

SUSTAINABLE YOUTH CENTER USING SHIPPING CONTAINERS

A Thesis

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

by

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**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 2022



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BONAFIDE CERTIFICATE

This is to certify that this Report is the bonafide work of **OVIYA K (40890012)** who carried out the Thesis entitled "**SUSTAINABLE YOUTH CENTER – USING SHIPPING CONTAINERS**" under our supervision from January 2022 to May 2022.

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I **OVIYA K** hereby declare that the Thesis Report entitled “**SUSTAINABLE YOUTH CENTER - USING SHIPPING CONTAINERS**” is done by me under the guidance of **Ar. ARUL MALAR** (Internal) and **Ar. R. BALAMURUGAN** (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: 06.05.2022

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ABSTRACT

Current trends in the construction sector are responsible for the majority of CO₂ emissions in India. Sustainable methods to reduce CO₂ emissions should include not just recycling but upcycling materials, for instance – shipping containers. Despite the industry's best efforts to minimize waste, millions of shipping containers end up in scrap every year. This can be effectively reduced by reusing them as alternate building materials. The trend of reusing shipping containers as building materials is at its peak in Western countries, while it's still an emerging notion in India. This thesis aims to design an energy efficient sustainable shipping container youth center in a warm humid climate. The study includes a literature review of shipping containers buildings; comparing and evaluating the thermal performance of base case conventional building and proposed shipping container building through Opaque and Design builder simulation. The results were obtained by comparing and assessing the thermal performance and life cycle cost of base case brick building and proposed shipping container building. This study is aimed at helping architects reuse shipping containers as a sustainable alternative building material in warm humid regions

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LIST OF SYMBOLS AND ABBREVIATIONS

UDI	-	Useful Daylight Illuminance
ASE	-	Annual Solar Exposure
STP	-	Sewage Treatment Plant
ECBC	-	Energy Conservation Building Code
IS	-	Indian Standards
WWR	-	Window Wall Ratio
ROI	-	Rate Of Interest
LCC	-	Life Cycle Cost
CMDA	-	Central Metropolitan Development Authority
RH	-	Relative Humidity
DBT	-	Dry Bulb Temperature
HLFF	-	Heat Loss Form Factor
EA	-	Envelope Area
NFA	-	Net Floor Area
SVR	-	Surface to Volume Ratio
RWH	-	Rainwater Harvesting

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

A youth centre, also known as a youth club, is a multipurpose facility where young people can congregate and engage in a variety of activities such as social, educational, and recreational events. Parks and green spaces, for example, are important built environment features inside neighbourhoods for fostering a range of physical activities. These spaces are frequently designed with children (under the age of 12) and adults (over the age of 25) in mind, with an emphasis on a small playground for children and seats for adults to sit and watch over their children. Teenagers use public spaces more than anybody else, yet most often, young adults aged 12 to 25 are excluded from the process of place-making and end up loitering in other places. As a result, the availability of these unique youth centres generates an attractive factor. Some people may regard these activity centres as a fun and stress-relieving place. These activities do, in fact, encourage them to participate in physical activities, as well as promote an active lifestyle. This idea would stimulate and build a healthy generation of young people, not only physically, but also psychologically and socially. This idea also promotes social cohesion among kids from diverse backgrounds.

1.2 AIM

To design a Sustainable Youth center, utilizing upcycled shipping containers in a warm-humid climate.

1.3 OBJECTIVE

- To understand from actual case examples how containers are arranged, staggered, and converted into habitable spaces.
- To create a sustainable, safe, and thoughtful environment for younger generation to enhance their physiological, psychological, and emotional health and well-being.
- To design and analyze the performance of a climate responsive, energy efficient shipping container youth center.
- To implement innovative design strategies to make the interior of a shipping container building more engaging, liveable, and creative, similar to the interior of a conventional building.

1.4 SCOPE

The market demand for recycled materials has shifted from niche to mainstream. The idea of recycling shipping containers can reduce the need to extract and process new raw materials; while also minimizing scrap metal waste. To create awareness on how

container buildings can be a better cost-effective and environmentally sustainable alternative to conventional construction materials.

1.5 LIMITATION

- As this design is limited to spaces that can be accommodated within shipping containers, other facilities, such as a sports complex, will be constructed as a composite structure.
- To some extent, this design is limited towards the integration of a youth and recreation centre.
- This design solely incorporates climate-responsive strategies for warm humid climates.

CHAPTER 2 LITERATURE REVIEW

2.1 YOUTH

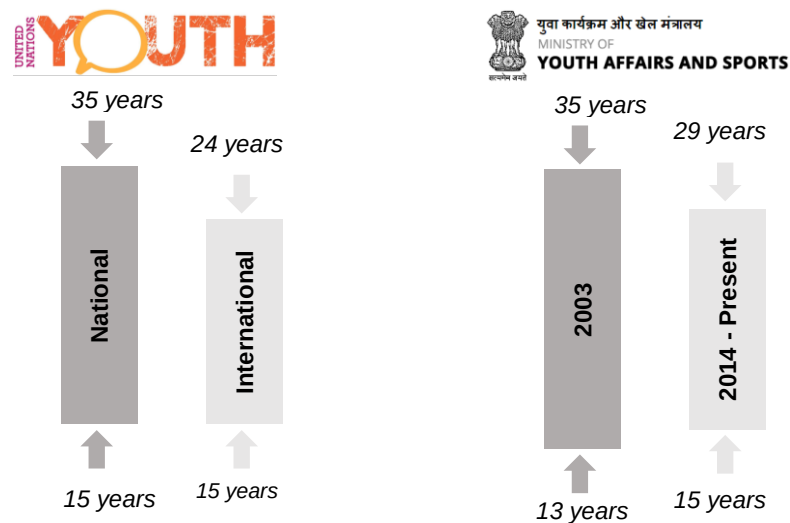


Fig 2.1 Youth age categorization

2.2 NEED FOR THE CENTER

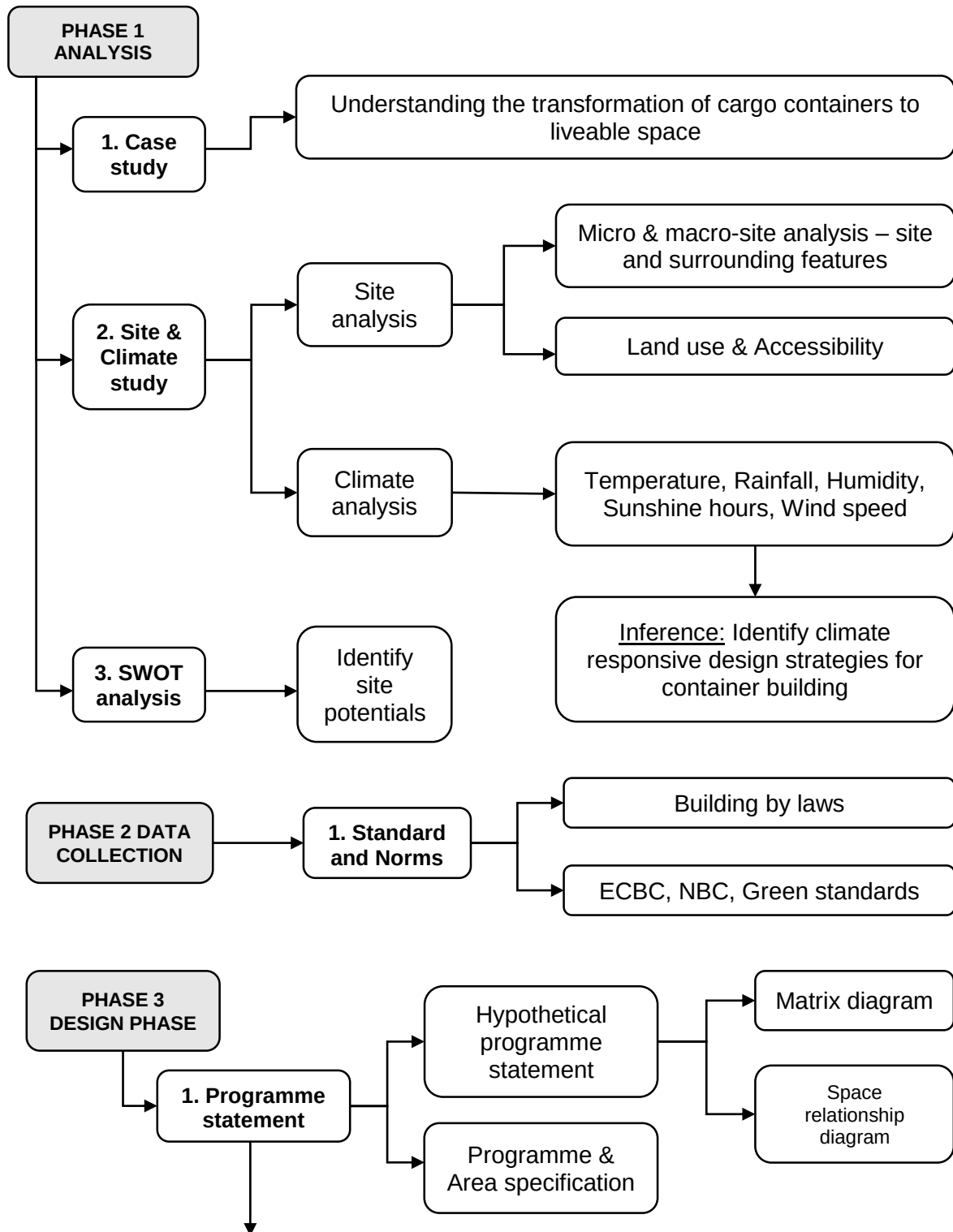
India now has the largest adolescent and youth population in its antiquity. According to Census 2011, India's youth population is expected to be 34.33 % (450 million) by 2020 [1]. Access to education, gainful employment, gender inequality, child marriage, and youth-friendly health services are some of the development challenges confronting India's youth [2]. These past incidents, attitudes, and perspectives have a negative impact on one's physical and emotional well-being. Youth Centers are supporting environments that foster a sense of belonging, promote well-being, and have a positive impact on the youth of the country.

