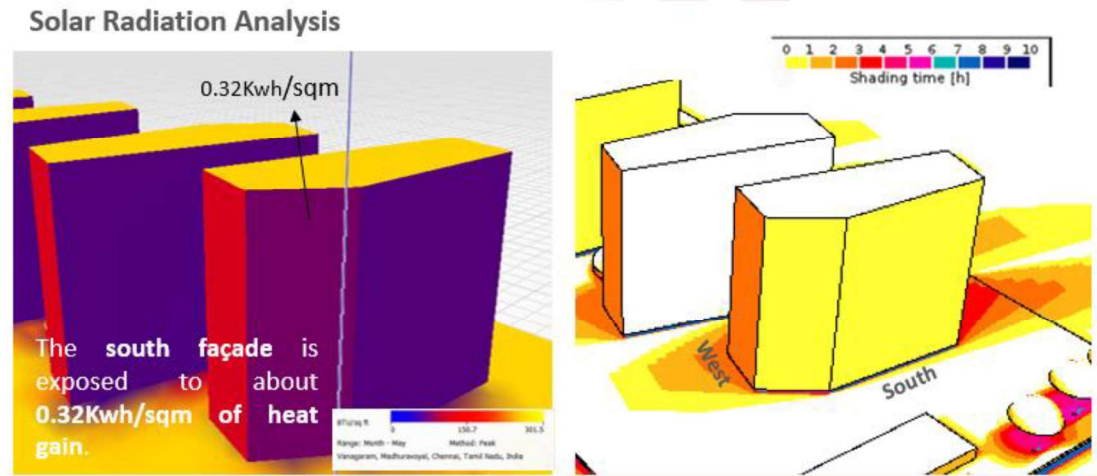


Fig 5.6 Shadow analysis and wind analysis for ltr 01



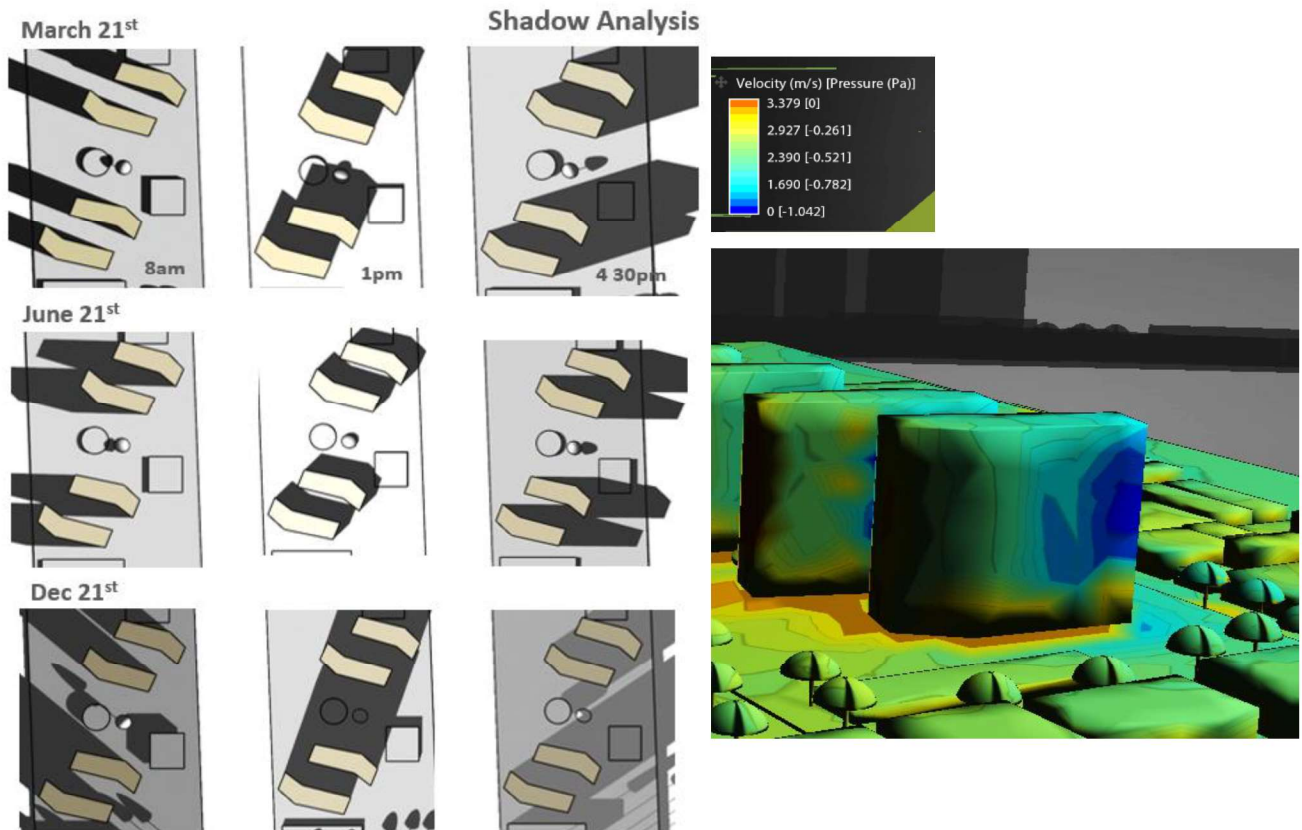
**Air velocity** on the southern façade is **inconsistent** and **less than 1m/s** is noted on the south eastern part of the facade. The form affects the distribution of wind velocity.

The **south façade** of the towers **receives shade** for **less than 1hr** during the day from **10am to 5pm** when the heat gain is high. This will **affect the indoor thermal comfort** as max openings will be provided in the south.



**Fig 5.7 Cumulative Shadow analysis for Itr 01**

## ITERATION 2



**Fig 5.8 Shadow analysis and wind analysis for Itr 02**



Increase in air velocity near the southern and western facades of upto 2.5m/s is noted but the velocity rate is not carried out throughout due to the form.

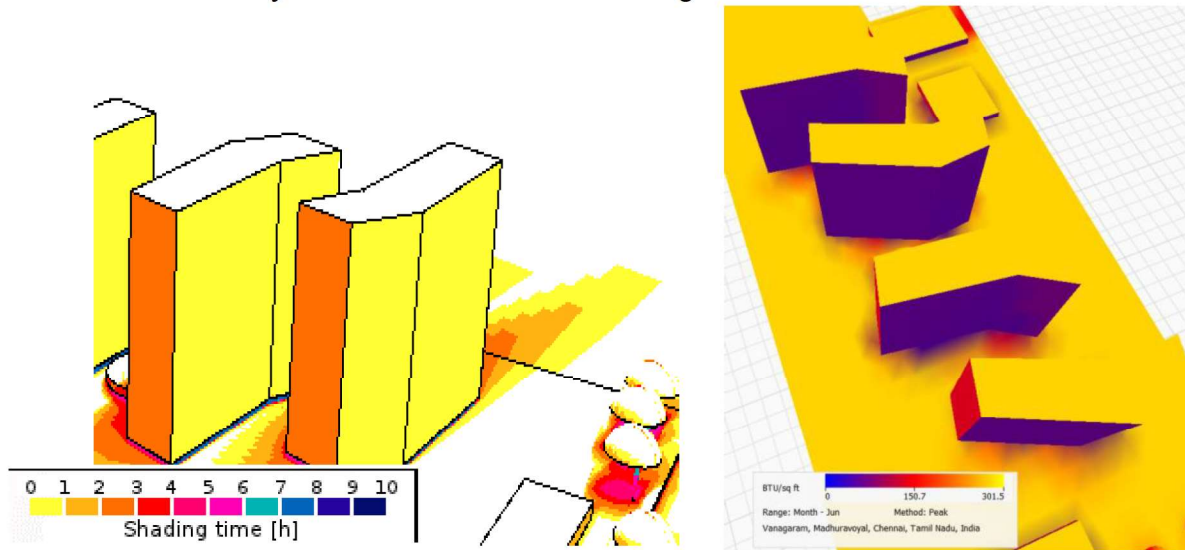


Fig 5.9 Cummulative Shadow analysis and solar radiation for Itr 02

The southern and western façade remains unshaded during the peak hours of the day. The form does not contribute to self shading hence the facades are exposed to radiations. Reduced heat gain is noted during the evening hours of summer solstice.

### ITERATION 3

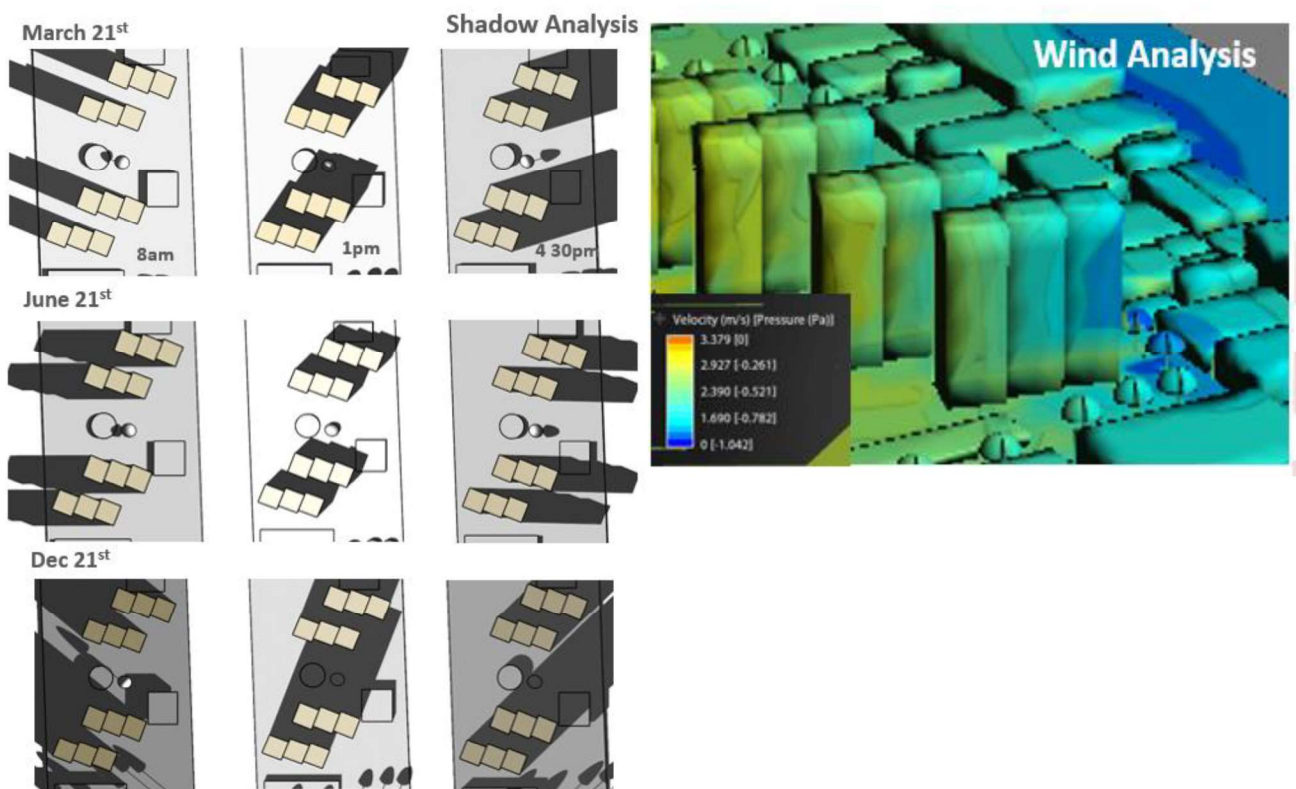


Fig 5.10 Shadow analysis and wind analysis for Itr 03

Wind velocity noted on the southern and western façade is above 2m/s as the stacking form increases the air pressure on the surface.

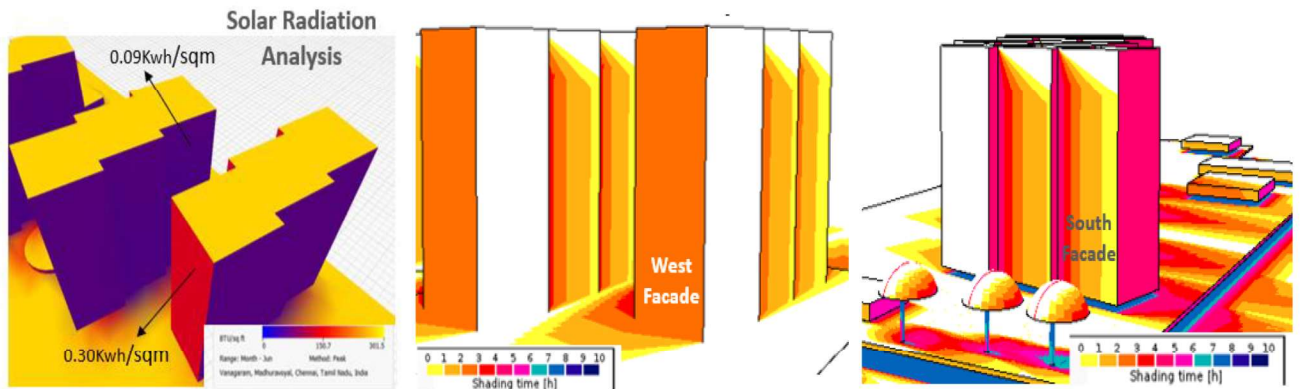


Fig 5.11 Cummulative Shadow analysis and solar radiation for Itr 03

Increased shade is created on the south façade as the form over shadows on the adjacent surface. The shadow casted prevents the surface form direct heat gain during the peak hours of the day.