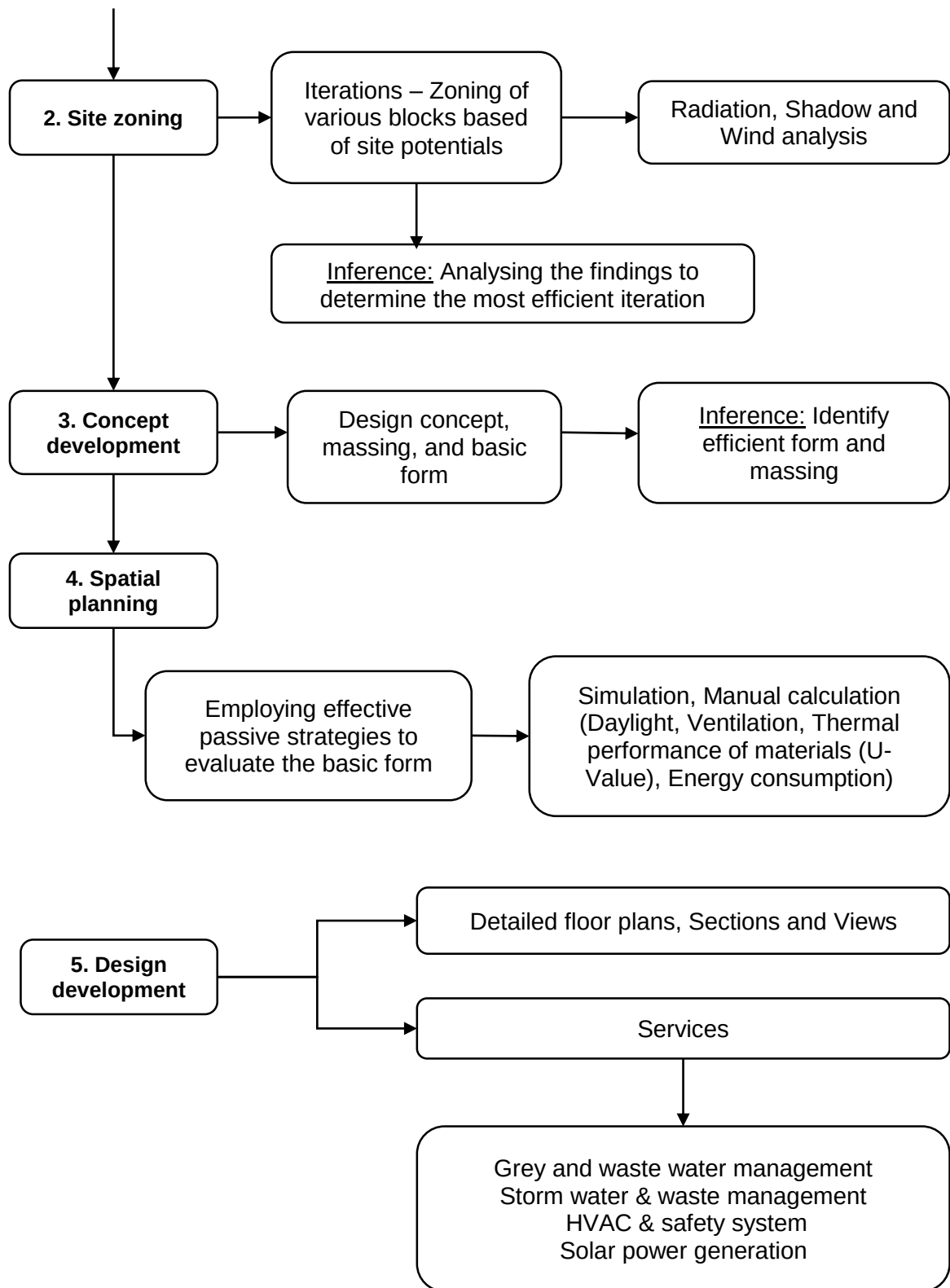
2.3 ISSUES FACED BY THE YOUTH



Fig 2.2 Issues faced by the youth

CHAPTER 3 METHODOLOGY





CHAPTER 4

CASE STUDY AND ANALYSIS

4.1 START-UP VILLAGE, AMSTERDAM, NETHERLANDS [3]

4.1.1 PROJECT FACT FILE

- **Location:** Amsterdam, The Netherlands
- **Year:** 2019
- **Architects:** Julium Taminiau Architects
- **Site area:** 2000m²
- **No. of containers used:** Total - 73 Shipping containers (40 (20' containers), 23 (40' containers))
- **Purpose:** Office space for start-ups
- **Climate:** Temperate climate
- **No. of floors:** 2-3 floors maximum



Fig 4.1 3D view of start-up village

4.1.2 INTRODUCTION

Startup Village was designed like a village. The upcycled container offices are placed around a big communal square which could be used for big open-air events. There is a co-working space at the beginning of the square, with “streets” next to it leading to the square.

4.1.3 ARRANGEMENT OF CONTAINERS

2.4 x 6m (small 20ft container) size of the upcycled containers are ideal for start-ups and provide affordable and lockable office space. There are also connected 20ft (4.8 x 6m) and 40 ft containers (4.8 x 12m) which could be used for scale-ups.

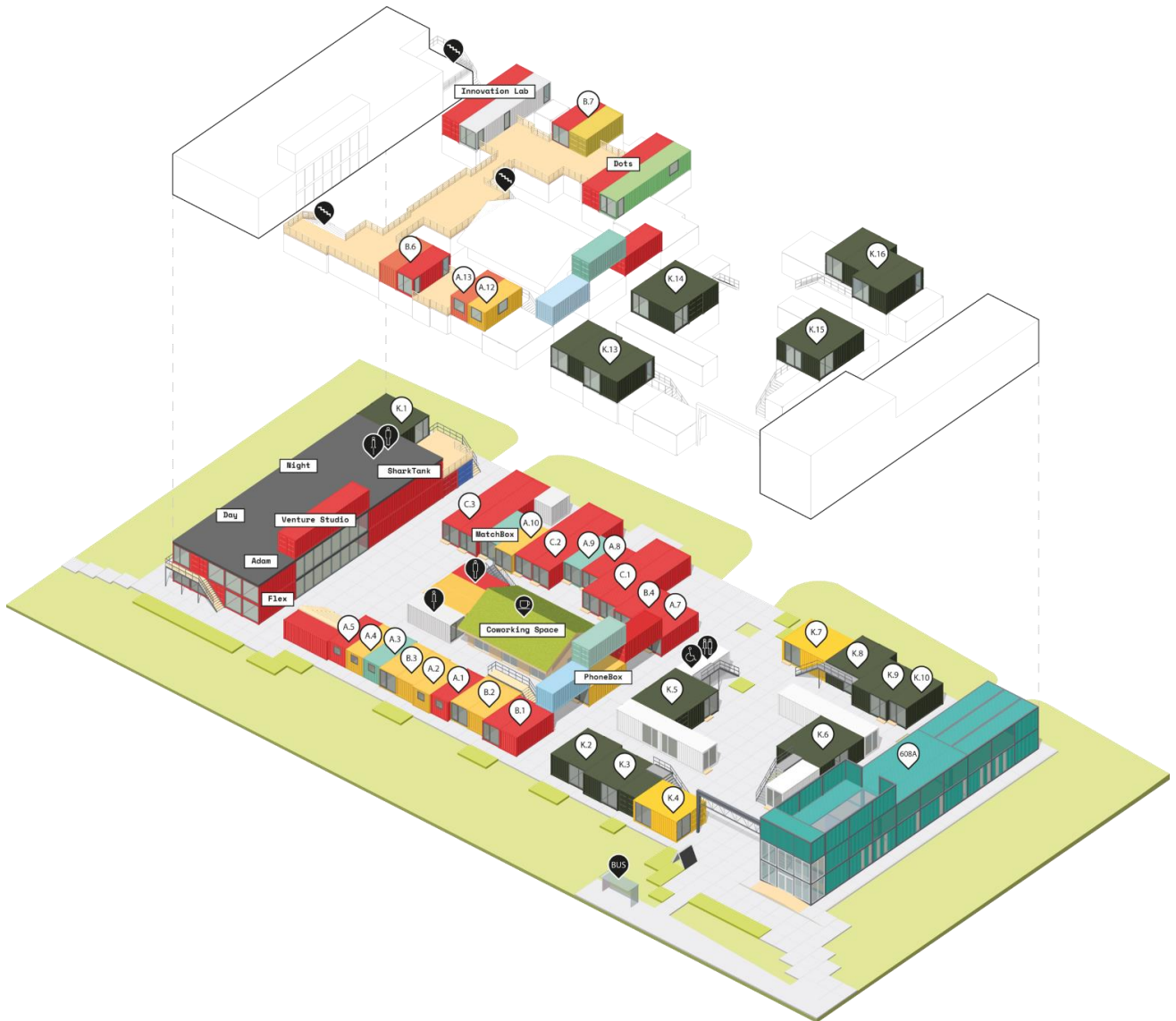


Fig 4.2 Exploded view of start-up village

4.1.4 DESIGN MODIFICATIONS MADE TO THE CONTAINERS

- There are no foundation piles, only concrete tiles on which the containers are set, so that when the village is dismantled in 10 years, everything may be reused and no trace would be left.
- Next to the Event Space there is a large set of steps (like the Spanish steps in Rome) which can be used as a communal space and for open-air lectures.



Fig 4.3 No foundation piles

- Coffee shops and meeting rooms housed in brightly coloured containers add to the "encounters and engagement," while wooden walkways and steps connect several levels of the village's paths.



Fig 4.4 Bright coloured space



Fig 4.5 High percentage of glazing

- The containers will feature a high percentage of glazing in relation to floor space and will be significantly brighter than "normal" workplaces.
- The windows are made of hardwood on the outside and softwood on the interior.
- To maintain warmth in the winter, these containers are insulated, locked, and well-sealed, with low-energy infrared heating.

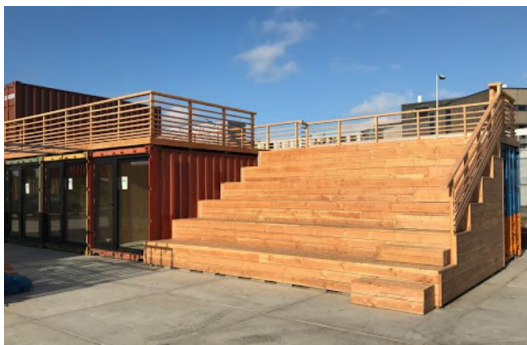


Fig 4.6 Wooden walkways



Fig 4.7 Green roof as insulation

- During the summer, windows are placed on each side of the container to enable fresh air to flow through.
- Greenery covers the containers and their surroundings to help keep them cool in the summer, while the foliage on the roof also serves as a rainwater barrier and air filter.

4.2 CONTAINER PARK, BORNOVA, TURKEY [4]

4.2.1 PROJECT FACT FILE

- **Location:** Bornova, Turkey
- **Year:** 2015
- **Architects:** ATOYLE Architects
- **Site area:** 1000m²
- **No. of containers used:** 35 repurposed second-hand Shipping containers
- **Purpose:** Techno park facility
- **Climate:** Temperate climate
- **No. of floors:** 2 floors maximum

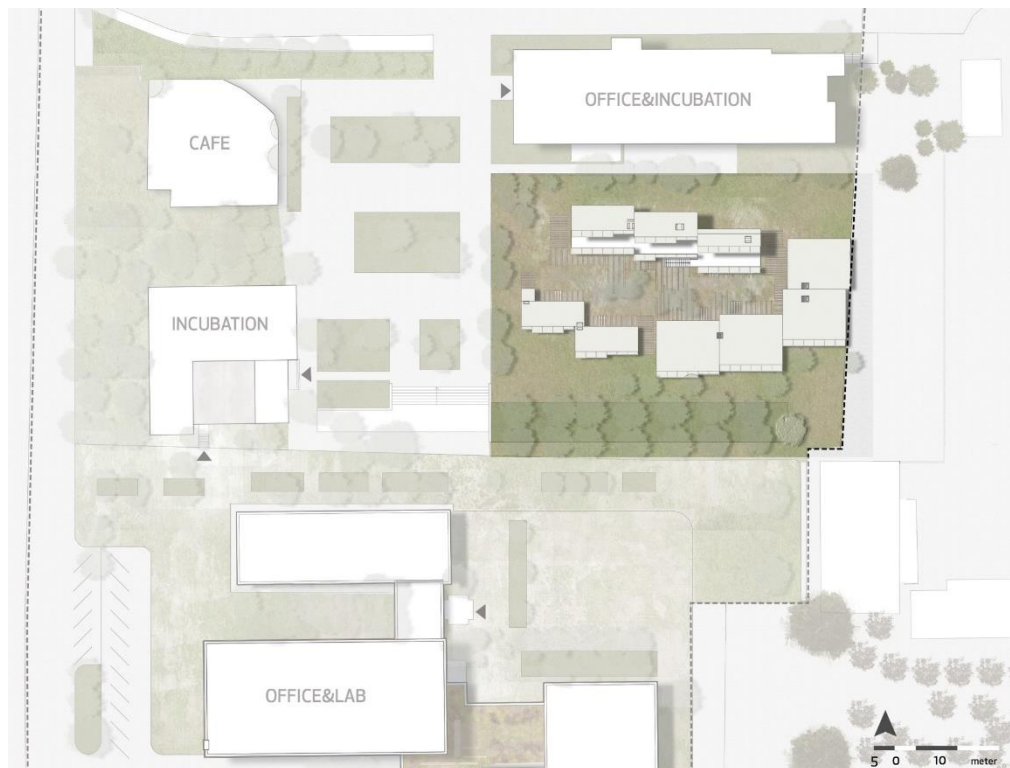


Fig 4.8 Site plan of Container Park

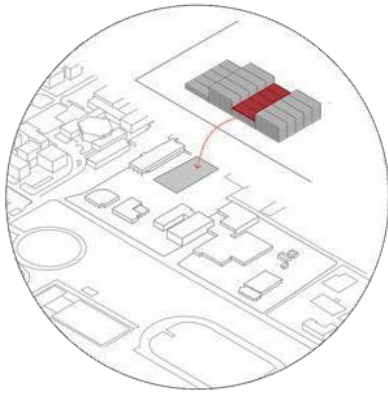
4.2.2 INTRODUCTION

The project's need was the creation of a space that houses office and laboratory units to be rented out as well as a mobile structure to be moved to different locations as needed.

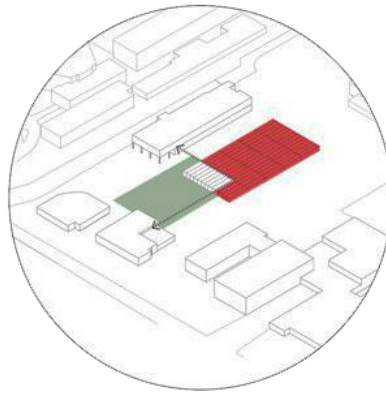
The resultant project repurposes 35 used shipping containers to serve as the heart of a new, lively research community on campus, as well as a creative magnet for talent in Ege University. The 1000m² techno-park will host independent R&D facilities of major Turkish and international companies specializing in biology, energy, materials, and software development.

4.2.3 DESIGN MODIFICATIONS MADE TO THE CONTAINERS

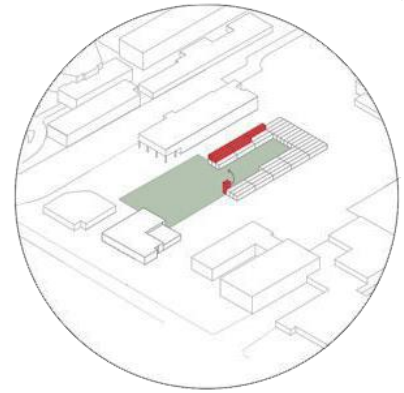
- By placing container modules with maximum north-south exposure and narrow cross sections, the design maximized the ability to use passive solar strategies coupled with natural ventilation.



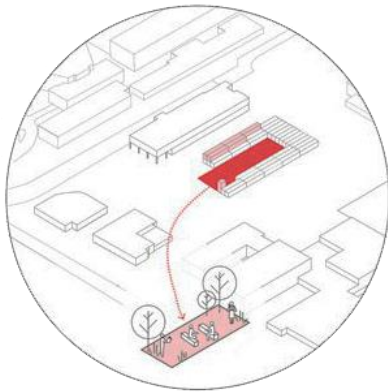
By **repurposing locally available containers**, the team was able to upcycle an underused site with underused materials



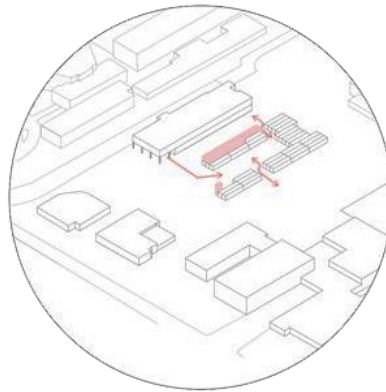
Engaging the site with its existing context, as well as addressing neighbouring buildings and sites



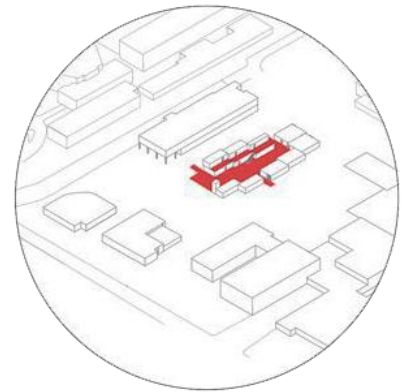
Stacking containers to generate volumetric dynamics and views, as well as to extend building areas.



Inner courtyards, corridors, and ample seating areas provide areas for solitude and retreat.



Cross-circulation corridors are introduced to enhance serendipity.



As a prototype, the **project becomes a manifestation** of a building.

Fig 4.9 Design implementation

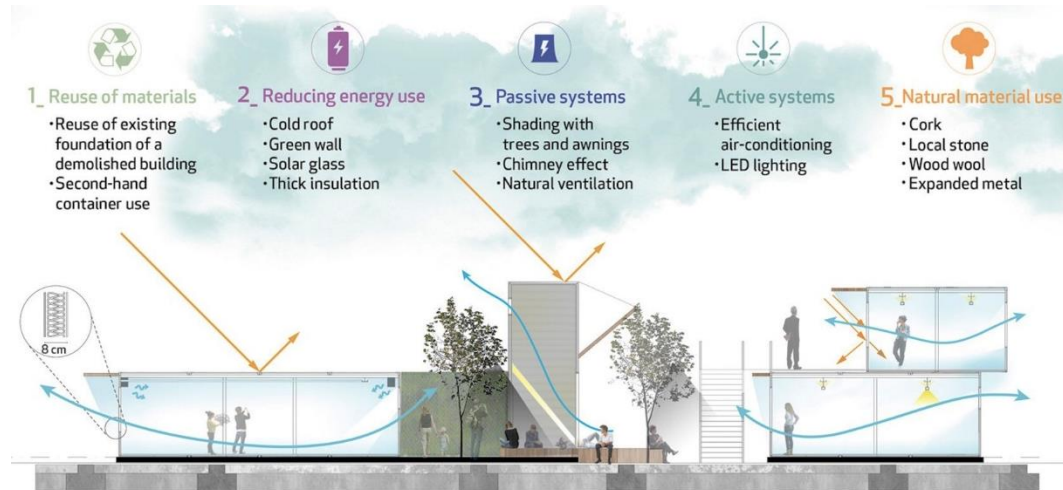


Fig 4.10 Utilizing site features

- Existing trees, well-designed shading devices, solar-coated southern windows, high insulation, efficient air conditioning, natural materials such as cork, and LED lighting systems all contributed to the building's low environmental impact.
- Given that a core & shell building's adaptability and resilience are its most valuable assets in the long run, the project includes numerous technical details such as
 - Exposed beams and columns,
 - Visible electrical trays,
 - Abundant plugs,
 - High-capacity ventilation,
 - Locally controllable heating-cooling systems, and
 - Supporting sub-structure to aid build separators in the future.

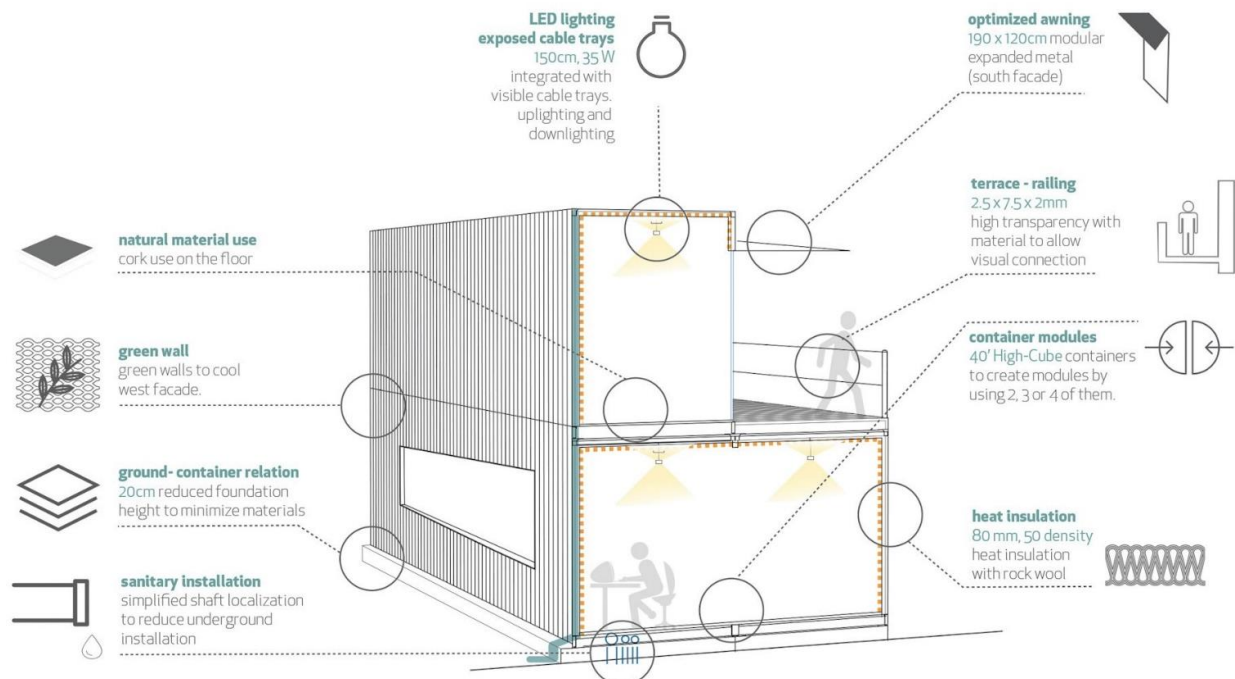


Fig 4.11 Energy efficient features

4.3 CONTAINER BLOCK, HAOJIAN, CHINA [5]

4.3.1 PROJECT FACT FILE

- **Location:** Haojian, China
- **Year:** 2019
- **Architects:** BA Studio, Bounds
- **Site area:** 2100m²
- **No. of containers used:** 87 (40 feet) Shipping containers
- **Purpose:** Commercial block
- **Climate:** Temperate climate
- **No. of floors:** 2 floors maximum

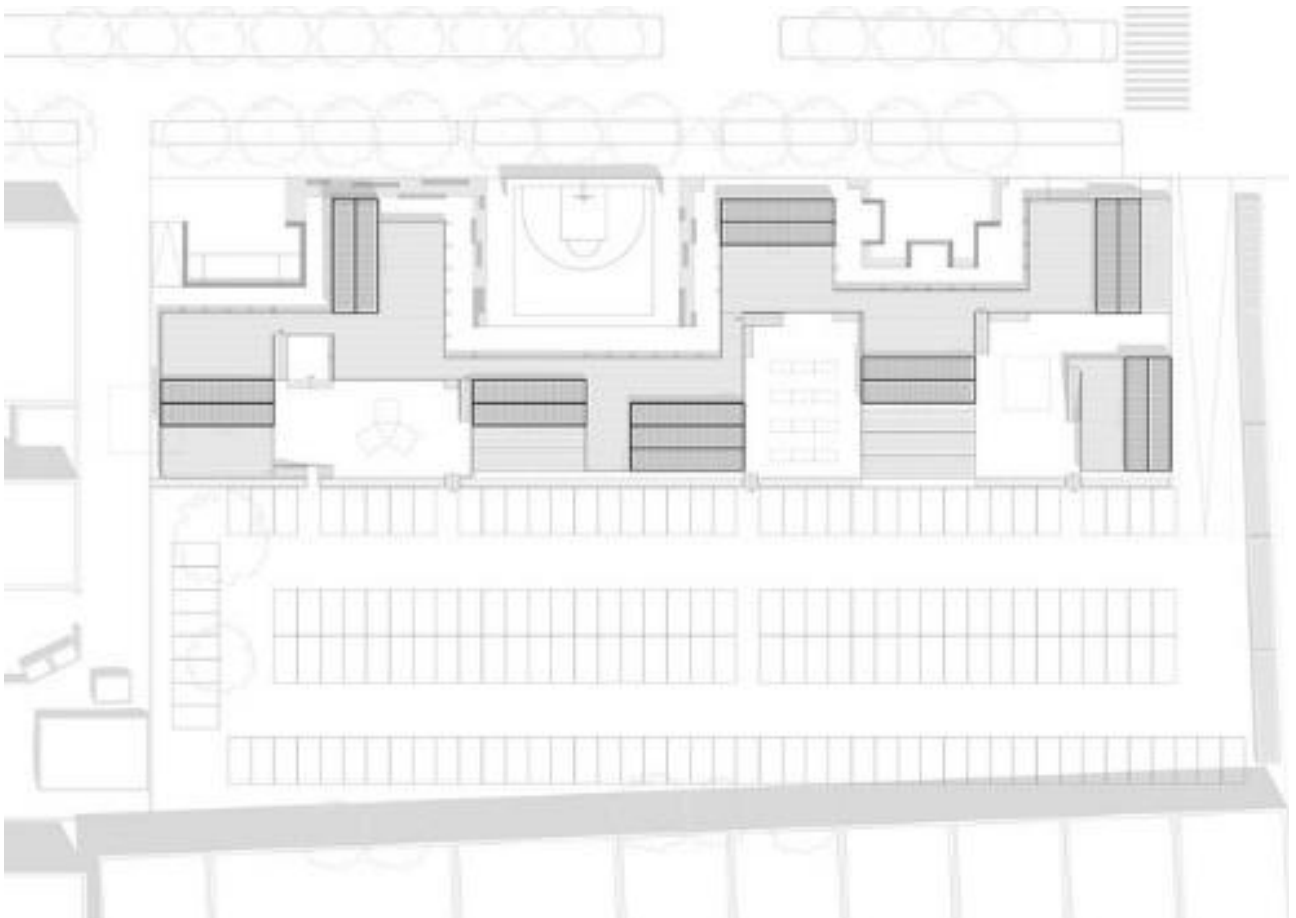


Fig 4.12 Site plan of container village block

4.3.2 INTRODUCTION

This one-of-a-kind creation arose from the long-running conflict between city and urban village, which used to favour one side. Arguments on the other side, such as those concerning urban fabrics, social rights, cultural variety, and so on, have just recently gained public recognition.