#### ITERATION 4

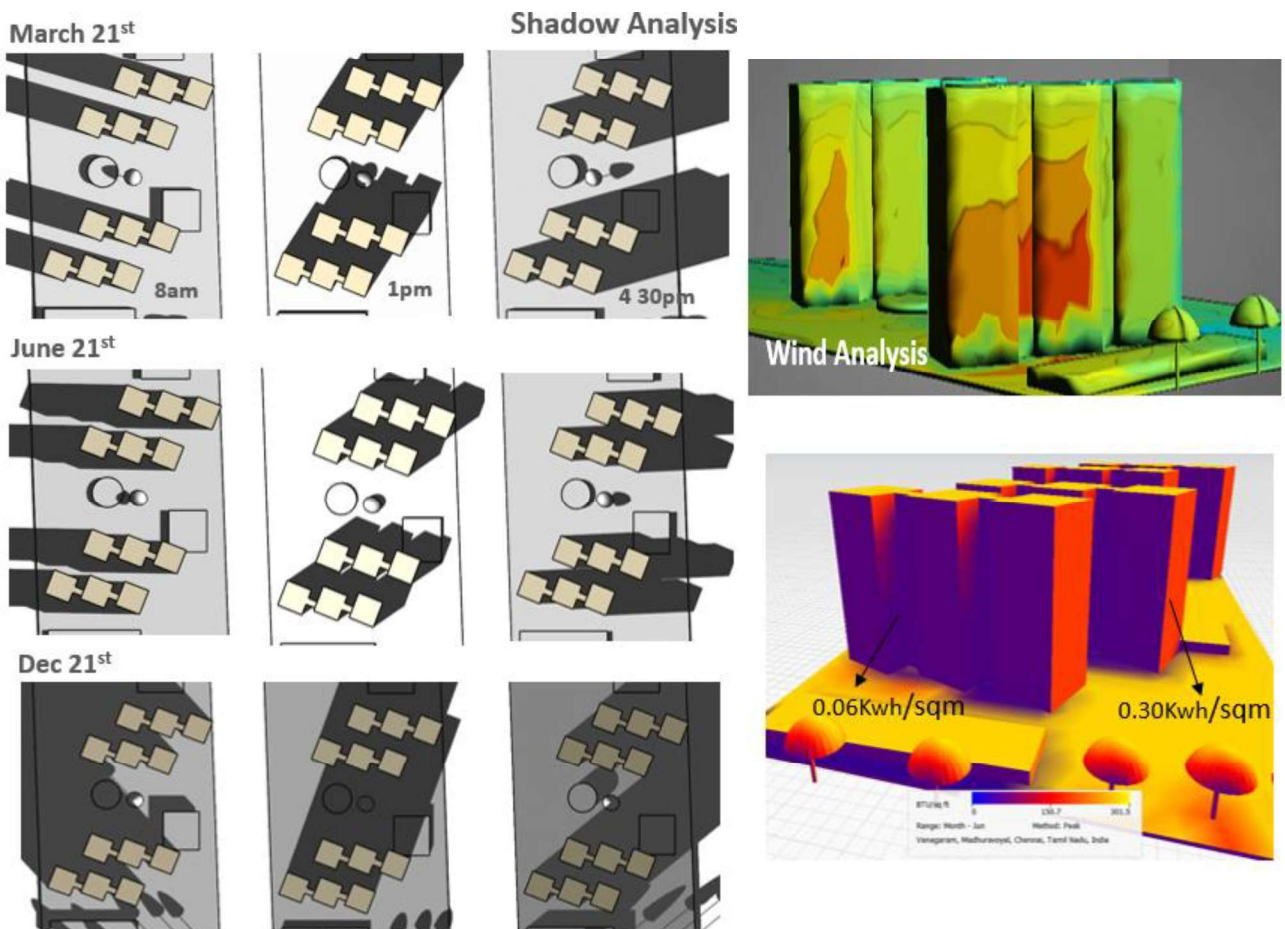


Fig 5.12 Shadow analysis and wind analysis for Itr 04



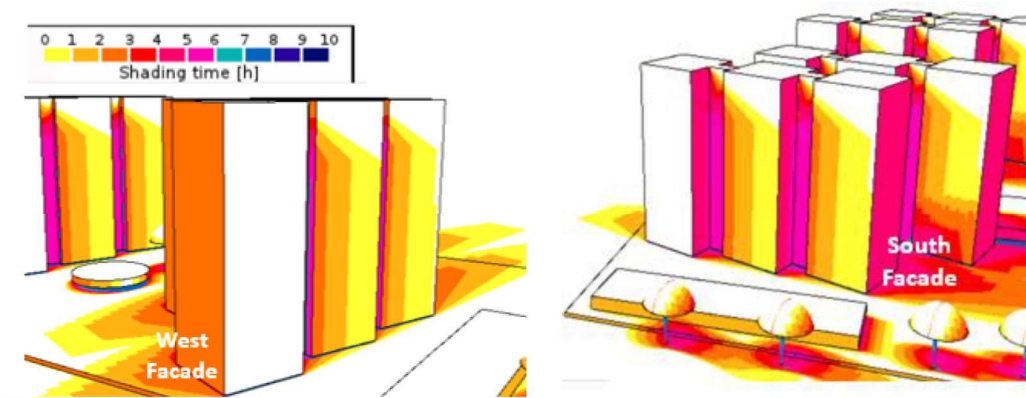


Fig 5.13 Cumulative Shadow analysis and solar radiation for Itr 04

Most of the **southern façade remains shaded** as the extended portion casts its shadow on the recessed part which is shaded throughout the day. The massing proved **efficient in reducing the solar radiations**. Only the west façade is exposed to radiations.

## ITERATION 5

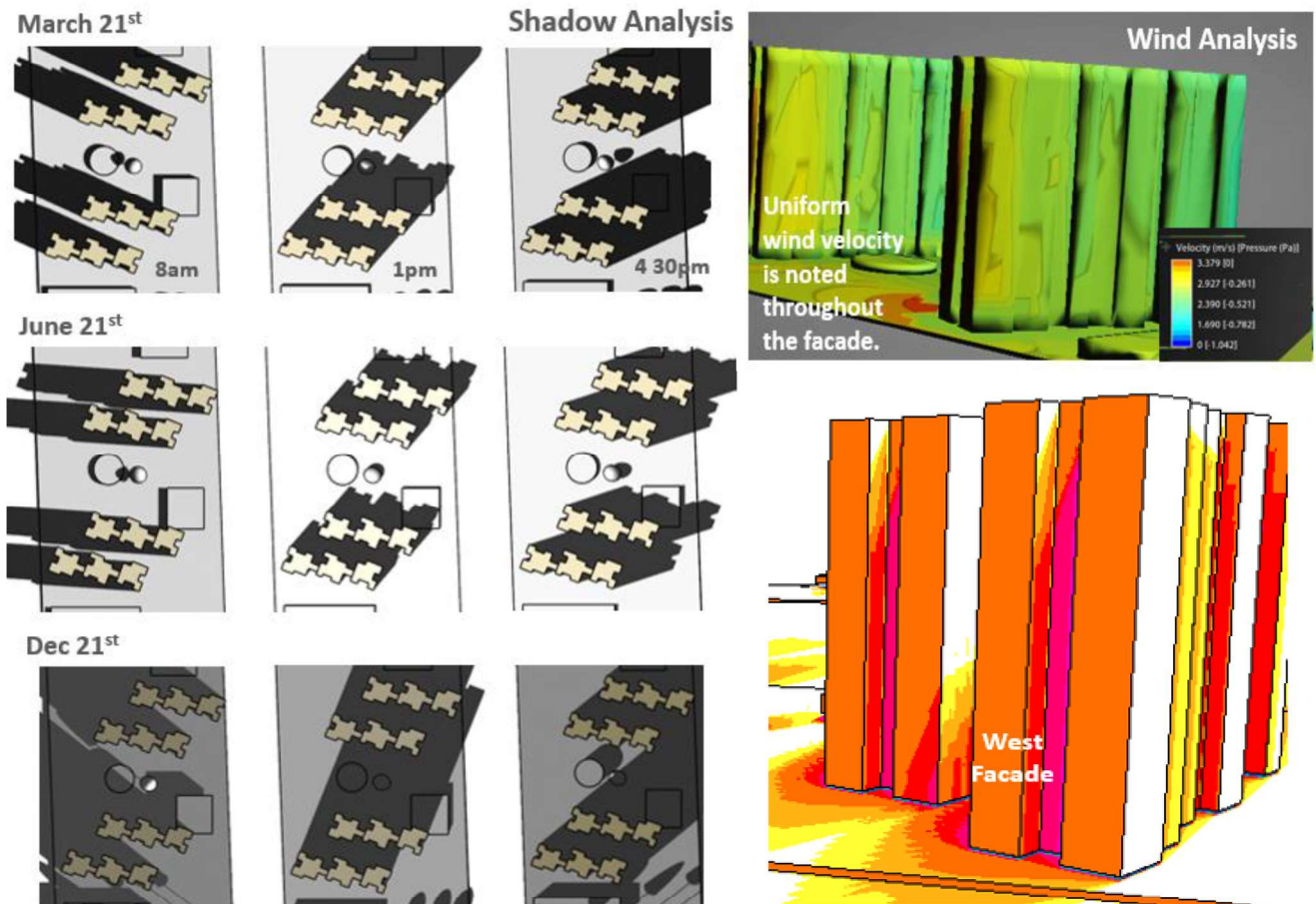
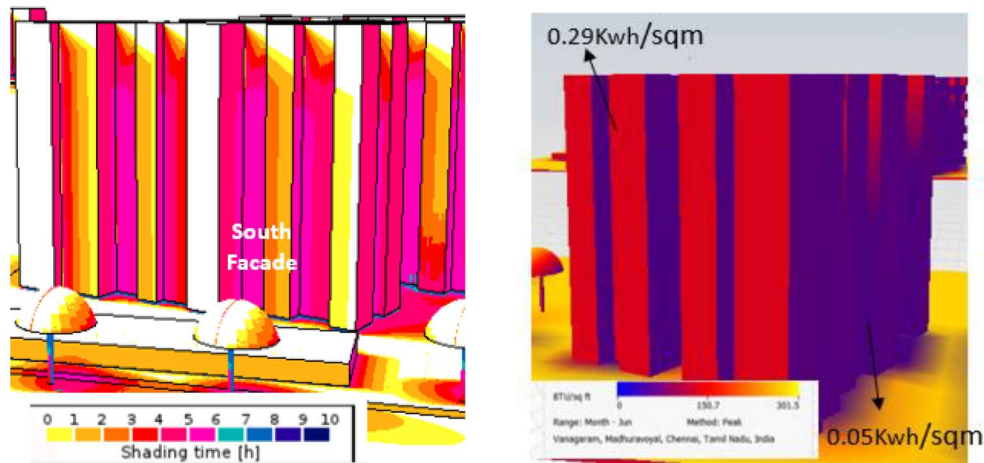


Fig 5.14 Shadow analysis and wind analysis for Itr 05

Increased air pressure on the façade is transmitted to the adjoining spaces and also to the tower behind due to the **spacing between the blocks**.

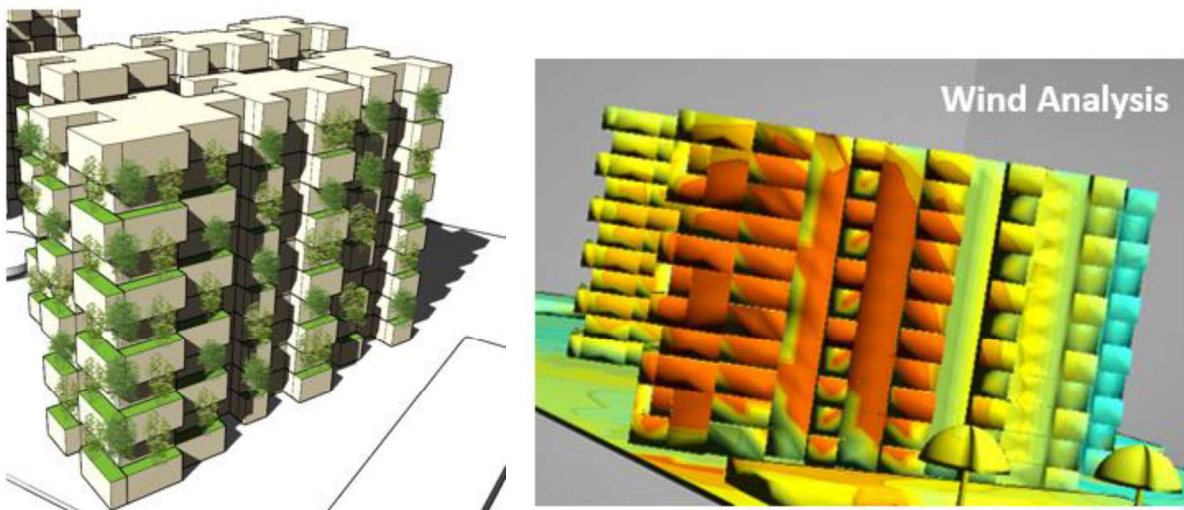




**Fig 5.15 Cumulative Shadow analysis and solar radiation for Itr 05**

The direct radiation is reduced both in the south and west façade and the number of shaded hours is increases in both facades (min 3hrs to max 8hrs) due to the concept of overshadowing.

## ITERATION 6



**Fig 5.16 Wind Analysis for Itr 06**

**The solids and voids in the façade increases the air pressure on the surface. This will help in increasing the indoor air velocity.**

Projected **cantilevers as green spaces** at alternate floors.

This is provided at the southern and south western façade **to mitigate the heat from the west** and the **wind passing through these plants loses its temperature and becomes cooler when reaching the indoor space.**

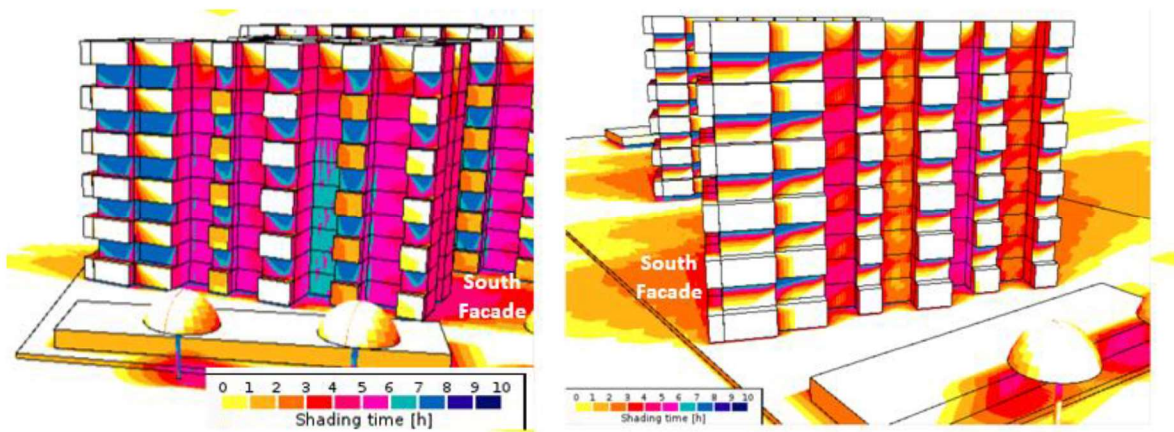
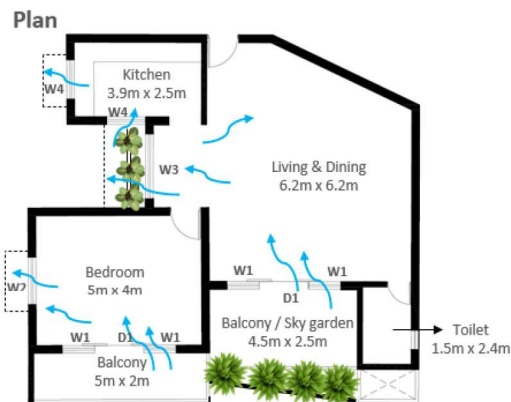


Fig 5.17 Cummulative Shadow analysis for Itr 06

## 5.5 FLOOR PLANS & ANALYSIS :

### 1 BHK : South



| WFR                               |           |            |            |                     |                |
|-----------------------------------|-----------|------------|------------|---------------------|----------------|
| Opening Name                      | Width (m) | Height (m) | Area (sqm) | Openable Area (sqm) | Opening Area % |
| W1 x 4                            | 1         | 2.1        | 1.92 x 4   | 7.68                | 90% Openable   |
| W2                                | 1.5       | 1.5        | 2.07       | 2.07                |                |
| W3                                | 1.8       | 1.5        | 2.52       | 2.52                |                |
| W4 x 2                            | 1.2       | 1.2        | 1.26 x 2   | 2.52                |                |
| V                                 | 0.6       | 0.6        | 0.36       | 0.36                |                |
| D1                                | 1.5       | 2.1        | 2.97 x 2   | 5.94                |                |
| Total Openable Area               |           |            |            | 18.12               |                |
| Total Carpet Area                 |           |            |            | 69.15               |                |
| WFR = Openable area / Carpet area |           |            |            | 25.06%              |                |

Fig 5.19 1BHK plan

Table : 5.1 WFR of 1 BHK

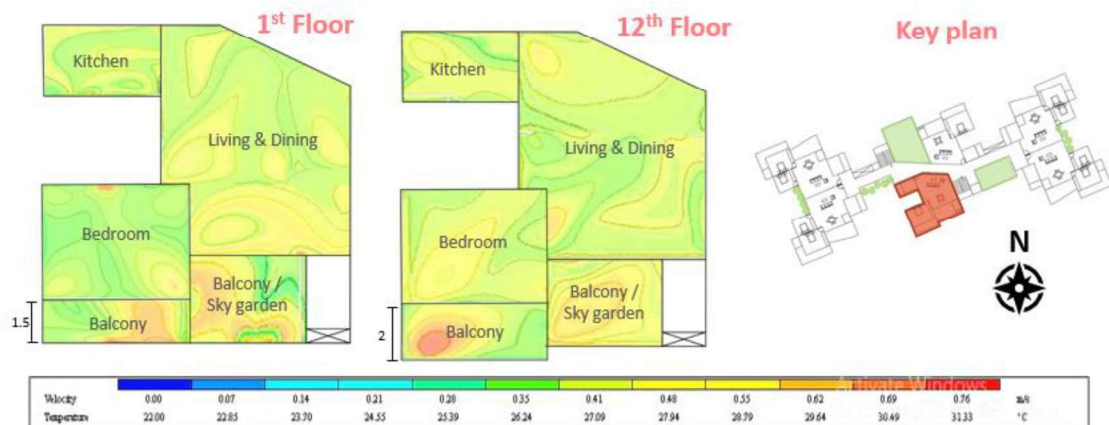


Fig 5.20 CFD analysis for 1BHK plan

The indoor air velocity ranges between 0.30m/s to 0.41m/s and the indoor air temperature is maintained between 27 – 28 degc which is ideal for achieving the indoor thermal comfort.



| WWR                                   |              |                    |                                      |                 |                          |                             |
|---------------------------------------|--------------|--------------------|--------------------------------------|-----------------|--------------------------|-----------------------------|
| Orientation                           | Opening Name | Opening Area (sqm) | Non Opaque Area in the opening (sqm) | No. of Openings | Total Opening Area (sqm) | Total Non Opaque Area (sqm) |
| South                                 | W1           | 2.1                | 1.92                                 | 4               | 8.4                      | 7.68                        |
|                                       | W4           | 1.44               | 1.26                                 | 1               | 1.44                     | 1.26                        |
|                                       | D1           | 3.15               | 2.97                                 | 2               | 6.3                      | 5.94                        |
| East                                  | V            | 0.36               | 0.36                                 | 1               | 0.36                     | 0.36                        |
| West                                  | W2           | 2.25               | 2.07                                 | 1               | 2.25                     | 2.07                        |
|                                       | W3           | 2.7                | 2.52                                 | 1               | 2.7                      | 2.52                        |
| Total                                 |              |                    |                                      |                 | 21.45                    | 19.83                       |
| Area of Envelope                      |              |                    |                                      |                 | 85.3                     |                             |
| WWR = Non opaque area / Envelope Area |              |                    |                                      |                 | 23.3%                    |                             |

Table : 5.2 WWR of 1 BHK

#### REFERENCE - ECO NIWAS SAMHITA 2018

- Min required WFR is 16.66% for warm humid climate.
- Where the wind direction is quite constant the size of the openings should be within **20% to 50% of the wall area** and perpendicular to the direction of wind.

## 2 BHK - TYPE 1: Southwest

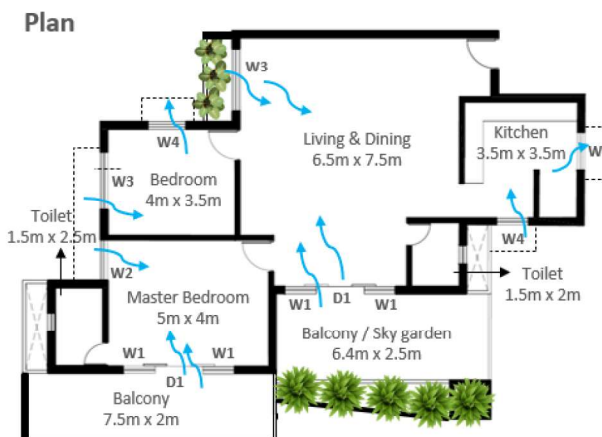


Fig 5.21 2BHK plan

| WFR                               |           |            |            |                     |                |
|-----------------------------------|-----------|------------|------------|---------------------|----------------|
| Opening Name                      | Width (m) | Height (m) | Area (sqm) | Openable Area (sqm) | Opening Area % |
| W1 x 4                            | 1         | 2.1        | 1.92 x 4   | 7.68                | 90% Openable   |
| W2                                | 1.5       | 1.5        | 2.07       | 2.07                |                |
| W3 x 2                            | 1.8       | 1.5        | 2.52 x 2   | 4.5                 |                |
| W4 x 3                            | 1.2       | 1.2        | 1.26 x 3   | 3.78                |                |
| V x 2                             | 0.6       | 0.6        | 0.36 x 2   | 0.72                |                |
| D1 x 2                            | 1.5       | 2.1        | 2.97 x 2   | 5.94                |                |
| Total Openable Area               |           |            |            | 24.33               |                |
| Total Carpet Area                 |           |            |            | 101.6               |                |
| WFR = Openable area / Carpet area |           |            |            | 24.82%              |                |

Table : 5.3 WFR of 2 BHK

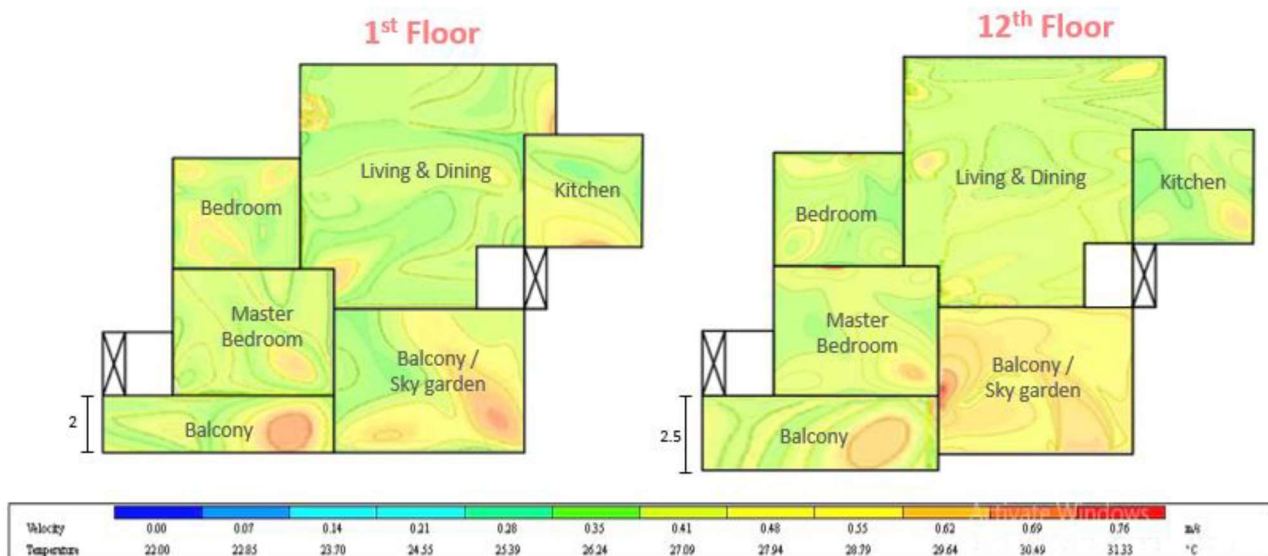
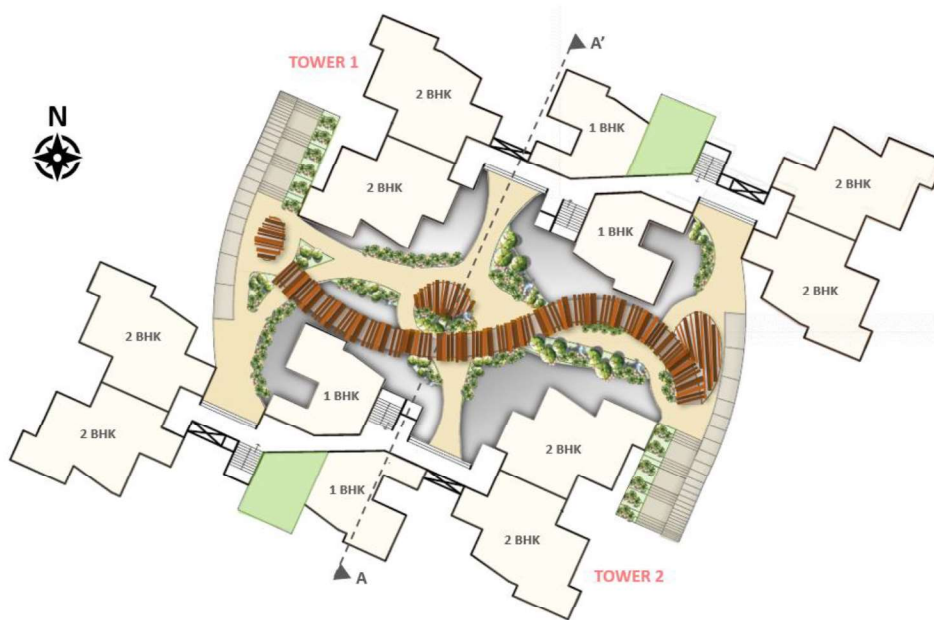


Fig 5.22 CFD analysis for 2BHK plan

The indoor air velocity ranges between 0.35m/s to 0.48m/s and the indoor air temperature is maintained between 27 – 28.7 degc.



### 1<sup>st</sup> LEVEL PODIUM :



An **Eco Deck / Podium** in the 1<sup>st</sup> floor level as a **connecting bridge** between the 2 towers with **Open and Semi covered walkways**, **Trellis seating spaces** with **vertical gardening** surrounded with vegetation. This

serves as a **common gathering space** increasing the social sustainability. **Atriums** allow **daylight** to the **parking at the below levels** and keeps it **naturally ventilated**.



Fig 5.23 Podium views

View of the **eco deck with semi covered walkways and seating spaces surrounded with shrubs** creates a better ambience. The space can be used at any part of the day as it remains shaded throughout.

## 2<sup>nd</sup> LEVEL PLAN :



Fig 5.24 Tower views

The **Eco deck/ podium** at the 1<sup>st</sup> floor level connecting the two towers serves as a common **community gathering space**. The distance between the towers is **18m**. **Suspended bridge** at the top floor also serves as a green walkway. The **west façade** is designed with **cool walls, large balconies and planters** to mitigate the heat.



# HIERARCHY OF GREEN SPACES :

**Community Garden space**  
10% of the total floor area

**Podium Garden space**

**Individual Garden space**  
7% of the unit area

**Family Garden space**  
13% of the unit area

**Vertical Garden**

**Connecting bridges**

**Concept of Biophilic design at different levels**

**Total garden space per unit**  
1 BHK – 10%  
2 BHK – 20%

**Community Garden space**

**Family Garden space**

**Vertical Garden**

**Connecting bridges**

**TOWER 1**

**TOWER 2**

**N**

**Fig 5.25 Biophilic design at different levels**

# PLANTER BOX DETAIL :

The diagram illustrates the construction of a planter box. The **PLAN** view shows a rectangular box with a **Parapet** wall and a **Duct** for a **Drain Pipe (38mm dia)**. The **SECTION** view shows the box filled with **Concrete** and **planter box** material. **DETAIL A** provides a cross-section of the layers: **Plants**, **Soil**, **Washed Coarse River Sand**, **Waterproof Liner**, **Geotextile**, **30mm Flo-Cell**, and **Substrate**. The **Layers of the Planter Box** are shown in a 3D perspective view.

**Plant Description**

- Plants suitable for warm humid climate.
- Less maintenance required.
- Requires less soil depth.
- Less water consumption.

**Areca Palm (0.9 - 1.5 m)**

**Croton Petra (1 - 1.8m ht)**

**Croton Mammy (1 - 1.8m)**

**Plumeria, Champa (1.5 - 2 m ht)**

These plants require sunlight for about 8 hours in a day. Hence suitable for balconies planters.

Façade view of **balconies** with vertical fins and **large sky gardens with** planters. The **double height green spaces** at every alternate floor serves as a common gathering space. The **pergolas at roof level** also serves as sit out space for the residents at top floors. The concept of **biophilic design** at various levels increasing social sustainability.



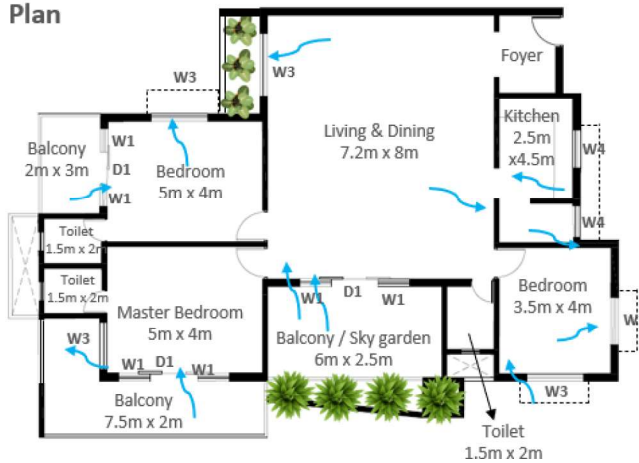


**Fig 5.26 South Façade views**

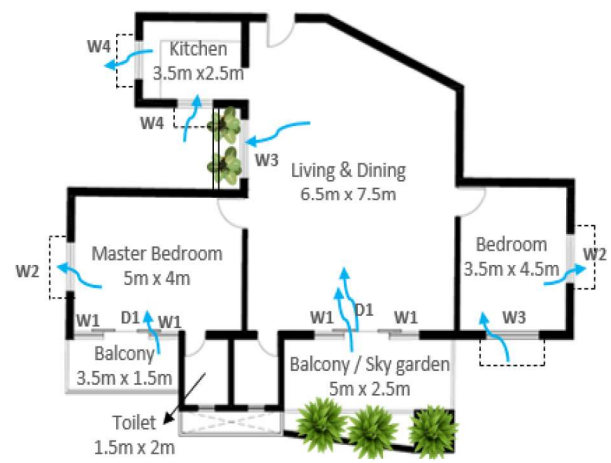


### 3 BHK – South west

Plan



### 2 BHK – South east



**Fig 5.27 3 & 2 BHK Floor Plans**

| WFR                               |           |            |            |                     |                |
|-----------------------------------|-----------|------------|------------|---------------------|----------------|
| Opening Name                      | Width (m) | Height (m) | Area (sqm) | Openable Area (sqm) | Opening Area % |
| W1 x 6                            | 1         | 2.1        | 1.92 x 6   | 11.52               | 90% Openable   |
| W2                                | 1.5       | 1.5        | 2.07       | 2.07                |                |
| W3 x 3                            | 1.8       | 1.5        | 2.52 x 3   | 7.56                |                |
| W4 x 2                            | 1.2       | 1.2        | 1.26 x 2   | 2.52                |                |
| V x 3                             | 0.6       | 0.6        | 0.36 x 3   | 1.08                |                |
| D1 x 3                            | 1.5       | 2.1        | 2.97 x 3   | 8.01                |                |
| Total Openable Area               |           |            |            | 30.76               |                |
| Total Carpet Area                 |           |            |            | 128.6               |                |
| WFR = Openable area / Carpet area |           |            |            | 24.91%              |                |