4.3.3 DESIGN MODIFICATIONS MADE TO THE CONTAINERS

- A unit is a 12m12m square block made out of 5 aligned shipping containers (12 x 2.4 x 2.9m) on the bottom floor and 2-3 on the upper level.
- Six stairway and a corridor connect the second-floor terraces to the ground-floor open areas.

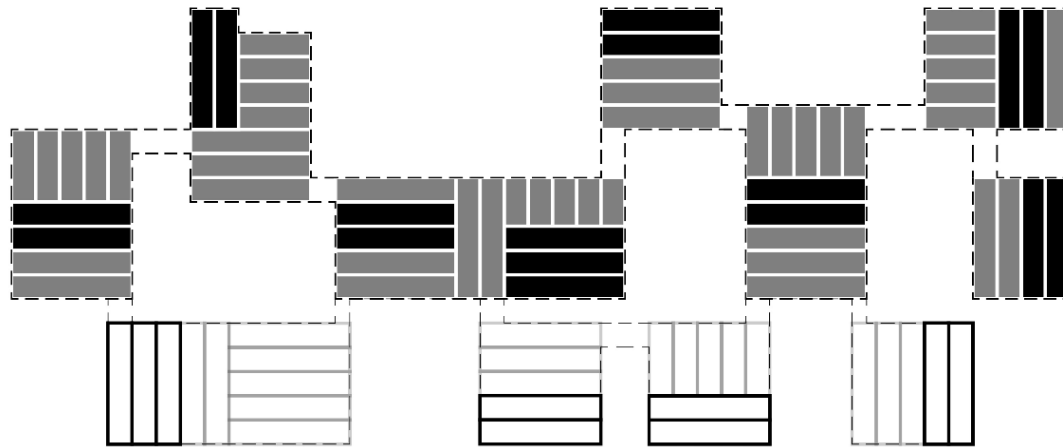


Fig 4.13 Basic arrangement of container blocks



Fig 4.14 Design of container blocks

4.4 INFINITY SCHOOL, POP-UP SCHOOL, SHENZHEN, CHINA [6]

4.4.1 PROJECT FACT FILE

- **Location:** Shenzhen, China
- **Year:** 2019
- **Architects:** Cross-boundaries
- **Site area:** 325m²
- **No. of containers used:** 12 Shipping containers
- **Purpose:** School
- **Climate:** Temperate climate
- **No. of floors:** 2 floors maximum

4.4.2 INTRODUCTION

The group exhibit includes five installations in total, each of which makes use of the standard shipping container module provided by the organizers. This concept pervades their vision of the future, in which school expands outside its boundaries to become an open, collaborative place.



Fig 4.15 Site plan of school

4.4.3 ARRANGEMENT OF CONTAINERS

- Cross boundaries' installation, dubbed "INFINITY 6," takes the form of an interlocking "X" on an 18x18m space.
- The "X" design provides plazas of varying sizes and moods, and the entire structure is open and welcome from any angle.

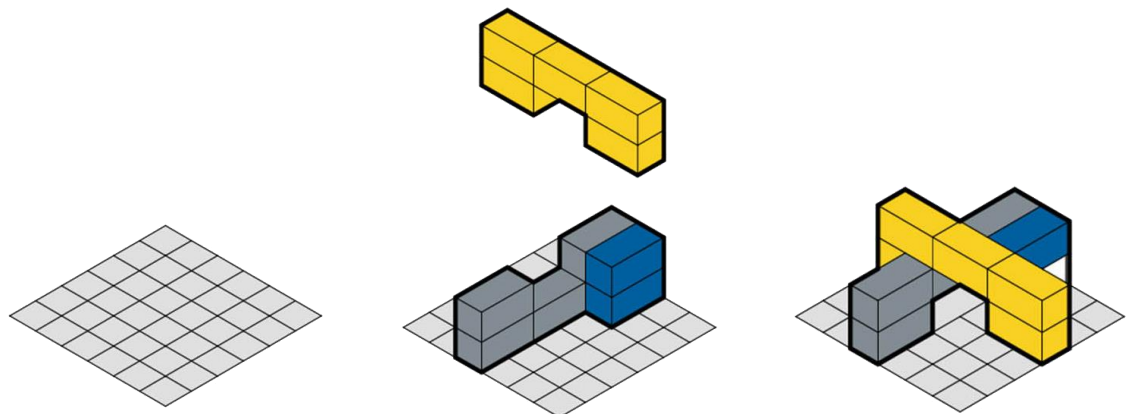


Fig 4.16 Stacking stages

4.4.4 DESIGN MODIFICATIONS MADE TO THE CONTAINERS

- Even a tiny effort to add texture and colour to the sensory palette of the school's outside and interior, along with children's boundless creativity, may dramatically broaden and enrich daily learning experiences.
- Generous openings on the building's façade can help to connect the school with its surroundings by allowing insights into the school's inner life and framing fascinating city vistas.
- The windows can play a larger role by creating mini reading nooks that participate in the new dynamic manner learning can take place outside of the classroom.



Fig 4.17 Rich colourful textures



Fig 4.18 Open floor plan

- The gathering plaza has "hang out stairs," the private plaza is more enclosed, the in-and-out concept is represented by a tiny porch that leads to a more open play area, and texture is given to the sport plaza.
- The structure itself exhibits the generous openings and semi-open corridors, as well as an exhibition of some of our proven school projects that elaborates on all the ways in which future schools might become smart.



Fig 4.19 Hangout stairs

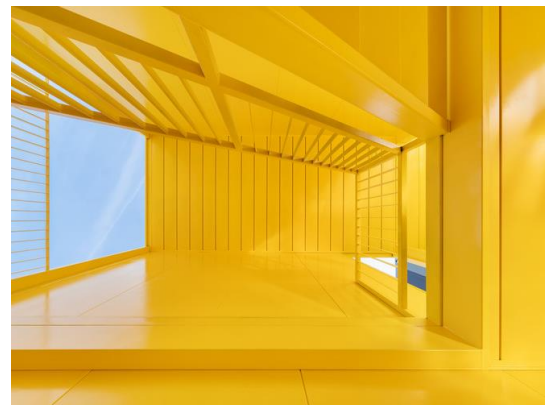


Fig 4.20 Interior reading corner

4.5 DOCK 45, HYDERABAD, INDIA [7]

4.5.1 PROJECT FACT FILE

- **Location:** Hyderabad, India
- **Year:** 2017
- **Architects:** Spacefiction studios
- **Site area:** 910m²
- **No. of containers used:** 8 Shipping containers, 5 (20' containers), 3 (40' containers)
- **Purpose:** Restaurant
- **Climate:** Composite climate
- **No. of floors:** 2 floors maximum

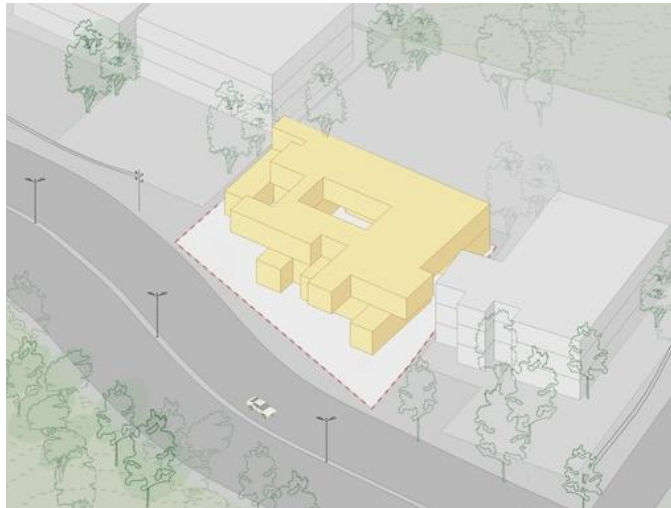


Fig 4.21 Site plan of dock 45 restaurant

4.5.2 INTRODUCTION

The client wanted a nautical motif throughout the place, from the cuisine to the architecture. Although acceptable, the concept of container architecture provided a fascinating challenge: is it feasible to create an expression that offers the appearance of container architecture; equally engaging; and without any of its flaws.

4.5.3 ARRANGEMENT OF CONTAINERS

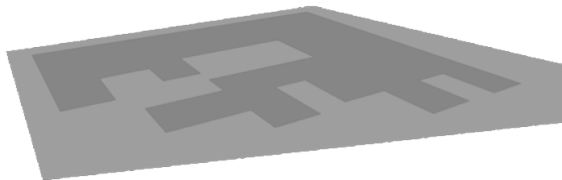


Fig 4.22 Preparing the Site

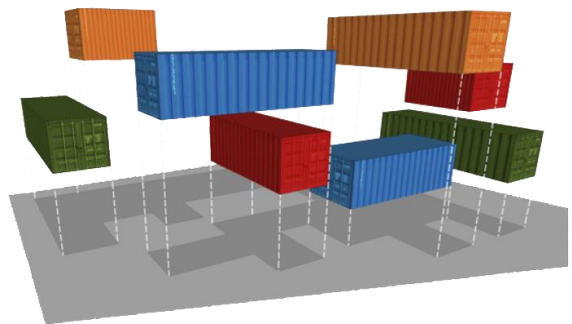


Fig 4.23 Placing of containers

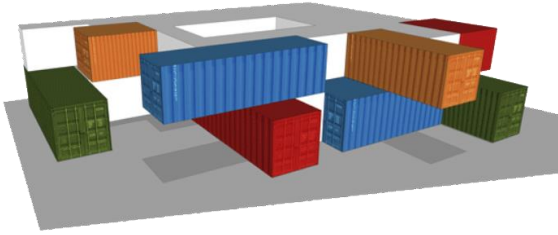


Fig 4.24 Connecting the containers



Fig 4.25 Creating openings

- Upon entering, the dual nature completely takes the user by surprise, with the expression of solid containers on the exterior progressively disappearing and one being welcomed by a huge, open to sky volume.
- In crucial locations, nautical shapes are imprinted on the cement flooring. A turtle, mollusk, sea-horse, and a fish fossil break up the monotony of the concrete floor's wide length.
- These white walls are drenched with recessed, automatic lights that progressively change the colour of the space.



Fig 4.26 Ground floor plan



Fig 4.27 First floor plan

4.5.4 DESIGN MODIFICATIONS MADE TO THE CONTAINERS

- The metal sheets are painted in dull yellow, red, blue, and green tones.
- Container doors that have been fabricated and graffitied over by local artists give them the appearance of actual containers.
- Most of the areas are visible from the stage on the first floor.
- One of the two sets of stairs leading to the first level is a single flight, folding metal plate staircase.



Fig 4.28 Interior fibre board fins



Fig 4.29 Cantilevered structure

- The walls can be seen via the enormous envelope of translucent glass that surrounds the central court.
- The interior elements are entirely genuine salvaged parts from broken ships.
- There are several windows, steam pipes, leverage hooks and chains, and, compasses, from broken ship
- All walls with a length of twenty feet or more are clad with waterproof medium density fibre board fins that have been parametrically developed to resemble sea waves.

4.6 ZERO-GRAVITY ZONE DAEBANG-DONG, SEOUL, SOUTH KOREA [8]

4.6.1 PROJECT FACT FILE

- **Location:** Seoul, South Korea
- **Year:** 2015
- **Architects:** Think Tree Architects
- **Site area:** 1640m²
- **No. of containers used:** 13 Shipping containers
- **Purpose:** Youth zone
- **Climate:** Cold climate
- **No. of floors:** 2 floors maximum



Fig 4.30 Zero-gravity zone

4.6.2 INTRODUCTION

Modern youths are troubled with worries about modern life and the issues that our society must tackle, including those about love, marriage, and human interactions. This initiative, known as the 'Seoul Youth Zone,' is a place where young people may focus on modest solutions in zero gravity, free of various constraints. This initiative provides a venue for youth activities and cultural interaction.