**Table : 5.4 WFR of 3 BHK**

| WWR                                   |              |                    |                                      |                 |                          |                             |
|---------------------------------------|--------------|--------------------|--------------------------------------|-----------------|--------------------------|-----------------------------|
| Orientation                           | Opening Name | Opening Area (sqm) | Non Opaque Area in the opening (sqm) | No. of Openings | Total Opening Area (sqm) | Total Non Opaque Area (sqm) |
| North                                 | W3           | 2.7                | 2.52                                 | 1               | 2.7                      | 2.52                        |
| South                                 | W1           | 2.1                | 1.92                                 | 4               | 8.4                      | 7.68                        |
|                                       | W3           | 2.7                | 2.52                                 | 1               | 2.7                      | 2.52                        |
|                                       | D1           | 3.15               | 2.97                                 | 2               | 6.3                      | 5.94                        |
|                                       | V            | 0.36               | 0.36                                 | 1               | 0.36                     | 0.36                        |
| East                                  | W4           | 1.44               | 1.26                                 | 2               | 2.88                     | 2.52                        |
| West                                  | W1           | 2.1                | 1.92                                 | 2               | 4.2                      | 3.84                        |
|                                       | W3           | 2.7                | 2.52                                 | 1               | 2.7                      | 2.52                        |
|                                       | V            | 0.36               | 0.36                                 | 2               | 0.72                     | 0.72                        |
|                                       | D1           | 3.15               | 2.97                                 | 1               | 3.15                     | 2.97                        |
| Total                                 |              |                    |                                      |                 | 34.11                    | 31.59                       |
| Area of Envelope                      |              |                    |                                      |                 | 136.4                    |                             |
| WWR = Non opaque area / Envelope Area |              |                    |                                      |                 | 23.15%                   |                             |

Table : 5.5 WWR of 3 BHK

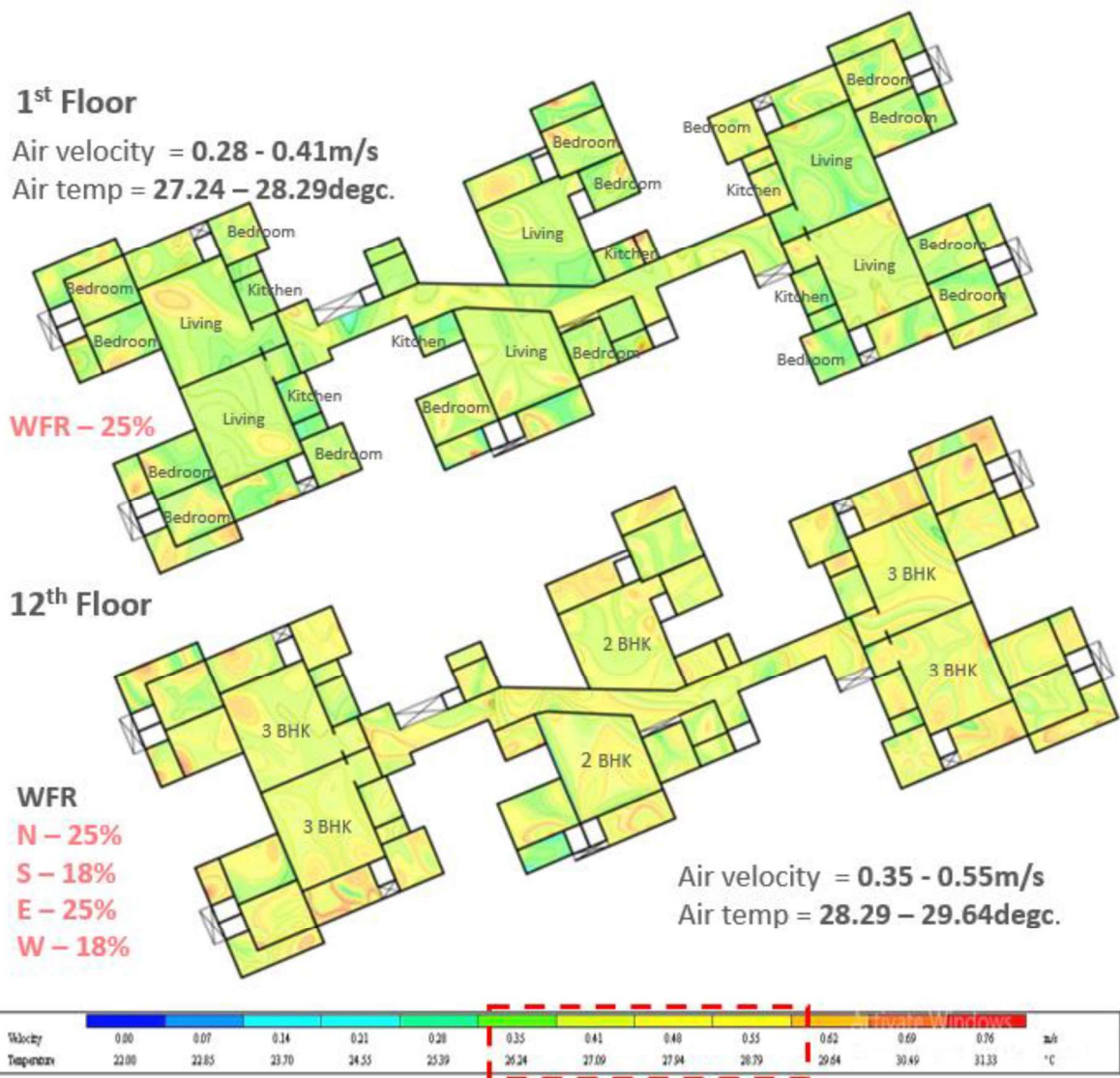
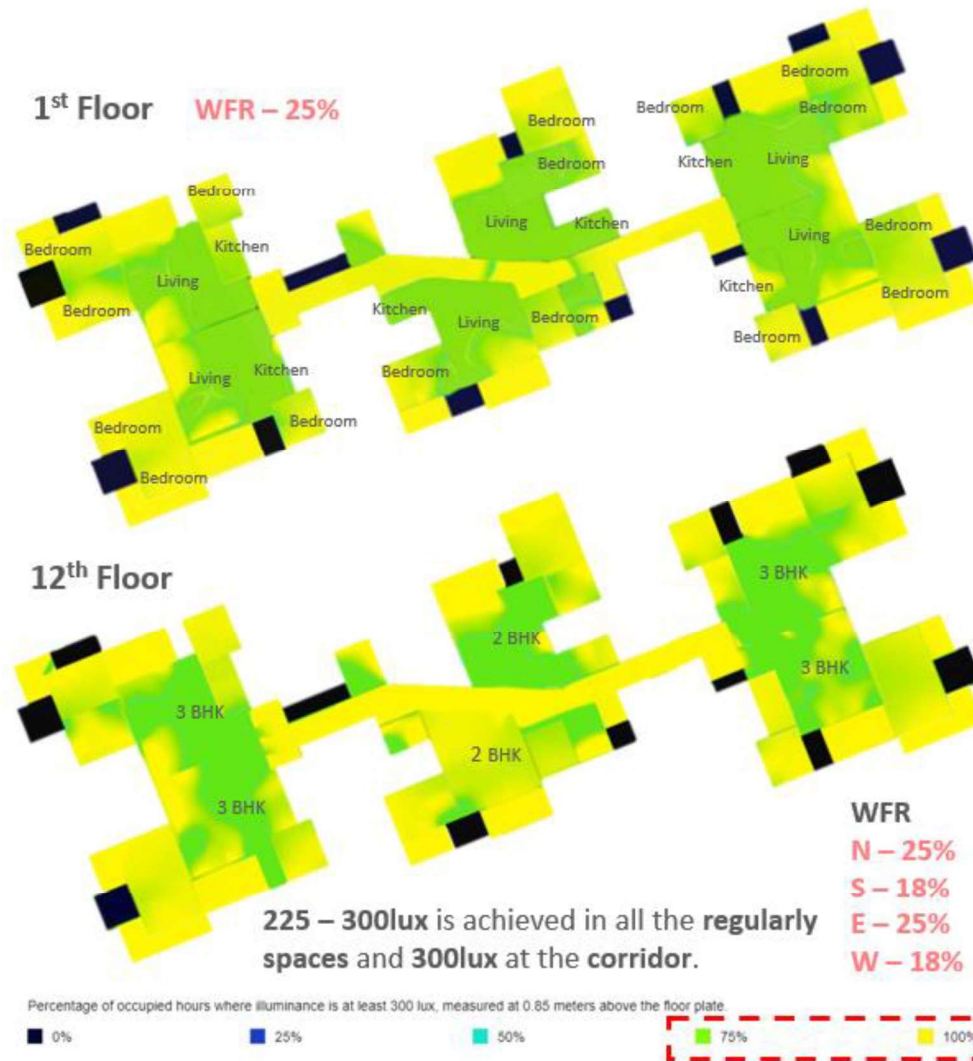
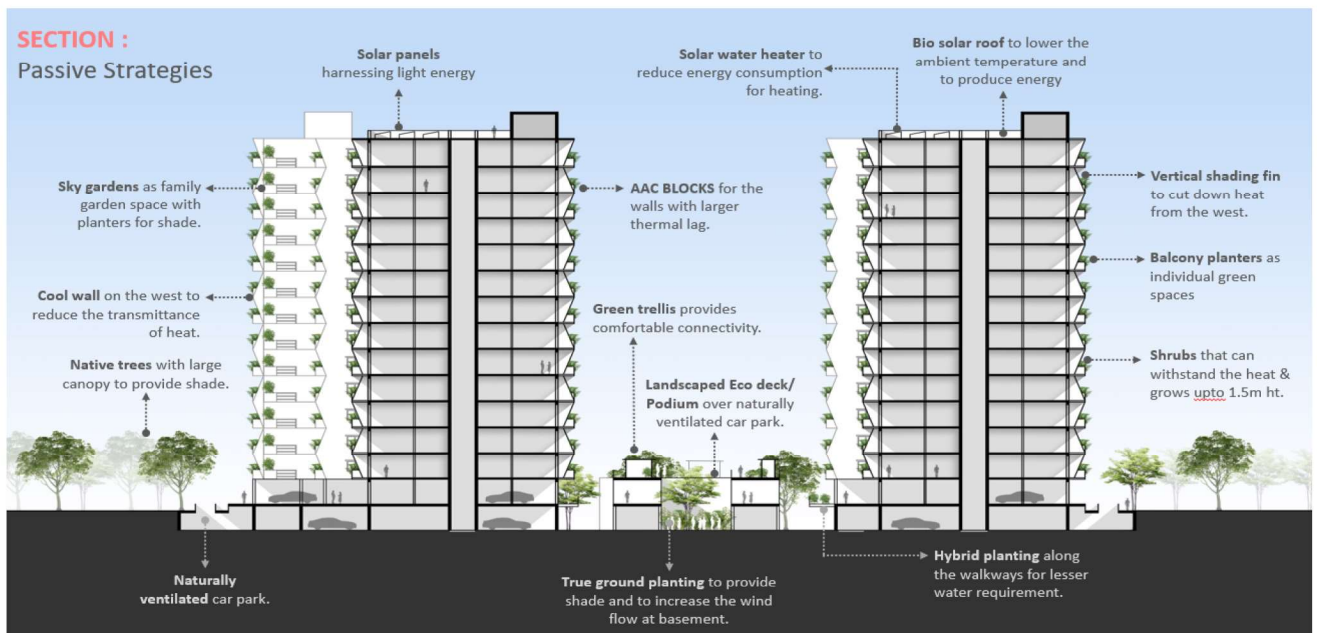


Fig 5.28 CFD analysis for Cross Ventilation





**Fig 5.29 CFD analysis for Daylight**



**Fig 5.30 Section with sustainable practices**



## CHAPTER 6

### ENVELOPE AREA ANALYSIS

#### 6.1 BIOSOLAR ROOF :



Semi Extensive Green Roof

| CRITERIA                                       | Extensive green roofs      | Semi-extensive green roofs      | Intensive green roofs (roof garden) |
|------------------------------------------------|----------------------------|---------------------------------|-------------------------------------|
| Load-bearing component                         | Concrete, RCC, Timber      | Concrete                        | Concrete<br>Maximum pitch 5%        |
| Plant choice                                   | Sedums, mosses, perennials | Perennials, small shrubs, lawns | Shrubs, trees, lawns                |
| Thickness of growing medium                    | 4 to 15 cm                 | 12 to 30 cm                     | 30 and over cm                      |
| Weight of complete system (kg/m <sup>2</sup> ) | 75 to 180                  | 200 to 500                      | 500 to 2000                         |



#### Layers of Roofing system

- 1 — base coating;
- 2 — waterproofing layer;
- 3 — grating;
- 4 — water flow;
- 5 — drainage layer;
- 6 — growing medium;
- 7 — low-growing plants;
- 8 — standard pot;
- 9 — fastener;
- 10 — rim;
- 11 — interlocking apparatus;
- 12 — hose;
- 13 — delivery tubes;
- 14 — perforated cup;
- 15 — drip watering tube;
- 16 — solar panel;
- 17 — sprinkler.

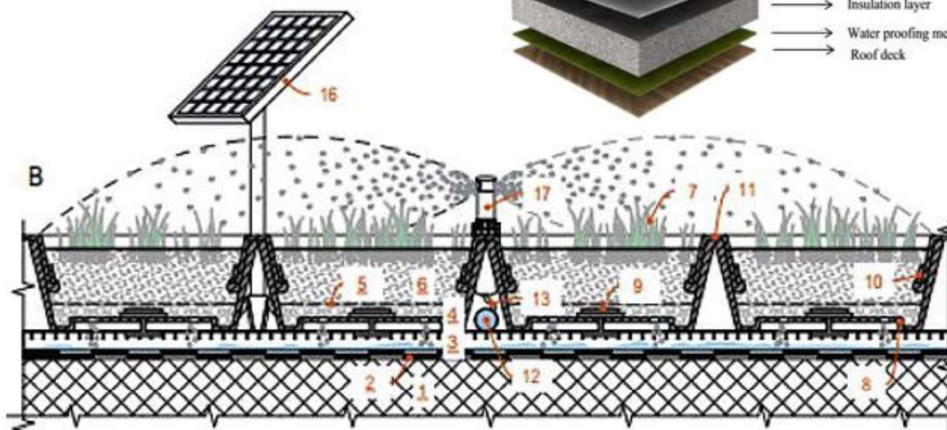


Fig 6.1 Biosolar roof details

#### THERMAL TRANSMITTANCE OF GREEN ROOF

| Material Layer       | Thickness t (m) | Thermal Conductivity | Thermal Resistance |
|----------------------|-----------------|----------------------|--------------------|
| Soil                 | 0.1             | 1.16                 | 0.09               |
| Gravel               | 0.15            | 0.7                  | 0.21               |
| Permeable Geotextile | 0.02            | 0.1                  | 0.20               |
| Drainage layer       | 0.02            | 0.27                 | 0.07               |
| Insulation           | 0.3             | 0.04                 | 7.50               |
| Anti root layer      | 0.01            | 0.7                  | 0.01               |
| Waterproofing        | 0.01            | 0.17                 | 0.06               |
| RCC slab             | 0.15            | 1.58                 | 0.09               |
| Internal Plaster     | 0.02            | 0.72                 | 0.02               |
| Sum of all material  |                 | 5.44                 | 8.26               |

$$RT = R_{si} + R_{se} + R_1 + R_2 + R_3 + \dots$$

$$= 0.17 + 0.04 + 8.26 = 8.473 \text{ m.K/W}$$

Thermal Transmittance of Roof,

$$U_{\text{roof}} = 1/RT = 0.12 \text{ W/m.K}$$

This is **less** than the maximum  $U_{\text{roof}}$  value of 1.2 W/m.K as per ECBC.

Hence it does complies with the requirement.

Table : 6.1 U value of green roof

## 6.2 GLAZING ANALYSIS :

The SHGC coefficient on all orientations is lesser than the Solar Factor of the double glazing from Saint-Gobain. The achieved visible light transmittance is 69%.

| Orientation | Opening Name | Width of glass (m) | Height of glass (m) | No. of Openings | Glass Area (sqm) | H overhang (m) | V overhang (m) | PF overhang | ESF overhang | SHGC equivalent |
|-------------|--------------|--------------------|---------------------|-----------------|------------------|----------------|----------------|-------------|--------------|-----------------|
| North       | W1           | 0.85               | 1.95                | 156             | 258.5            | 1.5            | 3.0            | 0.50        | 0.755        | 0.21            |
| North       | W2           | 1.35               | 1.35                | 26              | 47.4             | 1.0            | 2.4            | 0.42        | 0.782        | 0.22            |
| North       | W3           | 1.65               | 1.35                | 13              | 28.9             | 1.0            | 2.4            | 0.42        | 0.782        | 0.22            |
| North       | W4           | 1.06               | 1.06                | 39              | 43.8             | 0.6            | 2.1            | 0.29        | 0.864        | 0.24            |
| North       | D1           | 1.35               | 1.95                | 78              | 205.3            | 1.5            | 3.0            | 0.50        | 0.755        | 0.21            |
| South       | W1           | 0.85               | 1.95                | 156             | 258.5            | 2.0            | 3.0            | 0.50        | 0.681        | 0.19            |
| South       | W2           | 1.35               | 1.35                | 26              | 47.4             | 1.0            | 2.4            | 0.42        | 0.720        | 0.20            |
| South       | W3           | 1.65               | 1.35                | 13              | 28.9             | 1.0            | 2.4            | 0.42        | 0.720        | 0.20            |
| South       | W4           | 1.06               | 1.06                | 39              | 43.8             | 0.6            | 2.1            | 0.29        | 0.834        | 0.23            |
| South       | D1           | 1.35               | 1.95                | 78              | 205.3            | 2.0            | 3.0            | 0.50        | 0.681        | 0.19            |
| East        | W2           | 1.35               | 1.35                | 39              | 71.1             | 1.0            | 2.4            | 0.42        | 0.721        | 0.20            |
| East        | W3           | 1.65               | 1.35                | 65              | 144.8            | 1.0            | 2.4            | 0.42        | 0.721        | 0.20            |
| East        | W4           | 1.06               | 1.06                | 39              | 43.2             | 0.6            | 2.1            | 0.29        | 0.834        | 0.23            |
| West        | W2           | 1.35               | 1.35                | 39              | 71.1             | 1.0            | 2.4            | 0.42        | 0.782        | 0.22            |
| West        | W3           | 1.65               | 1.35                | 65              | 144.8            | 1.0            | 2.4            | 0.42        | 0.782        | 0.22            |
| West        | W4           | 1.06               | 1.06                | 39              | 43.2             | 0.6            | 2.1            | 0.29        | 0.864        | 0.24            |

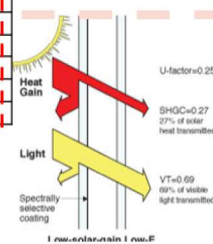
Table : 6.2 U value of Glazing

| Product           | Visual Comfort                | Thermal Comfort         | Thermal Comfort         |
|-------------------|-------------------------------|-------------------------|-------------------------|
| Product           | Visual light transmittance(%) | External Reflectance(%) | Internal Reflectance(%) |
| SGI Horizon Clear | 40                            | 34                      | 12                      |
| SGI Horizon Green | 35                            | 18                      | 11                      |

### ECBC reference for ESF Overhang

TABLE 11 External Shading Factor for Overhang (ESF<sub>overhang</sub>) for LAT < 23.5°N

| Orientation | North (30°E-42.5°E) | North-east (22.5°E-47.5°E) | East (45°E-102.5°E) | South-east (102.5°E-157.5°E) | South (157.5°E-214.5°E) | South-west (214.5°E-270°E) | West (270°E-326.5°E) | North-west (326.5°E-382.5°E) |
|-------------|---------------------|----------------------------|---------------------|------------------------------|-------------------------|----------------------------|----------------------|------------------------------|
| 0.00-0.10   | 1.000               | 1.000                      | 1.000               | 1.000                        | 1.000                   | 1.000                      | 1.000                | 1.000                        |
| 0.10-0.19   | 0.991               | 0.998                      | 0.992               | 0.990                        | 0.986                   | 0.990                      | 0.992                | 0.994                        |
| 0.20-0.29   | 0.888               | 0.894                      | 0.855               | 0.834                        | 0.806                   | 0.834                      | 0.854                | 0.864                        |
| 0.30-0.39   | 0.860               | 0.868                      | 0.797               | 0.771                        | 0.754                   | 0.771                      | 0.796                | 0.818                        |
| 0.40-0.49   | 0.838               | 0.842                      | 0.747               | 0.721                        | 0.708                   | 0.720                      | 0.746                | 0.762                        |
| 0.50-0.59   | 0.820               | 0.825                      | 0.705               | 0.682                        | 0.675                   | 0.681                      | 0.705                | 0.725                        |
| 0.60-0.69   | 0.806               | 0.814                      | 0.670               | 0.651                        | 0.653                   | 0.651                      | 0.670                | 0.734                        |
| 0.70-0.79   | 0.793               | 0.798                      | 0.641               | 0.628                        | 0.638                   | 0.627                      | 0.640                | 0.717                        |
| 0.80-0.89   | 0.783               | 0.796                      | 0.604               | 0.601                        | 0.628                   | 0.626                      | 0.615                | 0.705                        |
| 0.90-0.99   | 0.775               | 0.789                      | 0.596               | 0.621                        | 0.596                   | 0.621                      | 0.595                | 0.695                        |
| ≥1          | 0.768               | 0.688                      | 0.579               | 0.585                        | 0.604                   | 0.585                      | 0.578                | 0.688                        |



SHGC unshaded = 0.27%  
VLT = 69%  
Therefore,  
SHGC<sub>eg</sub> < SHGC unshaded

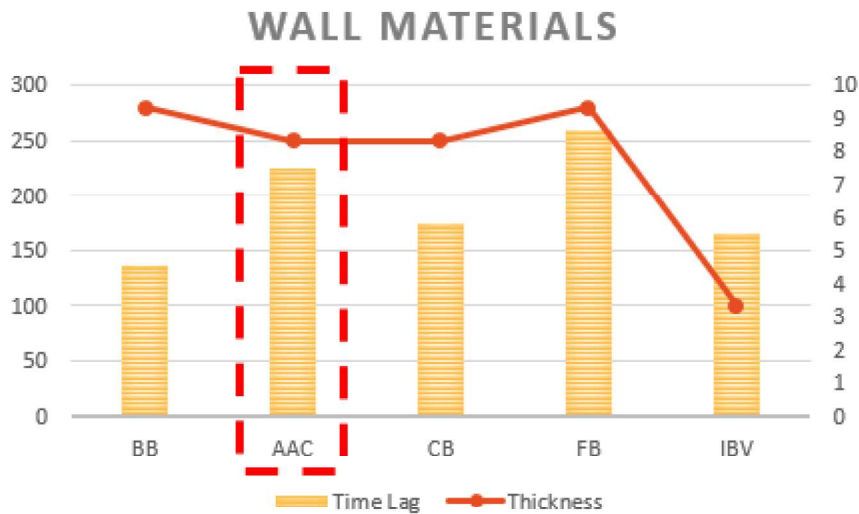
Double glazing with Low solar heat gain and higher visible daylight transmittance is used to reduce the indoor air temperature and to increase the daylight to the indoor space.

## 6.3 WALL MATERIAL ANALYSIS :

| ITERATION 1       |           |                | ITERATION 4            |           |                |
|-------------------|-----------|----------------|------------------------|-----------|----------------|
| MATERIAL LAYERS   | THICKNESS | TIME LAG (HRS) | MATERIAL LAYERS        | THICKNESS | TIME LAG (HRS) |
| Cement Plastering | 25mm      | 0.26 hrs       | Cement Plastering      | 25mm      | 0.26 hrs       |
| Burnt Brick       | 230mm     | 4.5 hrs        | Flyash Bricks          | 230mm     | 8.1 hrs        |
| Cement Plastering | 25mm      | 0.26 hrs       | Cement Plastering      | 25mm      | 0.26 hrs       |
| Time lag          |           | 4.52 hrs       | Time lag               |           | 8.62 hrs       |
| Thickness of wall |           | 280 mm         | Thickness of wall      |           | 280 mm         |
| ITERATION 2       |           |                | ITERATION 5            |           |                |
| MATERIAL LAYERS   | THICKNESS | TIME LAG (HRS) | MATERIAL LAYERS        | THICKNESS | TIME LAG (HRS) |
| Cement Plastering | 25mm      | 0.26 hrs       | Cement Plastering      | 25mm      | 0.26 hrs       |
| AAC Blocks        | 200mm     | 7 hrs          | Insulated Brick Veneer | 50mm      | 5 hrs          |
| Cement Plastering | 25mm      | 0.26 hrs       | Cement Plastering      | 25mm      | 0.26 hrs       |
| Time lag          |           | 7.52 hrs       | Time lag               |           | 5.52 hrs       |
| Thickness of wall |           | 250 mm         | Thickness of wall      |           | 100 mm         |
| ITERATION 3       |           |                |                        |           |                |
| MATERIAL LAYERS   | THICKNESS | TIME LAG (HRS) |                        |           |                |
| Cement Plastering | 25mm      | 0.26 hrs       |                        |           |                |
| Concrete Blocks   | 200mm     | 5.3 hrs        |                        |           |                |
| Cement Plastering | 25mm      | 0.26 hrs       |                        |           |                |
| Time lag          |           | 5.82 hrs       |                        |           |                |
| Thickness of wall |           | 250 mm         |                        |           |                |

Table : 6.3 Thermal Lag of Wall Materials





Flyash bricks with larger thermal lag is **not suitable** for load bearing walls in high rise construction due to its strength. Hence **AAC Blocks** are preferred.

Fig 6.2 Thermal lag of wall materials

**AAC Blocks** with cement plastering for the walls facing North, South and East facades. Its K value is 0.184 and its U value is 0.67w/m<sup>2</sup>k. It reduces dead load since light weight, high in strength and less thermal conductivity. Highest time lag of 7.52 hrs is noted and hence the transfer of heat to the indoor space is reduced.

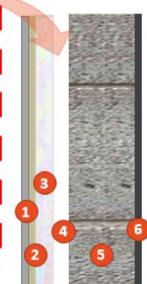
### COOL WALLS :

| ITERATION 1       |           |                |
|-------------------|-----------|----------------|
| MATERIAL LAYERS   | THICKNESS | TIME LAG (HRS) |
| Double Brick      | 250mm     | 8 hrs          |
| Adhesive          | 10mm      | 0.15 hrs       |
| Polystyrene       | 10mm      | 1.1 hrs        |
| Interior Finish   | 10mm      | 0.15 hrs       |
| Cement Plastering | 25mm      | 0.26           |
| Time lag          |           | 9.4 hrs        |
| Thickness of wall |           | 310 mm         |

| ITERATION 2       |           |                |
|-------------------|-----------|----------------|
| MATERIAL LAYERS   | THICKNESS | TIME LAG (HRS) |
| Brick Veneer      | 100mm     | 5 hrs          |
| Foam Insulation   | 25mm      | 1 hr           |
| Exterior Board    | 25mm      | 1 hr           |
| Steel Frame       | 75mm      | 0.38 hrs       |
| Interior Board    | 25mm      | 1 hr           |
| Time lag          |           | 8.88 hrs       |
| Thickness of wall |           | 250 mm         |

| ITERATION 3       |           |                |
|-------------------|-----------|----------------|
| MATERIAL LAYERS   | THICKNESS | TIME LAG (HRS) |
| Concrete Block    | 200mm     | 5.3 hrs        |
| Air Cavity        | 25mm      | 1 hr           |
| Polystyrene       | 10mm      | 1.1 hrs        |
| Interior Finish   | 10mm      | 0.15 hrs       |
| Time lag          |           | 7.55 hrs       |
| Thickness of wall |           | 245 mm         |

| ITERATION 4       |           |                |
|-------------------|-----------|----------------|
| MATERIAL LAYERS   | THICKNESS | TIME LAG (HRS) |
| AAC Block         | 200mm     | 7 hrs          |
| Air Cavity        | 25mm      | 1 hr           |
| XPS Board         | 50mm      | 1.5 hrs        |
| Adhesive          | 10mm      | 0.15           |
| Interior Finish   | 10mm      | 0.15 hrs       |
| Time lag          |           | 9.80 hrs       |
| Thickness of wall |           | 285 mm         |



- Layers of cool wall**
1. Exterior Finish
  2. Adhesive
  3. XPS Board
  4. Air Cavity
  5. AAC Block
  6. Interior Finish

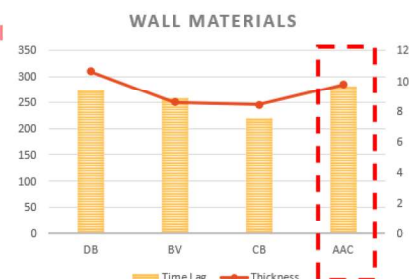


Table : 6.4 Thermal Lag of Cool Wall Materials

**AAC blocks** with enhanced thermal insulation, are incorporated with walls facing west direction to cut down heat radiation, improving the thermal comfort within the units. With the larger time lag of 9.80 hrs the heat transfer is reduced.



| Calculation for Opaque Area |       |            |                |                   |                        |           |
|-----------------------------|-------|------------|----------------|-------------------|------------------------|-----------|
| Orientation                 | Area  | Component  | (a) Area (sqm) | (b) U value W/m.K | (c) Orientation Factor | a x b x c |
| North                       | Wall  | AAC Block  | 1179.1         | 0.78              | 0.659                  | 606.08    |
|                             | Frame | UPVC       | 274.9          | 0.16              | 0.659                  | 28.98     |
| South                       | Wall  | AAC Block  | 1179.1         | 0.78              | 0.966                  | 888.42    |
|                             | Frame | UPVC       | 274.9          | 0.16              | 0.966                  | 42.5      |
| East                        | Wall  | AAC Block  | 1282.9         | 0.78              | 1.155                  | 1155.7    |
|                             | Frame | UPVC       | 170.5          | 0.16              | 1.155                  | 31.5      |
| West                        | Wall  | AAC Block  | 1282.9         | 0.78              | 1.156                  | 1156.7    |
|                             |       | Air cavity | 1282.9         | 0.15              | 1.156                  | 222.5     |
|                             |       | XPS Board  | 1282.9         | 0.034             | 1.156                  | 50.42     |
|                             | Frame | UPVC       | 170.5          | 0.16              | 1.156                  | 31.5      |
| Total                       |       |            |                |                   |                        | 4214.3    |

| Calculation for Non opaque Area |                          |                   |                      |                           |           |
|---------------------------------|--------------------------|-------------------|----------------------|---------------------------|-----------|
| Orientation                     | Component                | (a) Area<br>(sqm) | (b) U value<br>W/m.K | (c) Orientation<br>Factor | a x b x c |
| North                           | Non opaque glass<br>area | 916.5             | 2.5                  | 0.659                     | 1509.9    |
| South                           | Non opaque glass<br>area | 916.5             | 2.5                  | 0.966                     | 2213.3    |
| East                            | Non opaque glass<br>area | 568.3             | 2.5                  | 1.155                     | 1640.9    |
| West                            | Non opaque glass<br>area | 568.3             | 2.5                  | 1.156                     | 1642.3    |
| Total                           |                          |                   |                      |                           | 7006.4    |

| Calculation for Envelope Area |           |                |                     |                        |           |
|-------------------------------|-----------|----------------|---------------------|------------------------|-----------|
| Orientation                   | Component | (a) Area (sqm) | (b) SHGC Equivalent | (c) Orientation Factor | a x b x c |
| North                         | W1        | 258.5          | 0.21                | 0.659                  | 35.7      |
| North                         | W2        | 47.4           | 0.22                | 0.659                  | 6.872     |
| North                         | W3        | 28.9           | 0.22                | 0.659                  | 4.189     |
| North                         | W4        | 43.8           | 0.24                | 0.659                  | 6.927     |
|                               |           |                |                     |                        |           |
| South                         | W1        | 258.5          | 0.21                | 0.966                  | 52.43     |
| South                         | W2        | 47.4           | 0.22                | 0.966                  | 10.07     |
| South                         | W3        | 28.9           | 0.22                | 0.966                  | 6.141     |
| South                         | W4        | 43.8           | 0.24                | 0.966                  | 10.15     |
|                               |           |                |                     |                        |           |
| East                          | W2        | 71.1           | 0.20                | 1.155                  | 16.42     |
| East                          | W3        | 144.8          | 0.20                | 1.155                  | 26.5      |
| East                          | W4        | 43.2           | 0.23                | 1.155                  | 11.47     |
|                               |           |                |                     |                        |           |
| West                          | W2        | 71.1           | 0.20                | 1.156                  | 16.43     |
| West                          | W3        | 144.8          | 0.20                | 1.156                  | 33.5      |
| West                          | W4        | 43.2           | 0.23                | 1.156                  | 11.49     |
| Total                         |           |                |                     |                        | 248.29    |