4.6.3 DESIGN MODIFICATIONS MADE TO THE CONTAINERS

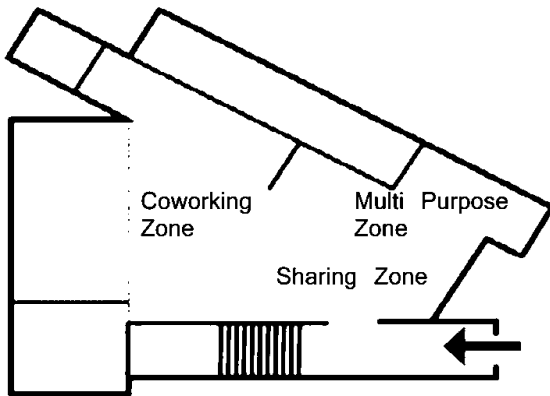


Fig 4.31 Ground floor plan

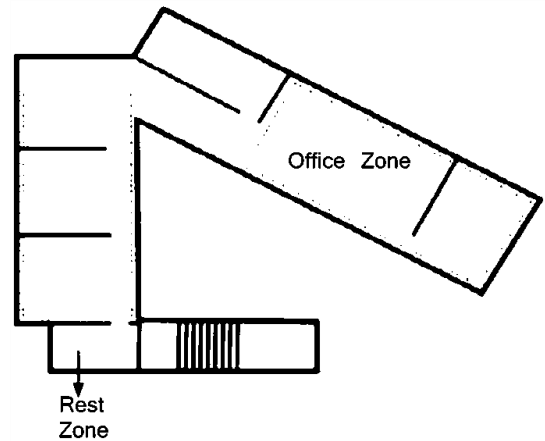


Fig 4.32 First floor plan

- The building was arranged considering conditions of the triangular shape of the building lot and the walking movement of the residents in mind, with the goal of creating a dynamic place where creativity and entrepreneurship may be seen as youth space.
- The first space created with shipping container is utilized as a mini lounge receiving natural light.
- Shipping container modules cover a central lounge space for all activities, while the interior spaces of the surrounding shipping container volumes are made up of lecture rooms, shared kitchens, bathrooms, and office spaces.



Fig 4.33 Well lit central Workspace



Fig 4.34 Expanded office area

- When visitors enter via the tilting volume, they will find on the bottom level an atrium, seminar room, and open kitchen, where they may find space for rest, events, communication, and education.
- When the folding glass door is opened, the lecture room opens into the atrium.
- The two sloped sloping containers contain the stairwell and display space.
- The office and seminar rooms were expanded by combining two modules.

CHAPTER 5 SUMMARY AND RESULTS

5.1 COMPARATIVE ANALYSIS OF CASE STUDIES

Table 5.1 Comparative analysis



Project Name and type	Start-up village Office space for start-ups	Container park Techno park facility	Container block Commercial block	Infinity 6 School	Dock 45 Restaurant	Zero-gravity zone Youth zone
Location	Amsterdam, Netherlands	Bornova, Turkey	Haojian, China	Shenzhen, china	Hyderabad, India	Seoul, South Korea
Site area	2000m ²	1000m ²	2100m ²	325m ²	910m ²	1640m ²
No. of containers	73	35	87	12	8	13
Type of containers	Both 20ft & 40ft shipping containers	40ft shipping containers	20ft shipping containers	20ft shipping containers	Both 20ft & 40ft shipping containers	40ft shipping containers
Architects	Julium Taminiau Architects	ATOYLE Architects	BA Studio, Bounds	Cross-boundaries	Spacefiction studios	Think Tree Architects
Year	2019	2015				
Openings	Doors and windows are added to the shorter side	Because maximum numbers of	At the corners of each container, a triangular	Openings are formed by removing a	Windows with supporting frames are fitted by	Linear windows along with supporting

A photograph of a modern building with a bright yellow facade. A grey staircase leads up to a second-floor balcony with a metal railing. The building has large glass windows and doors, and the overall design is clean and minimalist.

End to end
& vertical
arrangement
of
containers



6.1 SITE LOCATION - UNDERSTANDING THE CONTEXT

6.1 SITE LOCATION - UNDERSTANDING THE CONTEXT



Fig 6.1 Chennai in Tamil Nadu



Fig 6.2 Madhavaram in Chennai

- Located in Northern region of Chennai, Madhavaram is a planned mixed Residential zone.
- The local parks and gardens that gives relief from concrete spaces are key features in Madhavaram, which is commonly referred as an out-of-city neighbourhood in Chennai.

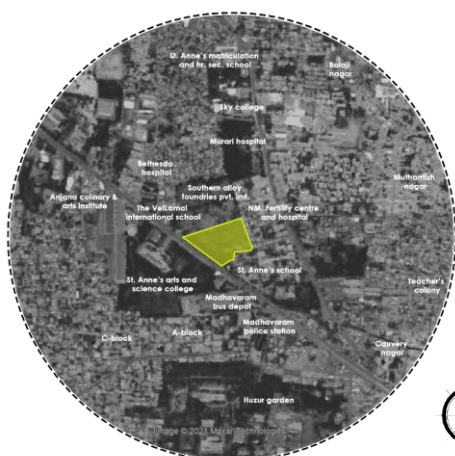


Fig 6.3 Madhavaram high road



Fig 6.4 Site location in Madhavaram

6.2 SITE JUSTIFICATION - UNDERSTANDING THE CONTEXT

PARAMETERS	SITE - MADHAVARAM
Known as	Educational hub
Site area	33,570 m ² (8.3 acres)
Land use	Institutional
Landmarks	• St. Anne's Arts and science college • St. Anne's school • St. George school • Sri Chaitanya Techno school Moolakadai
Near by educational buildings	12 schools 6 colleges & institutions
Walk-score	77
Access road	Erukkenchery high road
Distance – Nearest bus stop	Old Madhavaram bus depot – 120m
Issues	Because the site is so close to a busy road, noise may be a concern. It is necessary to create a soundproof design.

- In several regions of the Madhavaram constituency, commercial establishments are gradually taking up more land, showing indicators of growing urbanization.
- Work to enhance Red Hills Lake as a recreational place, as well as the recent completion of the phase II section of the Chennai Metro, which connects Madhavaram and CMBT, has energized people.
- The crowd is educated and well-mannered, as it is a significant hub for educational institutions such as Vruksha Vidhyaashram, Bosco Academy, and Agarsen College.
- The site has a Walk Score of 77 out of 100.

6.3 SITE EVOLUTION - MAPPING THE CHANGES

- Madhavaram has changed considerably in the last 15 years.
- In 2005, there was a sporadic settlement surrounding the site. The site was a barren place with minimal vegetation.
- In 2010, there were just shrubs and few trees on the site, and water lagging was discovered to the southwest.
- In 2015, more trees in the site area.
- 2020 - For the previous six years, there has been no clear change in site.

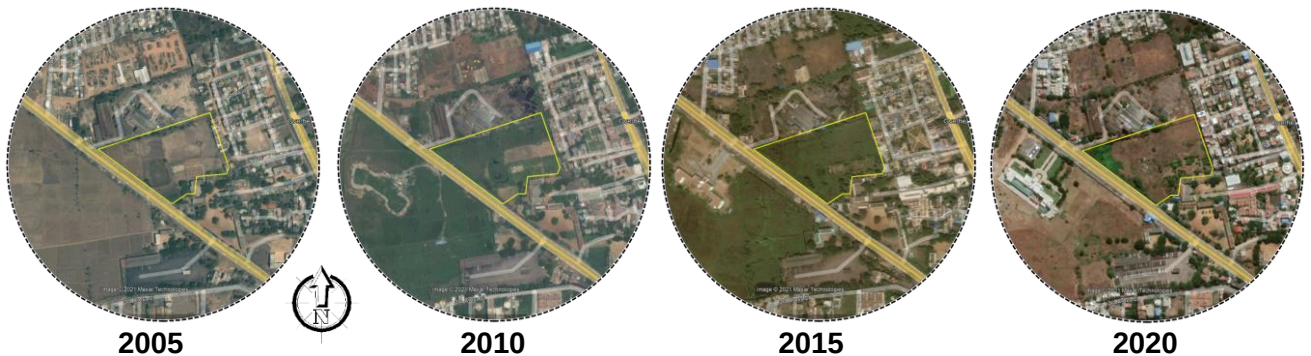


Fig 6.5 Site evolution

6.4 SURROUNDING AND INFRASTRUCTURE - CONTEXT AND CONNECTIVITY

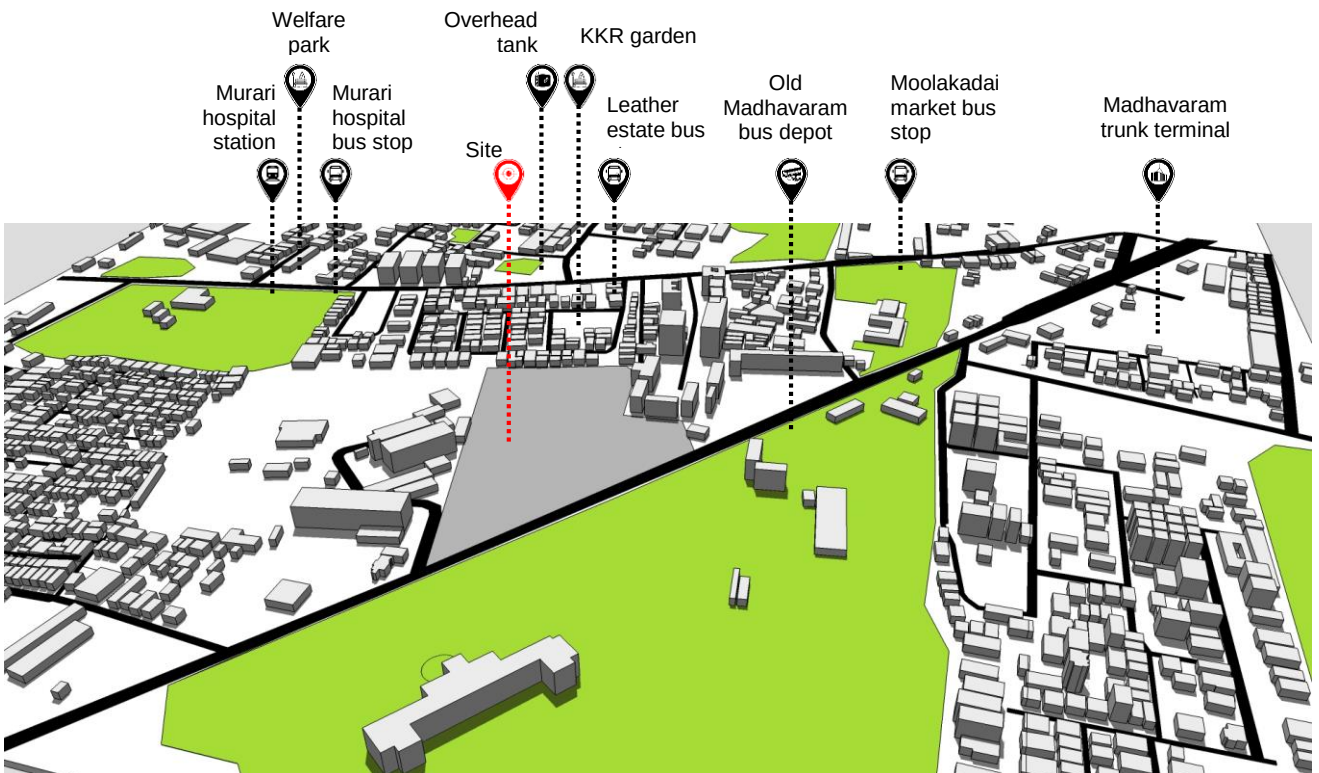


Fig 6.6 Site surrounding and infrastructure

6.5 LAND-USE & SOIL PATTERN - NEIGHBOURHOOD LEVEL

- According to the CMDA land-use map, Madhavaram has a majority of residence, mixed residential, Industrial and institutional zone.
- As per the DCR, a youth center can be constructed in a mixed residential or institutional zone.
- The land-use zone for the selected site is Institutional.