#### ECBC REFERENCE FOR ORIENTATION FACTOR

TABLE 9 Orientation factor (u) for different orientations

| Orientation                | Orientation factor (u) |                   |
|----------------------------|------------------------|-------------------|
|                            | Latitudes >23.5°N      | Latitudes <23.5°N |
| North (330°-225°)          | 0.550                  | 0.659             |
| North-east (225°-67.5°)    | 0.809                  | 0.906             |
| East (67.5°-112.5°)        | 1.155                  | 1.155             |
| South-east (112.5°-157.5°) | 1.211                  | 1.125             |
| South (157.5°-202.5°)      | 1.089                  | 0.966             |
| South-west (202.5°-247.5°) | 1.202                  | 1.124             |
| West (247.5°-292.5°)       | 1.143                  | 1.156             |
| North-west (292.5°-337.5°) | 0.821                  | 0.908             |

Table : 6.5 U value of Envelope Area

$$RETV = 1 / 10,980.2 \times ((5.15 \times 4214.3) + (1.31 \times 7006.4) + (65.21 \times 248.29))$$

$$RETV = 3.17 \text{ W/m}$$

This is less than max RETV of **15W/m**. Hence it complies with the ECBC requirement.

**U value of 3.17 W/m** is achieved at the envelope area with **AAC block walls** and **UPVC window frames** with **Double glazing** with **Low E value**.

## SITE PLAN :

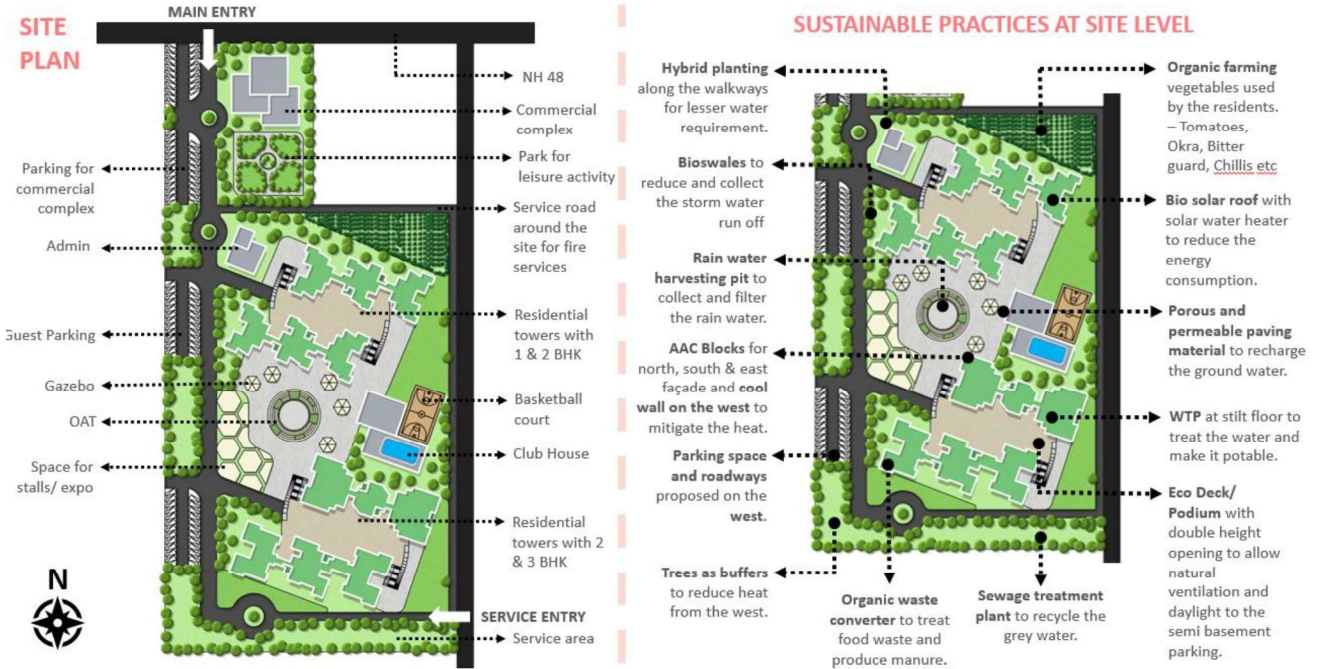


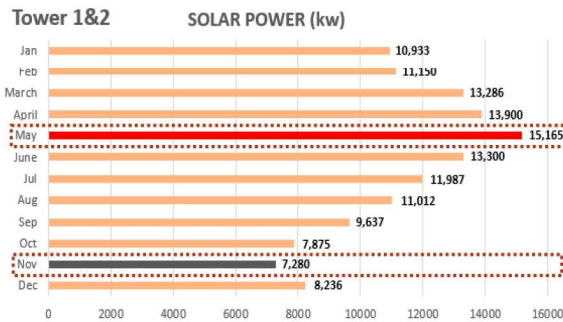
Fig 6.3 Site Plan with sustainable practices

## CHAPTER 7

### SERVICES

#### 7.1 SOLAR POWER :

##### Monthly production of Solar Power – 385 panels



##### Monthly Energy consumption for Fans

| 1 BHK                       |     |       |           |           |              |
|-----------------------------|-----|-------|-----------|-----------|--------------|
| Fixture                     | Nos | Hours | Watts/ hr | watts/day | watts/ month |
| Fans                        | 1   | 24    | 80        | 1920      | 57600        |
| Total                       |     |       |           |           | 57600        |
| 26 units                    |     |       |           |           | 1497600      |
|                             |     |       |           |           | 57.6kw       |
| 2 BHK                       |     |       |           |           |              |
| Fixture                     | Nos | Hours | Watts/ hr | watts/day | watts/ month |
| Fans                        | 1   | 24    | 80        | 1920      | 57600        |
| Total                       |     |       |           |           | 57600        |
| 52 units                    |     |       |           |           | 2995200      |
|                             |     |       |           |           | 2995.2kw     |
| Total consumption per tower |     |       |           |           | 4492800      |
|                             |     |       |           |           | 4492.8kw     |

##### Monthly Energy consumption for Lights

| 1 BHK & 2 BHK               |     |       |           |           |              |
|-----------------------------|-----|-------|-----------|-----------|--------------|
| Fixture                     | Nos | Hours | Watts/ hr | watts/day | watts/ month |
| LED Tube lights             | 1   | 6     | 36        | 216       | 6480         |
| LED Bulbs                   | 2   | 3     | 10        | 60        | 1800         |
| Total                       |     |       |           |           | 8280         |
| 78 units                    |     |       |           |           | 645840       |
|                             |     |       |           |           | 645.84kw     |
| CORRIDOR                    |     |       |           |           |              |
| Fixture                     | Nos | Hours | Watts/ hr | watts/day | watts/ month |
| LED lights                  | 6   | 6     | 40        | 1440      | 43200        |
| LED lights                  | 5   | 11    | 40        | 2200      | 66000        |
| Total                       |     |       |           |           | 109200       |
| 13 Floors                   |     |       |           |           | 1419600      |
|                             |     |       |           |           | 1419.6kw     |
| PARKING                     |     |       |           |           |              |
| Fixture                     | Nos | Hours | Watts/ hr | watts/day | watts/ month |
| LED Tube lights             | 24  | 6     | 40        | 5760      | 172800       |
| LED Tube lights             | 24  | 11    | 40        | 10560     | 316800       |
| Total                       |     |       |           |           | 489600       |
| Basement +Stilt             |     |       |           |           | 979200       |
|                             |     |       |           |           | 979.2kw      |
| Total consumption per tower |     |       |           |           | 3044640      |
|                             |     |       |           |           | 3044.6kw     |

Total Energy consumed = 7537440watts = 7,537.4kw

Table : 7.1 Solar Power calculations

### Annual Solar Power Production

| ANNUAL SOLAR PANEL CALCULATIONS                                                                                                                      |             |           |
|------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|-----------|
| Electricity produced by a single solar panel(wh per day)                                                                                             | 180         |           |
| Actual performance of solar panel based on climatic conditions is 75%                                                                                | 0.75        |           |
| No. of rainy days in a year                                                                                                                          | 87          |           |
| Average hours of sunlight in a year                                                                                                                  | 2552        |           |
| Total electricity produced annually                                                                                                                  | 344520      |           |
| Dimension of single solar panel ( standards for residential purpose)                                                                                 | 1.6m x 0.9m | 1.44 sq.m |
| NO. of solar panels to be installed                                                                                                                  | 1571 panels |           |
| Total generation of electricity in the site through solar panels -Electricity produced by a single solar panel * NO. of solar panels to be installed | 600996012   | W         |
|                                                                                                                                                      | 6,00,996 kW |           |

**Table : 7.2 Annual Solar Power**

**Total Solar Power generated on site annually = 6,00,996 kw**

The excess solar power will be used for lighting the club house and admin spaces and the walkways will have outdoor solar lights installed.

### 7.2 SOLAR WATER HEATER :

Per person requires 10 – 20 litres hot water per bath at 60degc

#### Tower 1 & 2

1 bhk units – 26 nos = 780 LPD

2 bhk units – 52 nos = 2080 LPD

**Total requirement = 2860 LPD**

#### Tower 3

2 bhk units – 26 nos = 1040 LPD

3 bhk units – 52 nos = 3120 LPD

**Total requirement = 4160 LPD**

#### Tower 4

3 bhk units – 52 nos = 3120 LPD

**Total requirement = 3120 LPD**

| Tower | Required LPD | Required water heater capacity (litres) | No of units required |
|-------|--------------|-----------------------------------------|----------------------|
| 1     | 2860         | 500                                     | 6                    |
| 2     | 2860         | 500                                     | 6                    |
| 3     | 4160         | 500                                     | 8                    |
|       |              | 250                                     | 1                    |
| 4     | 3120         | 500                                     | 6                    |
|       |              | 250                                     | 1                    |

**Table : 7.3 Solar Water Heater**

Required **hot water** for the **residential units** is got from the **solar water heaters** installed at the **roof top** of each towers thereby **reducing the energy consumption of geysers**.

### 7.3 STORM WATER RUN OFF :

Rain water harvesting from roof = Area of roof x coefficient x annual rainfall (in mm)

Area of the roof = **3220.5 sqm**



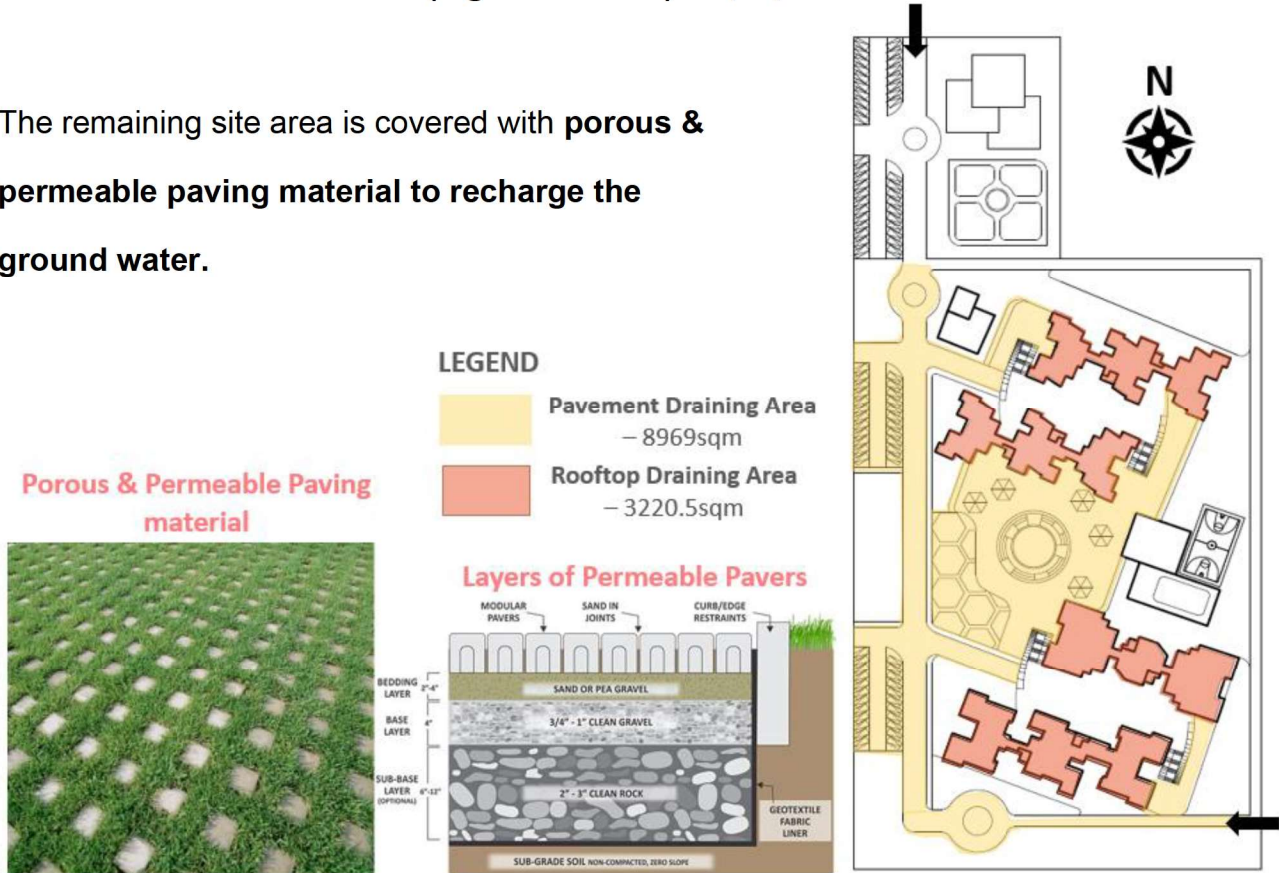
Coefficient of runoff = 0.3

Annual Rainfall of Chennai = 1400 mm

Rain water harvesting from roof = 13,52,610 litres annually.

For the month of November (highest rainfall) = 3,85,493.8 litres

The remaining site area is covered with porous & permeable paving material to recharge the ground water.



Total roof top draining area = 3220.5 sqm

Total pavement draining area = 8969sqm

Total bioswale area = 782 sqm

4% OF TOTAL DRAINING AREA

For the month of November)

Total collected litres from roof top = 3,85,493.8 litres

Total collected litres from pavements = 1,35,200 litres

Total collected water = 5,20,693.8 litres

TANK CAPACITY – 9m dia x 4.5m depth x 1000litres = 5,45,000 litres

| PAVEMENT AREA STORM WATER RUN-OFF                                                              |            |                                |
|------------------------------------------------------------------------------------------------|------------|--------------------------------|
| Qt =                                                                                           | C * It * A |                                |
| Qt: runoff rate for a T-year storm, in liters/second                                           |            |                                |
| C: runoff coefficient, nondimensional                                                          |            |                                |
| IT: rainfall intensity for a T-year storm at a storm duration t, in<br>liters/(second*hectare) |            |                                |
| A: area of the catchment area, in hectares                                                     |            |                                |
| C                                                                                              | 0.4        | ( With the ref. to the table ) |
| It                                                                                             | 1,400      | in mm(annual rainfall)         |
| A                                                                                              | 0.89       | in h.a(8969sq.mts)             |
| Qt =                                                                                           | 498.4      | (498400 litres annually)       |

For the month of November (highest rainfall 380mm)  
= 1,35,200 litres

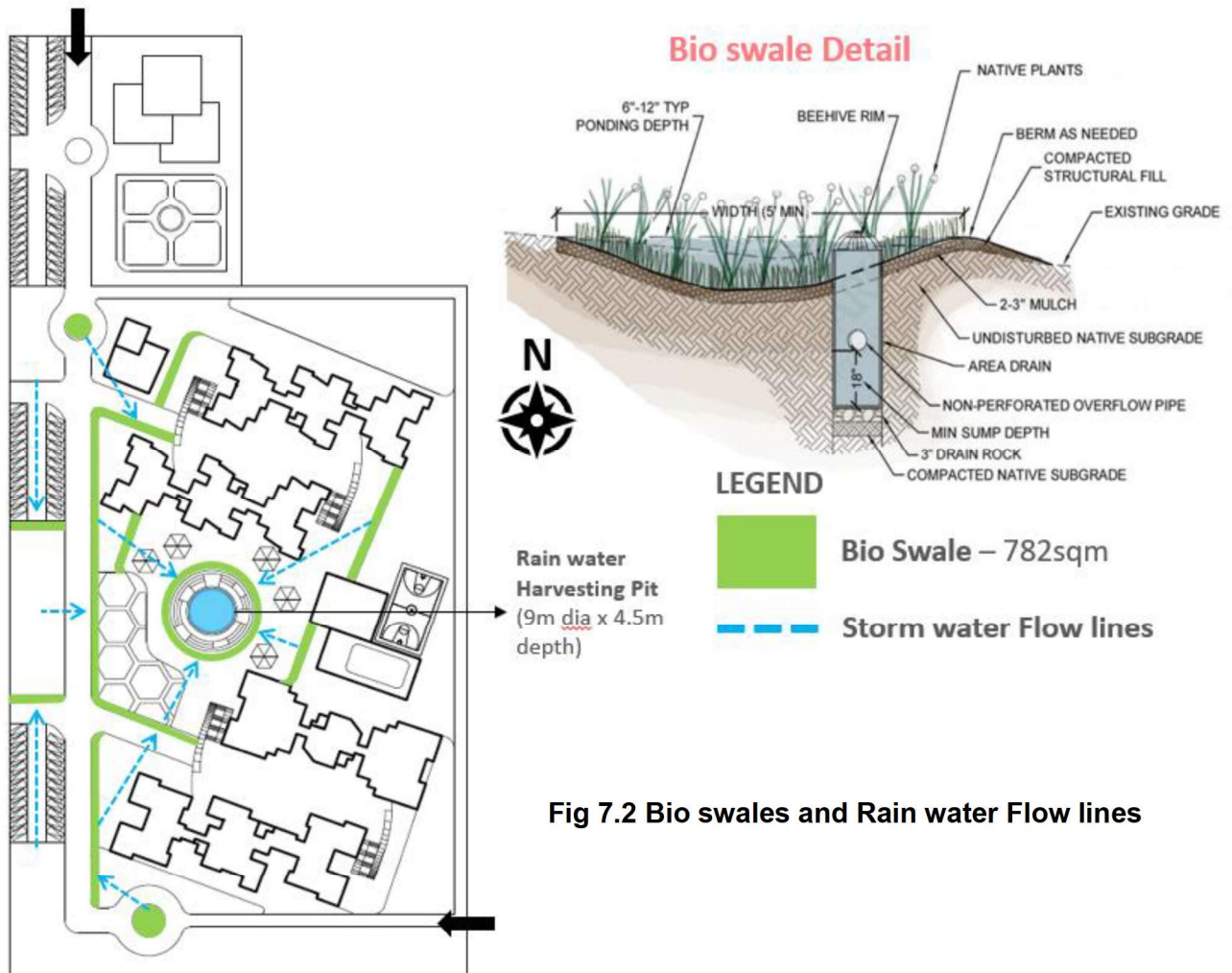
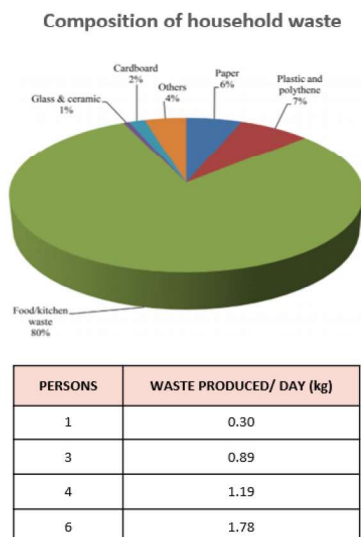


Fig 7.2 Bio swales and Rain water Flow lines

## 7.4 WASTE MANAGEMENT :



Source : Evaluation of Household Food Waste Generation and Policy Implications towards SDGs.

### Household Waste Generation

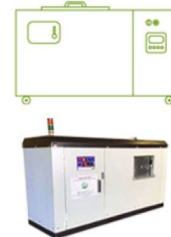
| 1 BHK                   |          |
|-------------------------|----------|
| No. of Persons          | 3        |
| Waste generated per day | 0.89 kg  |
| Total no of units       | 52nos    |
| Total waste generated   | 46.28kgs |

| 2 BHK                   |          |
|-------------------------|----------|
| No. of Persons          | 4        |
| Waste generated per day | 1.19 kg  |
| Total no of units       | 130nos   |
| Total waste generated   | 154.7kgs |

| 3 BHK                   |           |
|-------------------------|-----------|
| No. of Persons          | 6         |
| Waste generated per day | 1.78 kg   |
| Total no of units       | 104nos    |
| Total waste generated   | 185.12kgs |

### Organic Waste Converter (OWC)

#### MODEL GEV150



#### TECHNICAL SPECIFICATION

|                                        |                                                          |
|----------------------------------------|----------------------------------------------------------|
| CAPACITY: 150 kgs per day              | DIMENSION: L 7.6 x W 3.6 x H 5 ft                        |
| OPERATION: FULLY AUTOMATIC             | CONTROL SYSTEM: PLC                                      |
| HEATING METHOD: Flexible Thermo Jocket | GEAR BOX (ROSSI): Planetary Type - Torque 1500Nm (ITALY) |
| POWER RATING: 3ph, 5.5kw               | BODY MAKE: SS 304 GRADE                                  |
| DECOMPOSING METHOD: Aerobic composting | POWER CONSUMPTION: 0.88kw/h                              |

Table : 7.4 Waste Management

OWC from Greenviron India, it **processes the waste** within **15mins** and **converts into nutrient rich compost within 24hrs**.

The **obtained manures** can be used for the plants and for **organic farming** in the site.

## 7.5 GREY WATER MANAGEMENT :

### Waste Water Calculation

| 1 BHK – 3 PERSONS                  |                                 |         |        |
|------------------------------------|---------------------------------|---------|--------|
| EQUIPMENTS                         | SPECIFICATIONS                  | GALLONS | LITRES |
| WC                                 | Per flush                       | 1.6     | 6      |
|                                    | Avg no of flushes per person    | 5       |        |
|                                    | Avg no of flushes for 3 persons | 15      |        |
|                                    | Total                           | 23.7    | 90     |
| Shower                             | Flow per min                    | 1.3     | 5      |
|                                    | Avg time per person             | 10 mins |        |
|                                    | 3 persons (30 mins)             | 39.6    | 150    |
| Wash Basin                         | Flow per min                    | 1       | 3.7    |
|                                    | Avg no of uses per person       | 5       |        |
|                                    | Avg no of uses for 3 persons    | 15      |        |
|                                    | Avg time (1 min)                | 15      | 56.7   |
| Kitchen Sink                       | Dish washing                    | 20      | 75     |
|                                    | Avg no of uses                  | 1       |        |
|                                    | Total                           | 20      | 75     |
| Washing Machine                    | Per wash                        | 15.9    | 60     |
| Total waste water produced per day |                                 | 114     | 431.7  |

| 2 BHK – 4 PERSONS                  |                                 |         |        |
|------------------------------------|---------------------------------|---------|--------|
| EQUIPMENTS                         | SPECIFICATIONS                  | GALLONS | LITRES |
| WC                                 | Per flush                       | 1.6     | 6      |
|                                    | Avg no of flushes per person    | 5       |        |
|                                    | Avg no of flushes for 4 persons | 20      |        |
|                                    | Total                           | 31.7    | 120    |
| Shower                             | Flow per min                    | 1.3     | 5      |
|                                    | Avg time per person             | 10 mins |        |
|                                    | 4 persons (40 mins)             | 52.8    | 200    |
| Wash Basin                         | Flow per min                    | 1       | 3.7    |
|                                    | Avg no of uses per person       | 5       |        |
|                                    | Avg no of uses for 4 persons    | 20      |        |
|                                    | Avg time (1 min)                | 20      | 75.7   |
| Kitchen Sink                       | Dish washing                    | 20      | 75     |
|                                    | Avg no of uses                  | 1       |        |
|                                    | Total                           | 20      | 75     |
| Washing Machine                    | Per wash                        | 15.9    | 60     |
| Total waste water produced per day |                                 | 140     | 530.5  |

| 3 BHK – 6 PERSONS                  |                                 |         |        |
|------------------------------------|---------------------------------|---------|--------|
| EQUIPMENTS                         | SPECIFICATIONS                  | GALLONS | LITRES |
| WC                                 | Per flush                       | 1.6     | 6      |
|                                    | Avg no of flushes per person    | 5       |        |
|                                    | Avg no of flushes for 6 persons | 30      |        |
|                                    | Total                           | 47.5    | 180    |
| Shower                             | Flow per min                    | 1.3     | 5      |
|                                    | Avg time per person             | 10 mins |        |
|                                    | 6 persons (60 mins)             | 79.3    | 300    |
| Wash Basin                         | Flow per min                    | 1       | 3.7    |
|                                    | Avg no of uses per person       | 5       |        |
|                                    | Avg no of uses for 6 persons    | 30      |        |
|                                    | Avg time (1 min)                | 30      | 113.5  |
| Kitchen Sink                       | Dish washing                    | 20      | 75     |
|                                    | Avg no of uses                  | 1       |        |
|                                    | Total                           | 20      | 75     |
| Washing Machine                    | Per wash                        | 15.9    | 60     |
| Total waste water produced per day |                                 | 192     | 728.5  |

### Waste water collected (per day)

1 bhk units (52 units) = 5928 gallons ( 22,439.9 litres)  
 2 bhk units (130 units) = 18,200 gallons ( 68,894.4 litres)  
 3 bhk units (104 units) = 19,968 gallons ( 75,587 litres)

**Total Waste water (per day) = 44,096 gallons (1, 66,921.5 litres)**

**Total Black water (per day) = 10,302 gallons (39,000 litres)**

**Total Grey water (per day) = 33,793 gallons (1,27,921.5litres)**

Table : 7.5 Grey water Management

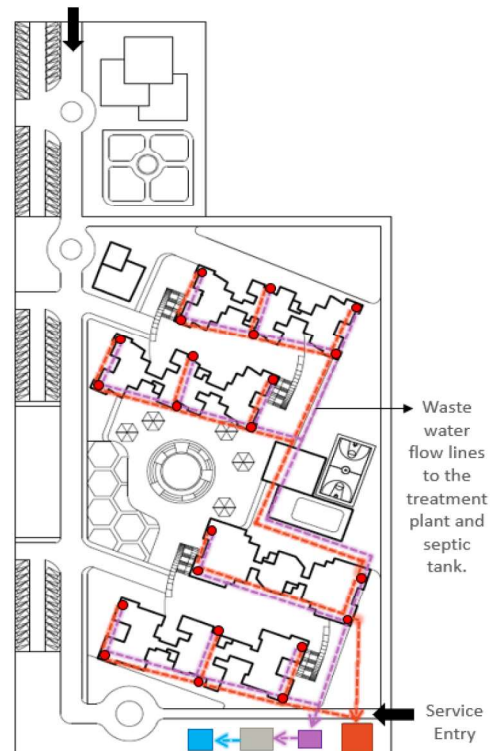
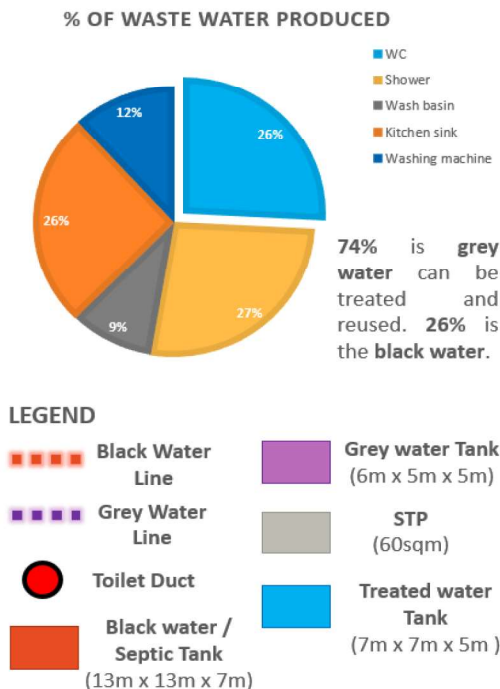
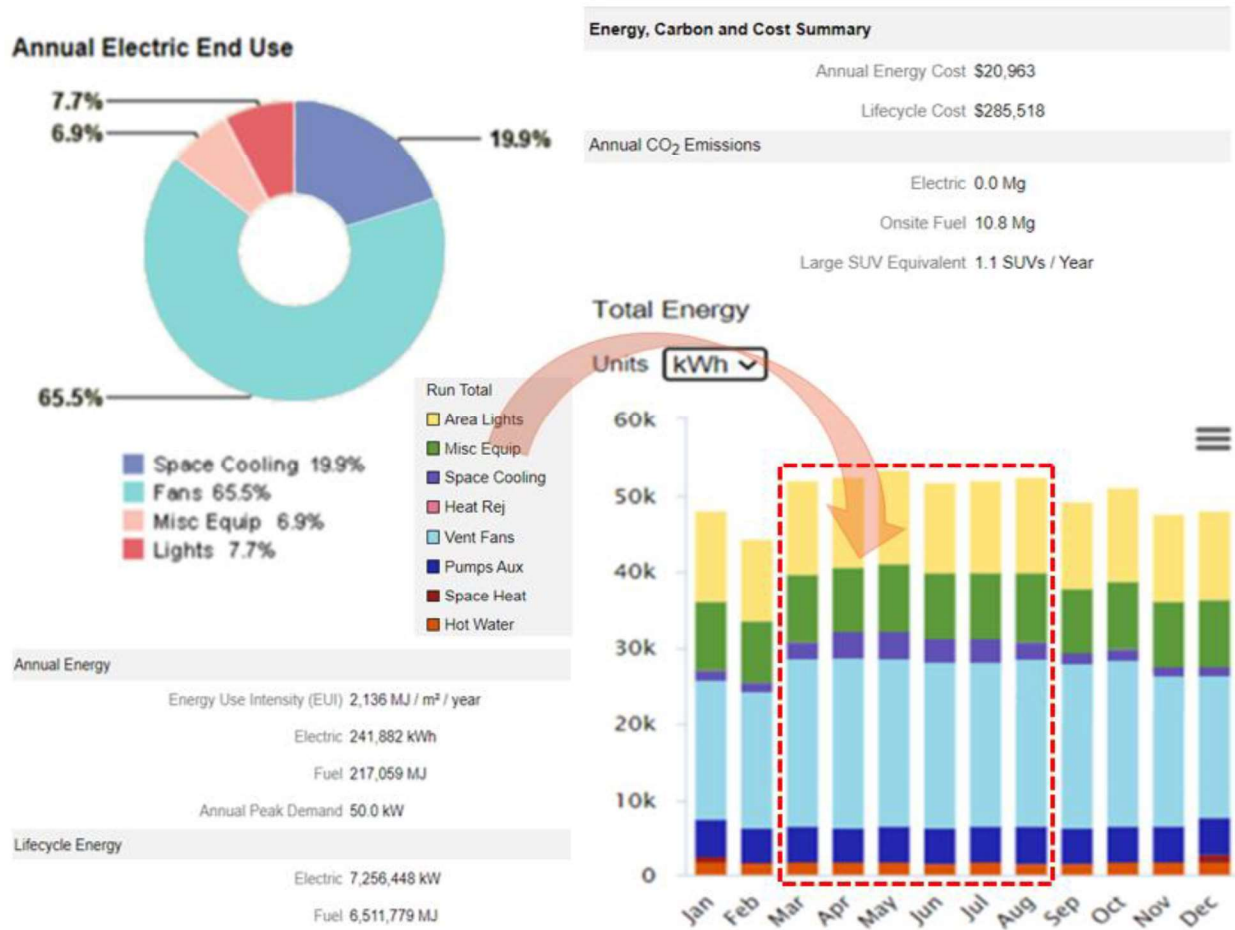