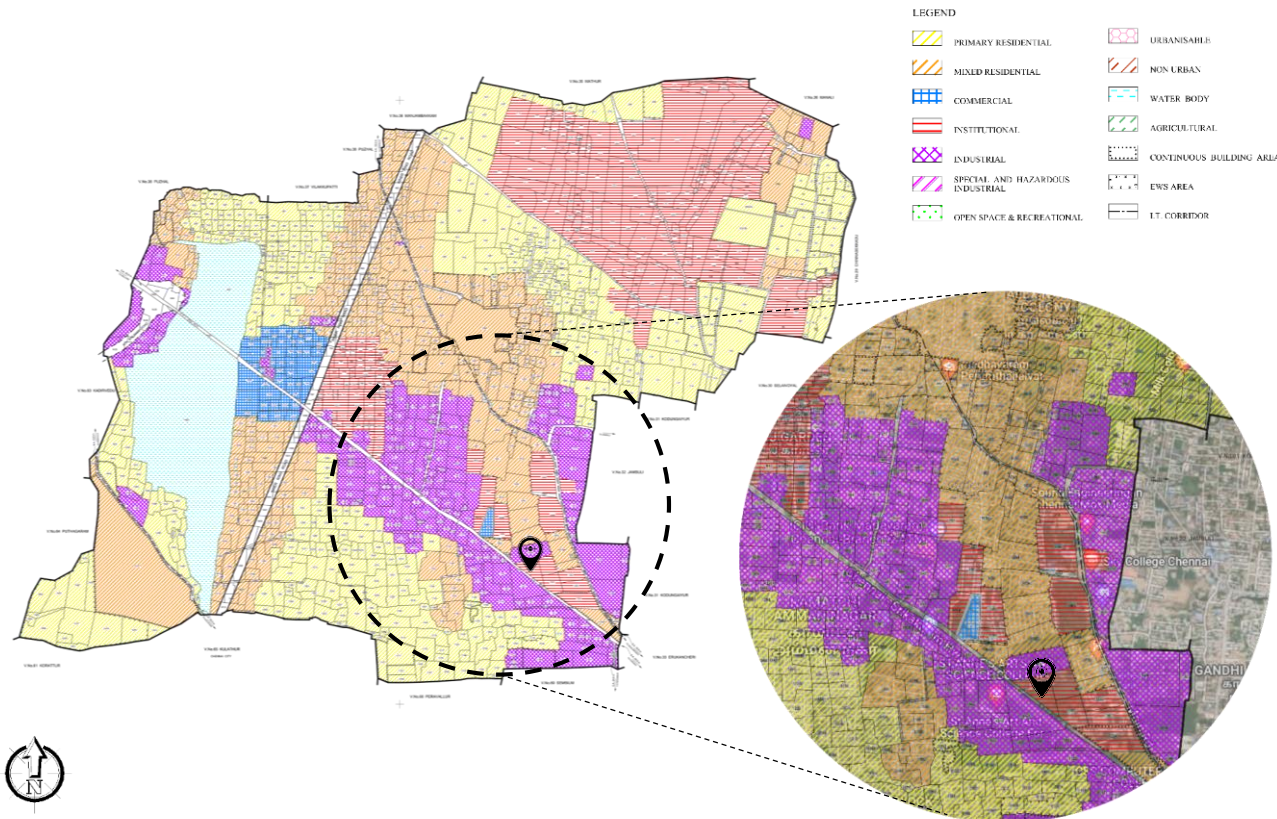


Fig 6.7 CMDA Land-use plan [9]

- Soil type – Clayey soil
- Foundation – a pier and beam foundation is best suited for clayey soil and shipping container buildings

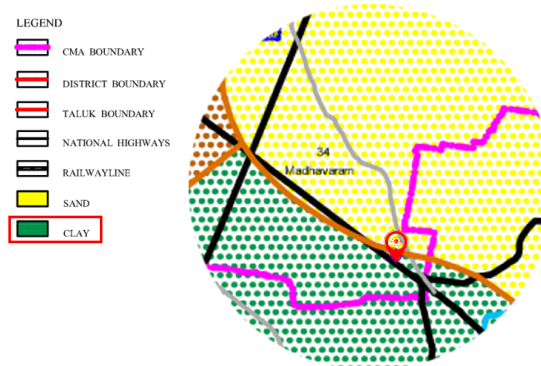


Fig 6.8 Soil map

6.6 CONTEXT PLAN - SITE AND SURROUNDINGS

- The chosen location is adjacent to the Grand Northern Trunk Road.
- St. Anne's college in the west, Southern alloy foundries in the north, residences in the east, and St. Anne's girls' higher secondary school in the south surround the site.
- The site is bounded by three shipping container storage warehouses.

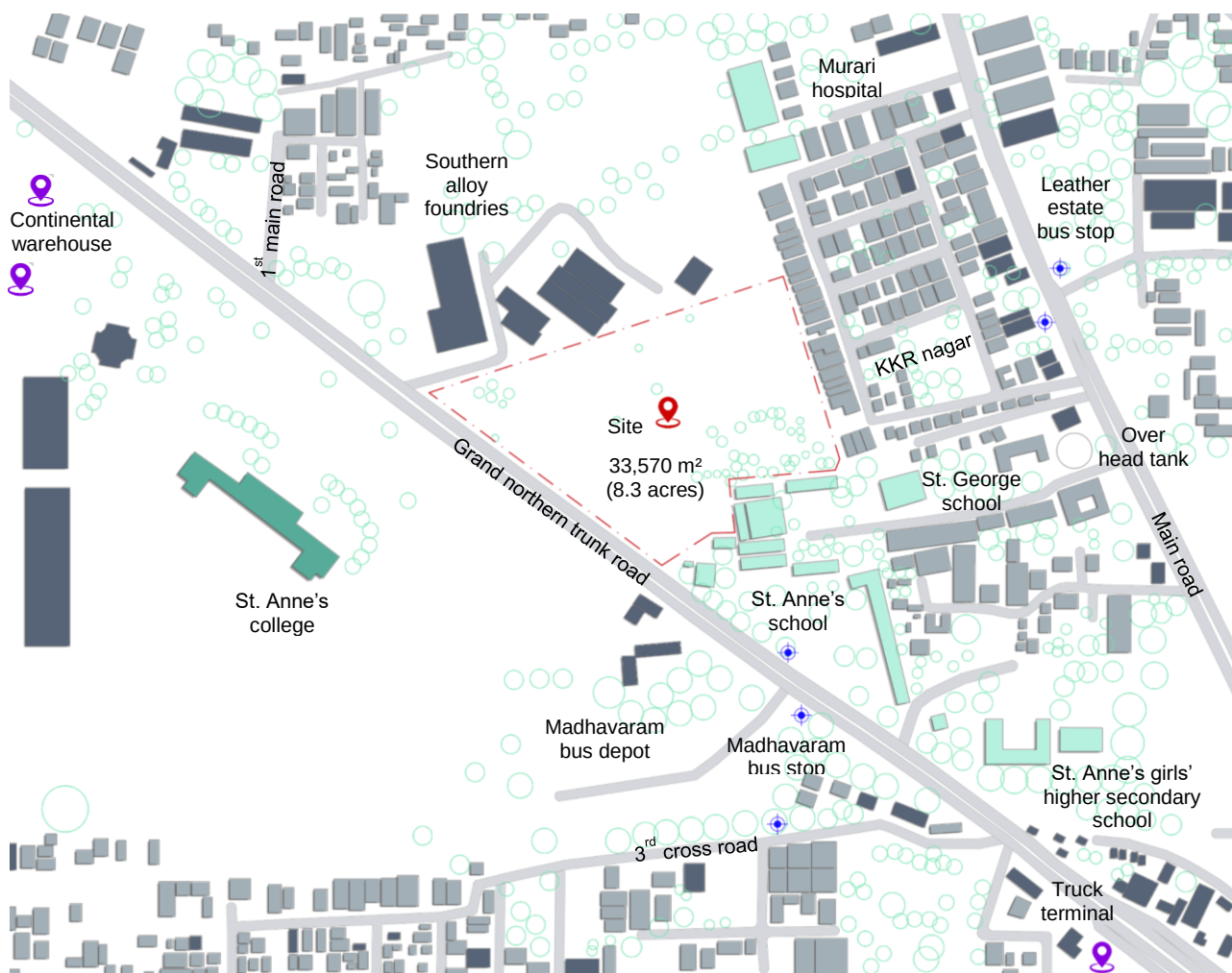


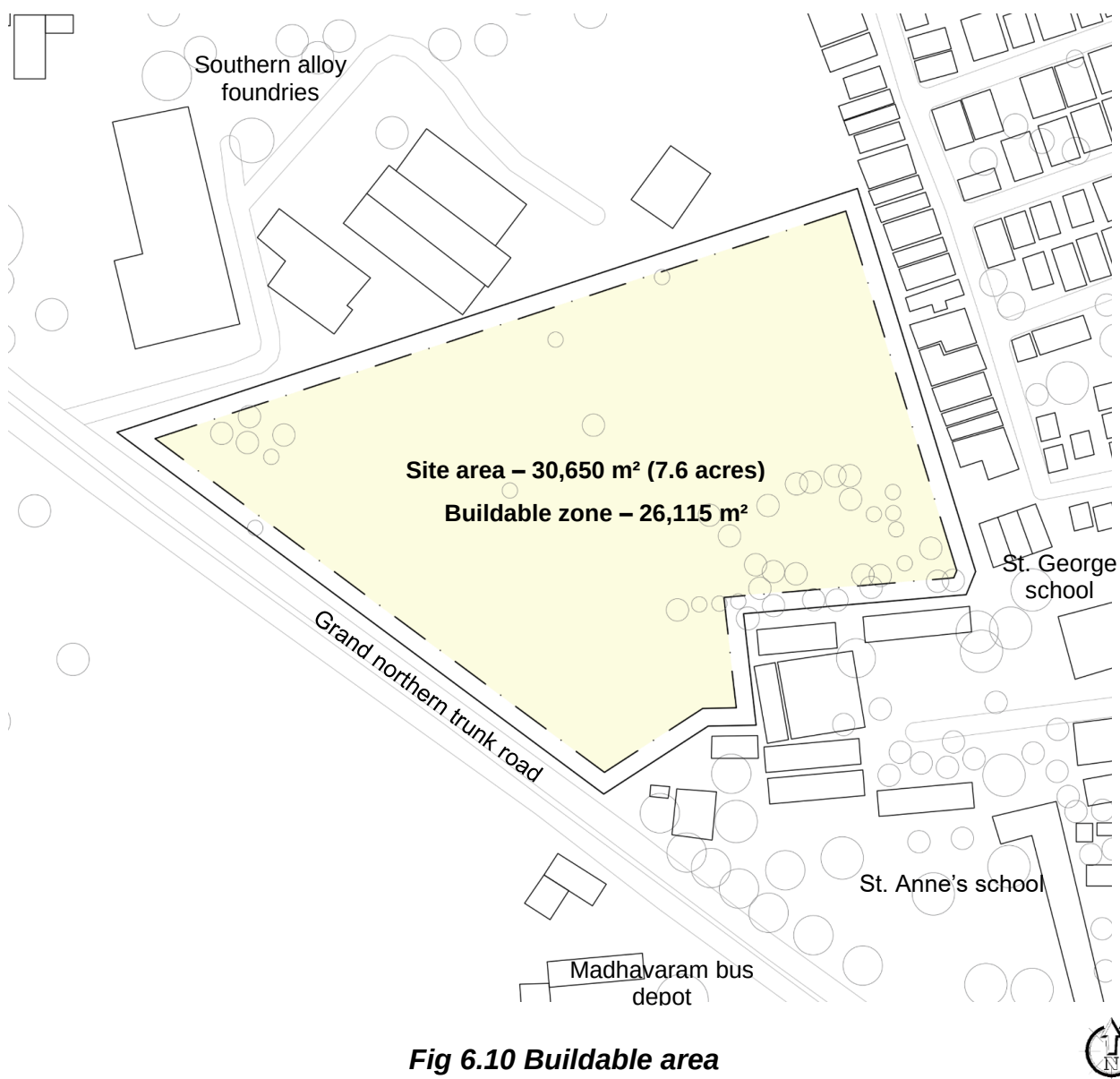
Fig 6.9 Context plan



6.7 DEVELOPMENT CONTROL RULES - SITE DATA AND BYE-LAWS [10]

Road width	24m
Maximum building height allowed	18.3m
Permissible FSI	2.0
Site area	30,650 m ²
Plot coverage	50%

Allowable built up area	61,300 m ²
Buildable zone	26,115 m ²
Allowable ground coverage	15,325 m ²
Front set back	6m
Side set back	6m on either side
Rear side set back	6m
Vehicular access	7.2m wide path
OSR	10% of the site area
1 car space and 1 Two wheeler space for every 75m² of floor area	



6.8 VOLUMETRIC ANALYSIS - BUILT FABRIC

- The site, in particular, is bordered by a diverse range of urban densities, from planned residential colonies to industrial blocks.
- The majority of the residential blocks varies in height from 6 to 12 metres. Institutional buildings range in height from 10 to 12 metres, whereas apartment blocks range in height from 15 to 18 m.

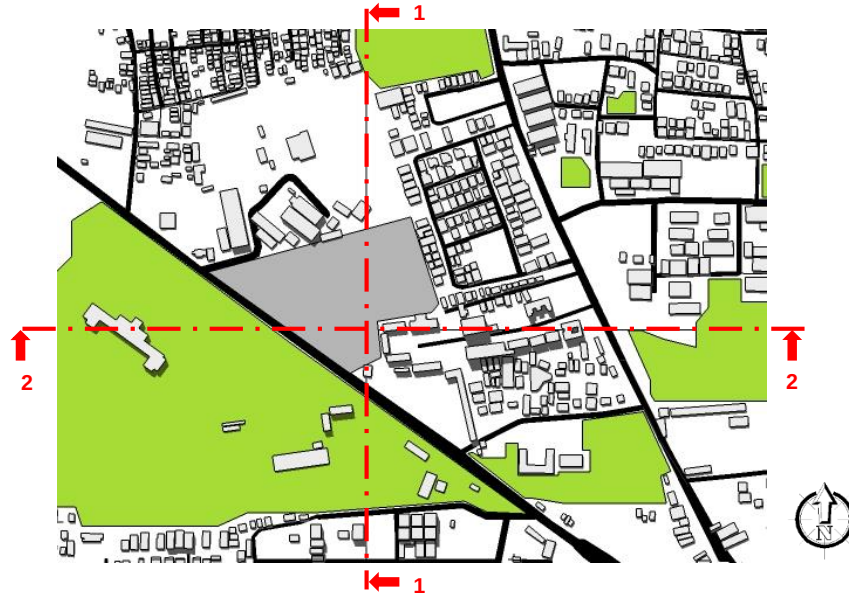


Fig 6.11 Key plan

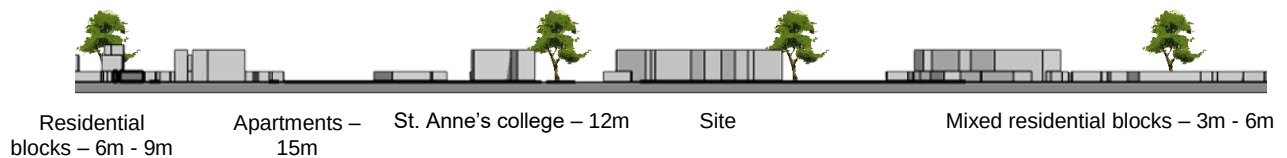


Fig 6.12 Section 1

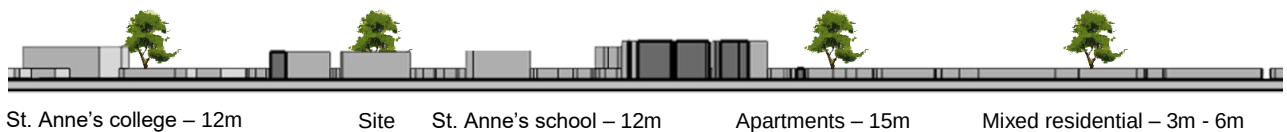


Fig 6.13 Section 2

6.9 FIGURE GROUND ANALYSIS

- Residential blocks are likely to be densely packed with very few open spaces, whereas
- Industrial and
- Institutional blocks are loosely packed with maximum open spaces.



Fig 6.14 Figure ground map

6.10 OPEN SPACE ANALYSIS

- Despite the abundance of many open vacant fields, they are rarely turned into vegetated, green lungs and are mostly left barren.
- There is a lot of undeveloped space around the chosen site area that might be repurposed into a public garden to foster social ties.

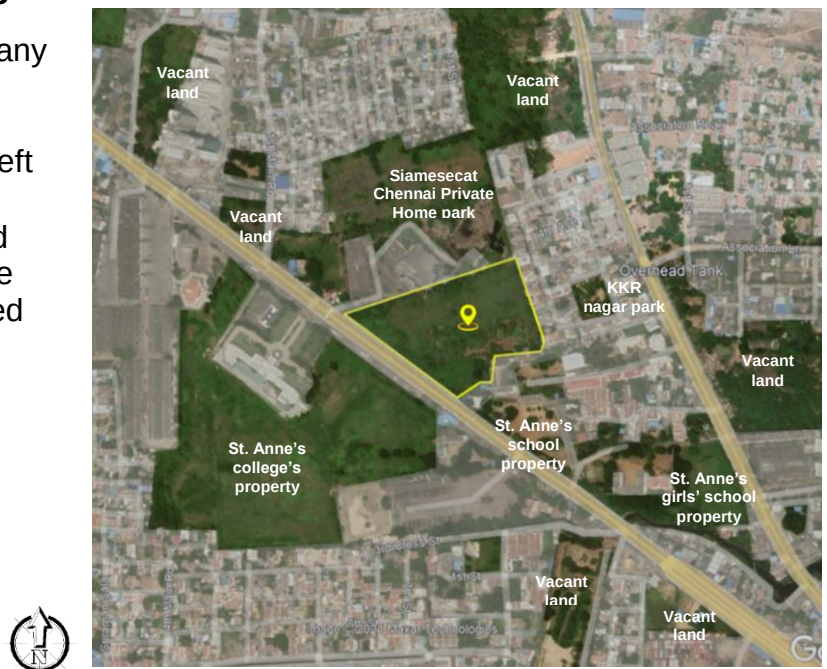


Fig 6.15 Open space map

6.11 VEHICULAR MOVEMENT - TRAFFIC ANALYSIS

- Despite the fact that the roads are sufficiently wide, the buses generate significant traffic during peak school hours due to the vast number of schools and colleges nearby.
- The Moolakadai junction road and the Madhavaram Red Hills road are likely to be congested.

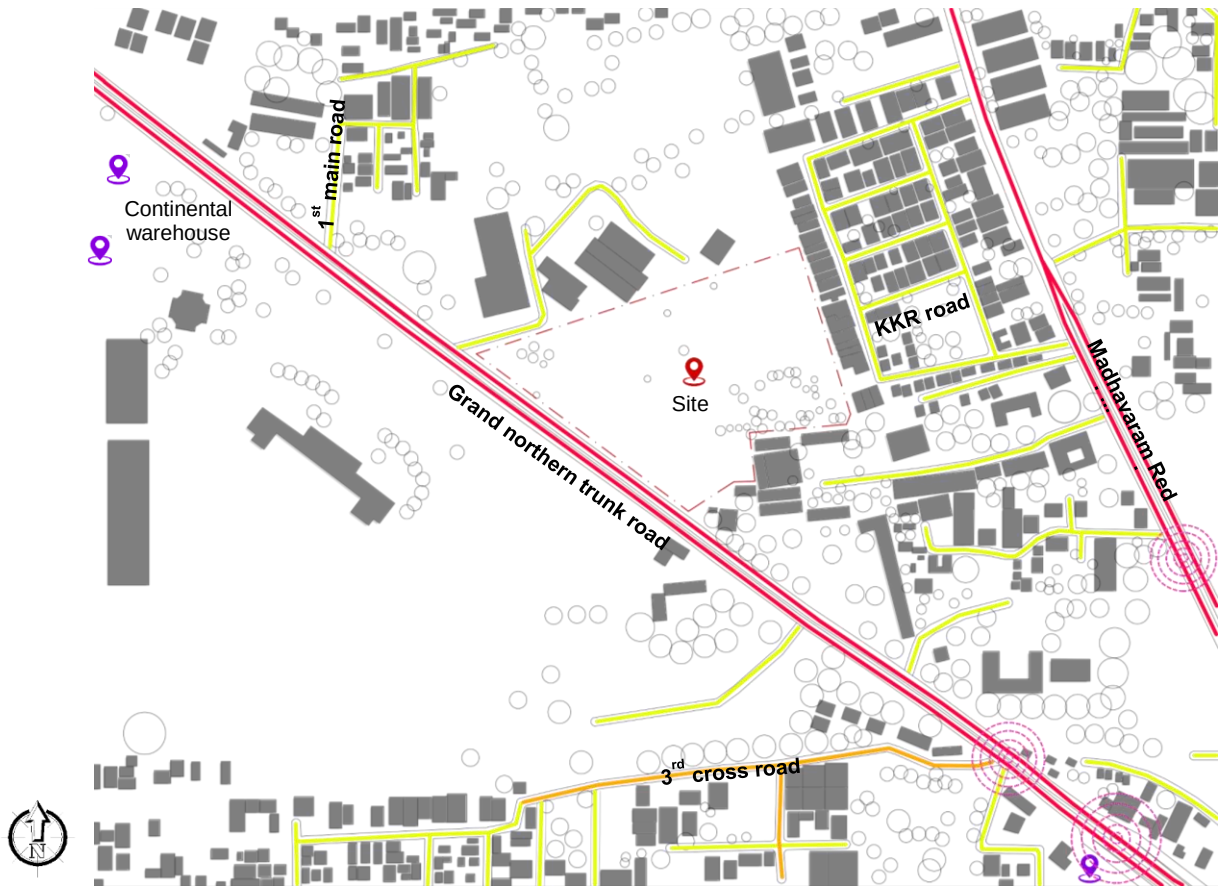


Fig 6.16 Traffic map

6.12 PEDESTRIAN MOVEMENT - PUBLIC TRANSPORT

- With designated stops at regular intervals, the bus is a convenient means of transit in this location.
- Although the pedestrian walkway is more functional, there is a shortage of shade and sidewalk furniture.

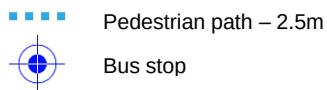


Fig 6.17 Pedestrian path

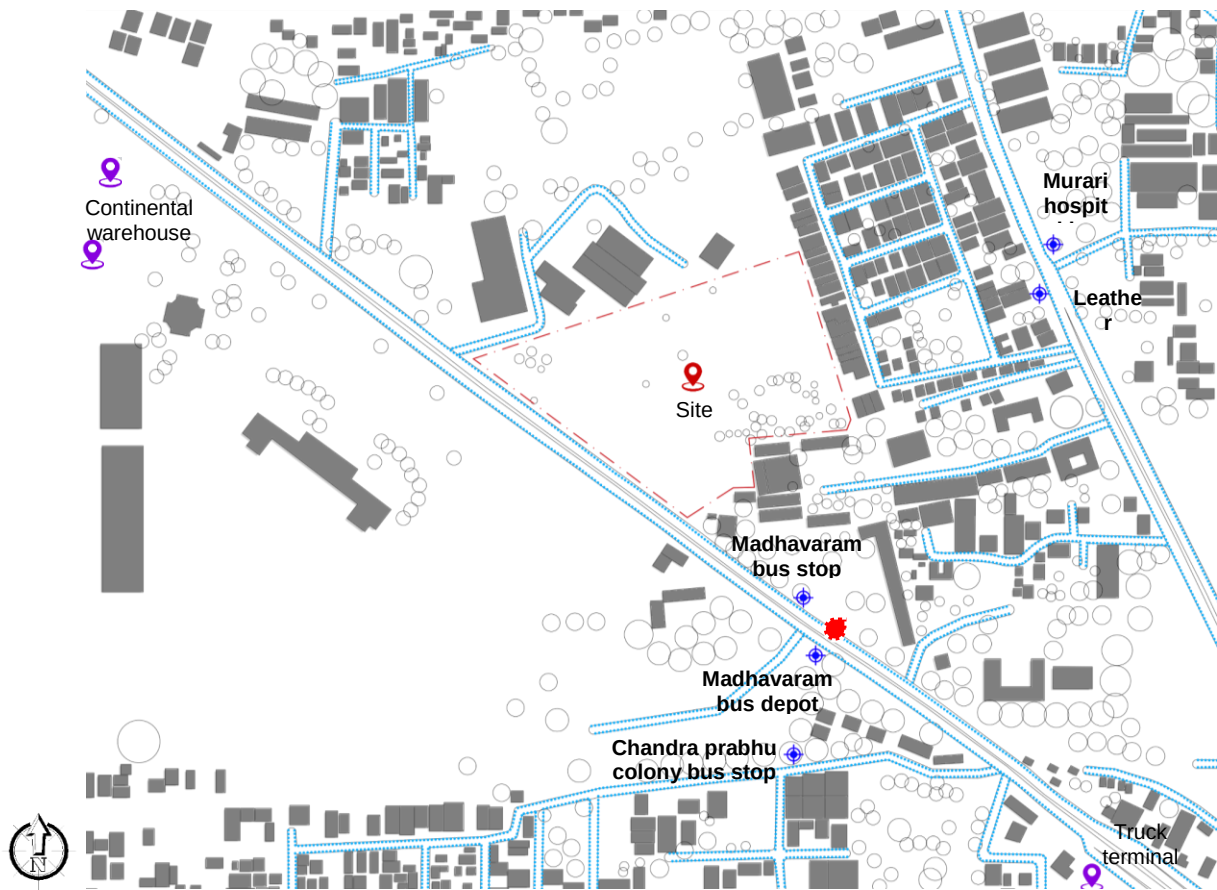


Fig 6.18 Pedestrian path map

6.13 VEGETATION MAP - FLORA AND IT'S HEIGHT

	Ficus benamina (Weeping fig)	2m
	Borassus flabellifer (Palmyra palm)	30m
	Cocos nucifera (Coconut tree)	30m
	Saraca asoca (Ashoka tree)	7m
	Azadirachta indica (Neem tree)	15m
	Albizia lebbeck (Vaagai tree)	18m-30m
	Mangifera indica (Mango)	20m

Table 6.1 Key for existing vegetation



Fig 6.19 Existing vegetation map

6.14 NATURAL SITE FEATURES - SLOPE AND CONTOUR ANALYSIS

- The site has a mildly undulating slope. From west to east, there is a 2 meters gradual slope.
- The site's lowest slope is found in the north-eastern corner (5m), and its highest elevation is found in the west corner (7m).
- This gentle slope is useful for site drainage and surface runoff collection.