Fig 7.3 Grey water Demarcation Plan



## 7.6 ENERGY ANALYSIS :



**Fig 7.4 Energy Analysis**

Approx 5m x 4m room space requires 1.5 ton Split AC for sufficient cooling

1 unit of **1.5 ton Split AC** consumes = **1.7 kwh**

1 bhk units = 52 nos x 1 fixture = 52 fixtures

2 bhk units = 130 nos x 1 fixture = 130 fixtures

3 bhk units = 104 nos x 2 fixtures = 208 fixtures

**Total = 390 fixtures**

Energy consumed for **8 hours/ day** = **5304 Kw/ day**

Considering the **summer months** for air conditioning

**Total energy consumed = 9,54,720 Kw annually**

Total energy saved annually by using passive strategies for natural ventilation and by reducing the usage of air conditioning = 9,54,720 Kw

## 7.7 LIFE CYCLE COST ANALYSIS :

Cost analysis for a 3bhk unit in the apartment for a period of 30 years.

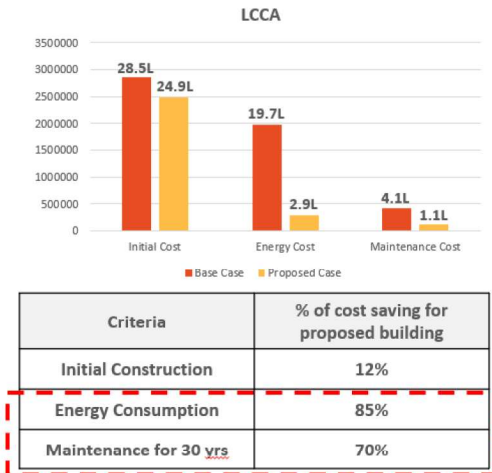
| INITIAL COST ANALYSIS |                                                                            |                                                       |                                                        |
|-----------------------|----------------------------------------------------------------------------|-------------------------------------------------------|--------------------------------------------------------|
| CRITERIA              | SPECIFICATIONS                                                             | BASE CASE                                             | PROPOSED CASE                                          |
| CONSTRUCTION          | Wall Material                                                              | Brick                                                 | AAC Block                                              |
|                       | Total cost including material cost, labour cost & Construction time period | Rs. 27,40,000                                         | Rs. 24,66,000                                          |
|                       |                                                                            |                                                       |                                                        |
| HEATING               | Water heating for domestic use                                             | Geyser - 15 litres (3 nos/house)                      | Solar Water Heater (6 nos/ tower) Geyser – 1nos/ house |
|                       | Buying + Installation Cost                                                 | Rs. 12,000                                            | Rs. 12,000 + Rs. 4000                                  |
|                       | Total cost                                                                 | Rs. 36,000                                            | Rs. 16,000                                             |
| SPACE COOLING         | Cooling Technique                                                          | Air conditioning Split AC unit 1.5 ton (2 nos/ house) | Fans Electricity & Solar Power (5 nos/ house)          |
|                       | Buying + Installation Cost                                                 | Rs. 40,000                                            | Rs. 1500                                               |
|                       | Total cost                                                                 | Rs. 80,000                                            | Rs. 7500                                               |
| LIGHTING              | Energy Consumption                                                         | Electricity                                           | Electricity & Solar Power                              |
|                       | No of Lights                                                               | 5 Tube lights (40w) 5 CFL Bulbs (25w)                 | 5 LED Tube lights (30w) 5 LED Bulbs (10w)              |
|                       | Buying cost                                                                | Rs. 1400                                              | Rs. 2750                                               |
|                       | Total cost                                                                 | Rs. 1400                                              | Rs. 2750                                               |
|                       |                                                                            |                                                       |                                                        |
| TOTAL COST            |                                                                            | Rs. 28,57,400                                         | Rs. 24,92,250                                          |

Total Cost savings = Rs. 3,65,150

| ENERGY COST ANALYSIS @ Rs. 5.5/ Kw |                                                                         |                                                       |                                                                   |
|------------------------------------|-------------------------------------------------------------------------|-------------------------------------------------------|-------------------------------------------------------------------|
| CRITERIA                           | SPECIFICATIONS                                                          | BASE CASE                                             | PROPOSED CASE                                                     |
| HEATING COST                       | Water heating for domestic use                                          | Geyser - 15 litres (3 nos/house)                      | Solar Water Heater (6 nos/ tower) Geyser – 1nos/ house            |
|                                    | Energy consumed & Cost Per Year (2000wh/ unit)                          | 1460 Kw/yr Rs. 8,030                                  | 485 Kw/yr Rs. 2,676                                               |
|                                    | Total energy consumed & cost for heating for a period of 30 years       | 43,800 Kw Rs. 2,40,900                                | 14,600 Kw Rs. 80,300                                              |
| SPACE COOLING                      | Cooling Technique                                                       | Air conditioning Split AC unit 1.5 ton (2 nos/ house) | Fans – 5 nos (3 nos in electricity & 2 nos in solar power/ house) |
|                                    | Energy consumed & Cost Per Year                                         | (1700 wh/ unit) 9928 Kw/yr Rs.54,604                  | (80wh/ unit) 1051Kw/yr Rs. 5,780                                  |
|                                    | Total energy consumed & cost for space cooling for a period of 30 years | 2,97,840 Kw Rs. 16,38,120                             | 31, 530 Kw Rs. 1,73,415                                           |
| LIGHTING                           | Energy Consumption                                                      | Electricity                                           | Electricity & Solar Power                                         |
|                                    | No of Lights in electricity                                             | 5 Tube lights (40w) 5 CFL Bulbs (25w)                 | 3 LED Tube lights (30w) 3 LED Bulbs (10w)                         |
|                                    | No of Lights in Solar Power                                             | Nil                                                   | 2 LED Tube lights (30w) 2 LED Bulbs (10w)                         |
|                                    | Energy consumed & Cost Per Year                                         | 602 Kw Rs. 3312                                       | 260 Kw Rs. 1485                                                   |
|                                    | Total energy consumed & cost for lighting for a period of 30 years      | 18,060 Kw Rs. 99,360                                  | 7800 Kw Rs. 42,900                                                |
| TOTAL COST/ YEAR                   |                                                                         | Rs. 65,946                                            | Rs. 9,941                                                         |
| TOTAL COST for 30 YRS              |                                                                         | Rs. 19,78,380                                         | Rs. 2,96,615                                                      |

Total Cost savings = Rs. 16,81,765

Table : 7.6 Construction & Energy cost



| MAINTENANCE COST ANALYSIS                  |                                                                   |                                                          |                                                |
|--------------------------------------------|-------------------------------------------------------------------|----------------------------------------------------------|------------------------------------------------|
| CRITERIA                                   | SPECIFICATIONS                                                    | BASE CASE                                                | PROPOSED CASE                                  |
| CONSTRUCTION COST                          | Wall Material                                                     | Brick                                                    | AAC Block                                      |
|                                            | Cost for painting (1 time)                                        | 252sqm @ Rs. 65/ sqm Rs.16,272                           | 252sqm @ Rs. 65/sqm Rs.16,272                  |
|                                            | Total cost for painting (every 5 years) in a period of 30 years   | Rs. 81,360                                               | Rs. 81,360                                     |
| HEATING COST                               | Water heating for domestic use                                    | Geyser - 15 litres (3 nos/house)                         | Solar Water Heater (6 nos/ tower)              |
|                                            | Maintenance Frequency                                             | Every 5 years                                            | Every 5 years                                  |
|                                            | Maintenance (labour charge) + Replacement Cost                    | Replacement of heating coil - (Rs.2000/ coil) Rs. 36,000 | Geyser + solar water heater charges Rs. 13,000 |
|                                            | Total cost for heating maintenance for a period of 30 years       | Rs. 36,000                                               | Rs. 13,000                                     |
| SPACE COOLING                              | Cooling Technique                                                 | Air conditioning Split AC unit 1.5 ton (2 nos/ house)    | Fans (5 nos/ house)                            |
|                                            | Maintenance Frequency                                             | Every year                                               | Not required                                   |
|                                            | Maintenance Cost (Rs. 2000/ unit/ year)                           | Rs. 1,20,000                                             | Nil                                            |
|                                            | Replacement Frequency                                             | Every 10 years                                           | Every 15 years                                 |
|                                            | Replacement + Installation Cost                                   | Rs. 160000                                               | Rs. 7500                                       |
|                                            | Total cost for space cooling maintenance for a period of 30 years | Rs. 2,80,000                                             | Rs. 7500                                       |
| LIGHTING                                   | Energy Consumption                                                | Electricity                                              | Solar Power                                    |
|                                            | No of Lights                                                      | 5 Tube lights (40w) 5 CFL Bulbs (25w)                    | 5 LED Tube lights (30w) 5 LED Bulbs (10w)      |
|                                            | Replacement Frequency                                             | Every 2 years                                            | Every 5 years                                  |
|                                            | Replacement Cost                                                  | Rs. 21000                                                | Rs. 16,500                                     |
|                                            | Total cost for lighting for a period of 30 years                  | Rs. 21,000                                               | Rs. 16,500                                     |
| TOTAL COST for 1 MAINTENANCE & REPLACEMENT |                                                                   | Rs. 1,07,672                                             | Rs. 29,522                                     |
| TOTAL COST for 30 YRS                      |                                                                   | Rs. 4,18,360                                             | Rs. 1,18,360                                   |

Total Cost savings = Rs. 3,00,000

Table : 7.7 Maintenance cost

Major cost reduction in the proposed case is noted in energy consumption and maintenance charges by the usage of solar power and natural ventilation.

## 7.8 IGBC CERTIFICATION :

| IGBC GREEN HOMES VERSION 3.0 |                                                 |             |
|------------------------------|-------------------------------------------------|-------------|
| SUSTAINABLE DESIGN           | CRITERIA                                        | POINTS - 20 |
| SD Credit 1                  | Natural Topography & Vegetation                 | 4           |
| SD Credit 2                  | Heat Island Effect, Roof & Non roof             | 3           |
| SD Credit 3                  | Passive Architecture                            | 2           |
| SD Credit 4                  | Universal Design                                | 2           |
| SD Credit 5                  | Green Parking Facility                          | 1           |
| SD Credit 6                  | Access to Amenities                             | 2           |
| SD Credit 7                  | Basic Facilities for Construction Workforce     | -           |
| SD Credit 8                  | Green Education & Awareness                     | -           |
| ACHIEVED SD CREDIT POINTS    |                                                 | 14          |
| WATER CONSERVATION           | CRITERIA                                        | POINTS - 23 |
| WC Credit 1                  | Water Efficient Plumbing Fixtures               | 6           |
| WC Credit 2                  | Landscape Design                                | 3           |
| WC Credit 3                  | Management of Irrigation System                 | -           |
| WC Credit 4                  | Recycle & Reuse of Waste water                  | 4           |
| WC Credit 5                  | Water Quality                                   | 1           |
| WC Credit 6                  | Enhanced Rainwater Harvesting                   | 4           |
| WC Credit 7                  | Water Metering                                  | 3           |
| ACHIEVED WC CREDIT POINTS    |                                                 | 21          |
| ENERGY EFFICIENCY            | CRITERIA                                        | POINTS - 20 |
| EE Credit 1                  | Enhanced Energy Performance                     | 10          |
| EE Credit 2                  | Alternate Water Heating system                  | 3           |
| EE Credit 3                  | On-site Renewable Energy - Common area Lighting | 4           |
| EE Credit 4                  | Energy efficiency in common area equipment      | 1           |
| EE Credit 5                  | Integrated Energy Monitoring System             | -           |
| ACHIEVED EE CREDIT POINTS    |                                                 | 18          |

| MATERIALS & RESOURCES        | CRITERIA                                    | POINTS - 18 |
|------------------------------|---------------------------------------------|-------------|
| MR Credit 1                  | Green Procurement Policy                    | 1           |
| MR Credit 2                  | Optimisation on Structural Design           | -           |
| MR Credit 3                  | Certified Green Products                    | 5           |
| MR Credit 4                  | Local Materials                             | 2           |
| MR Credit 5                  | Eco friendly wood based materials           | 2           |
| MR Credit 6                  | Alternative Construction Material           | -           |
| MR Credit 7                  | Handling of Construction & Demolition Waste | -           |
| MR Credit 8                  | Organic Waste treatment Post Occupancy      | 3           |
| ACHIEVED MR CREDIT POINTS    |                                             | 14          |
| RESIDENT HEALTH & WELL BEING | CRITERIA                                    | POINTS - 14 |
| RHW Credit 1                 | Enhanced Daylighting                        | 2           |
| RHW Credit 2                 | Enhanced Ventilation Design                 | 2           |
| RHW Credit 3                 | Cross Ventilation                           | 4           |
| RHW Credit 4                 | Connectivity to Exteriors                   | 2           |
| RHW Credit 5                 | Low VOC Materials, Paints & Adhesives       | 2           |
| RHW Credit 6                 | Facility for Physical Wellbeing             | 2           |
| ACHIEVED RHW CREDIT POINTS   |                                             | 14          |
| INNOVATION & DESIGN          | CRITERIA                                    | POINTS - 5  |
| ID Credit 1.1-1.2            | Innovation                                  | 2           |
| ID Credit 2.1 2.2            | Exemplary Performance                       | -           |
| ID Credit 3                  | IGBC Accredited Professional                | -           |
| ACHIEVED ID CREDIT POINTS    |                                             | 2           |

Total achieved IGBC credits  
= 82 points

Certification Level  
Platinum

| Certification Level | Points   | Recognition             |
|---------------------|----------|-------------------------|
| Certified           | 50 - 59  | Best Practices          |
| Silver              | 60 - 69  | Outstanding Performance |
| Gold                | 70 - 79  | National Excellence     |
| Platinum            | 80 - 100 | Global Leadership       |

Table : 7.8 IGBC Credit points