Fig 6.20 Contour sections

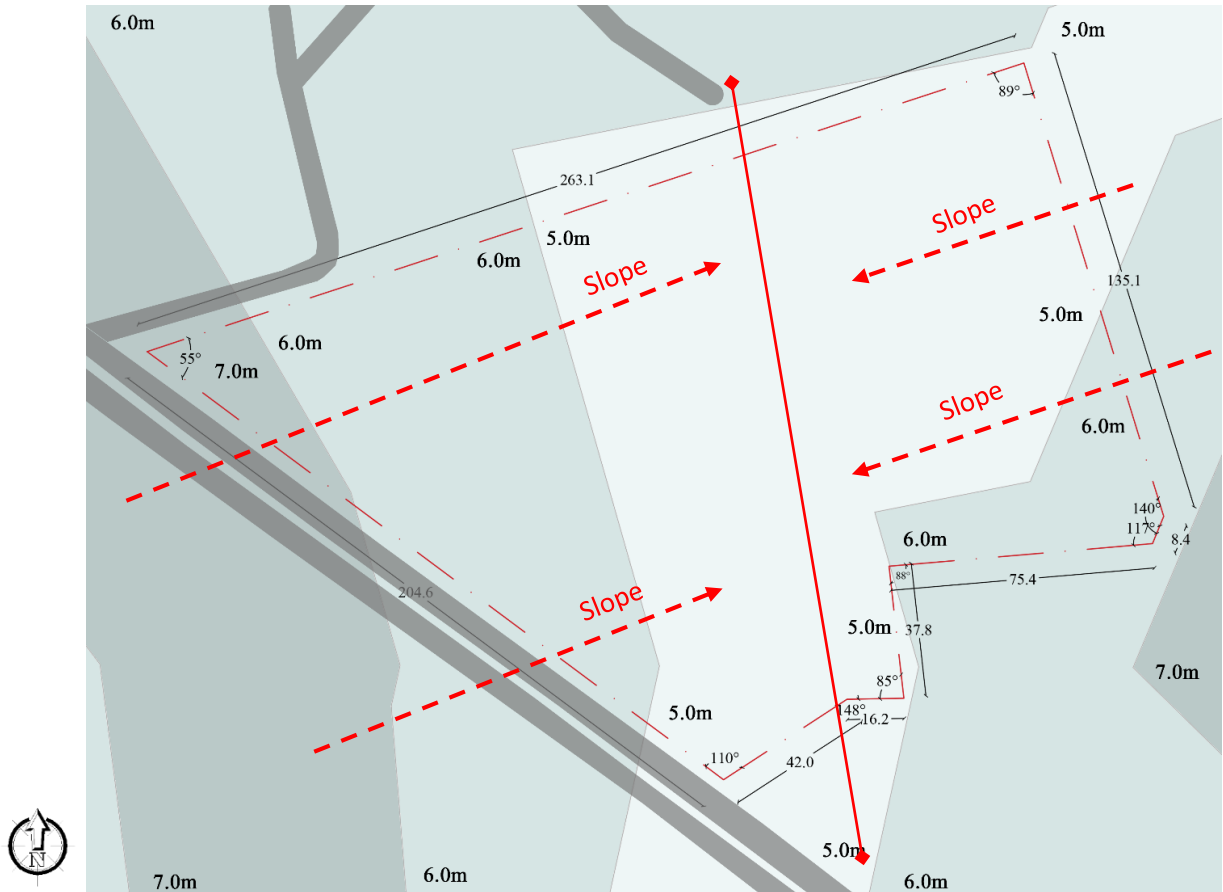


Fig 6.21 Contour layout

6.15 SURROUNDING CONTEXT - PHOTO SHEET

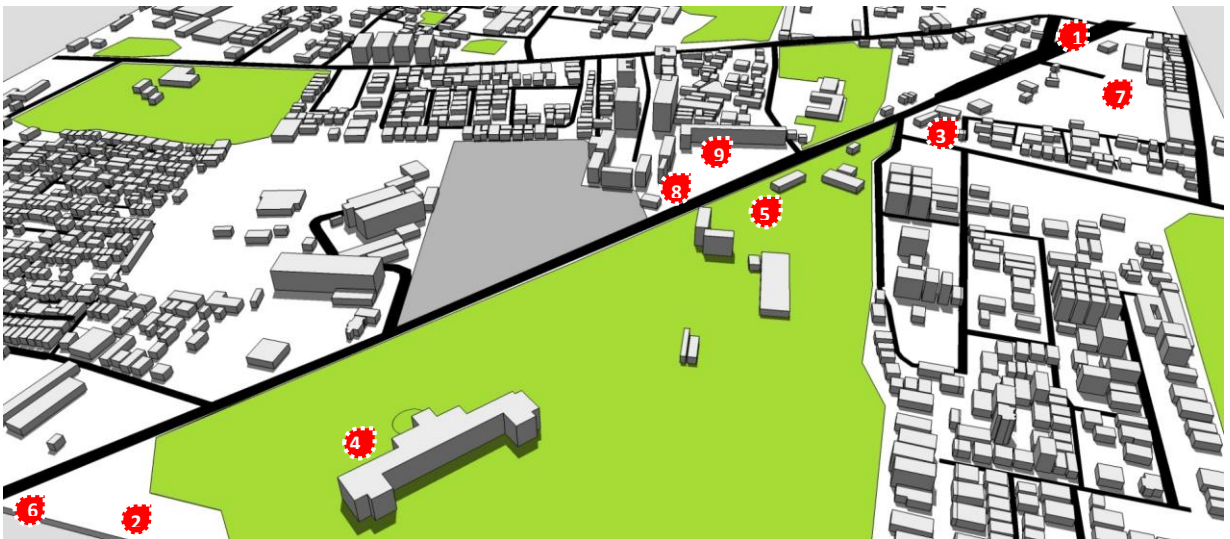


Fig 6.22 Key map



1
Moolakadai junction



2
Continental CFS Chennai



3
Madhavaram police station



4
St. Anne's college



5
Madhavaram bus depot



6
Continental warehouse



7
Madhavaram truck terminal



8
Madhavaram bus stop



9
St. Anne's girls' higher secondary school

Fig 6.23 Site surrounding – Photo sheet

6.16 SITE CONDITION - PHOTO SHEET

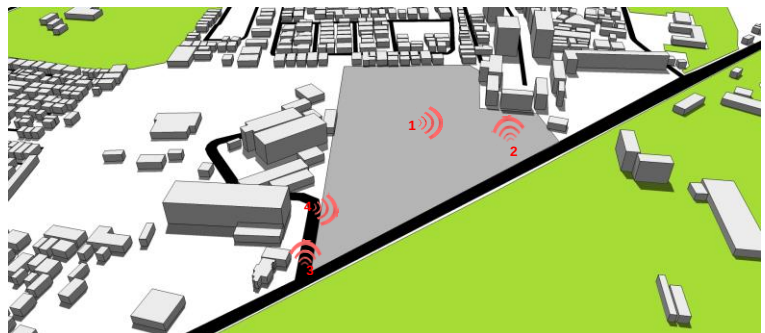


Fig 6.24 Key map



Fig 6.25 Site photos

6.17 SWOT ANALYSIS - SITE SPECIFIC

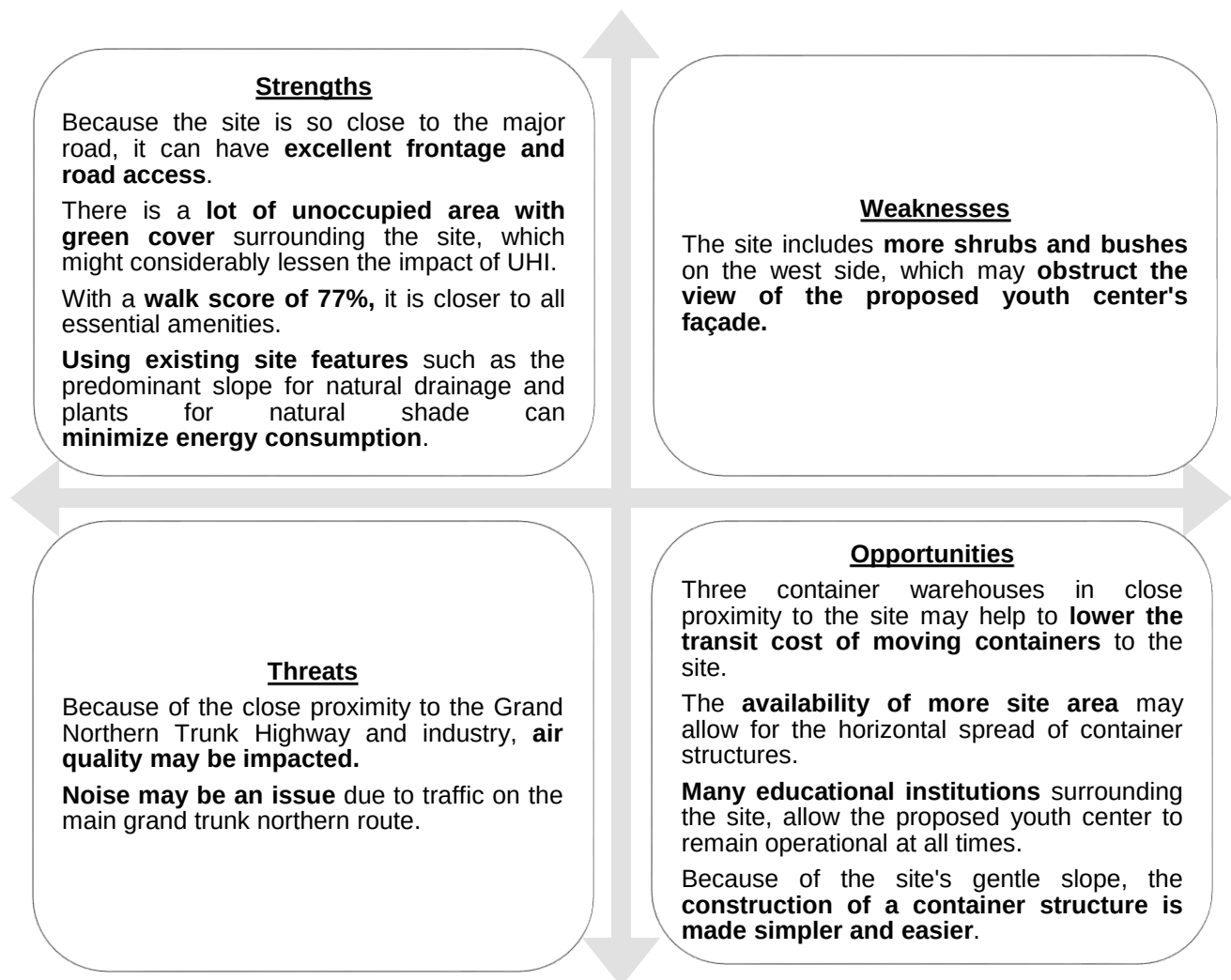


Fig 6.26 SWOT analysis

CHAPTER 7 CLIMATE STUDY

7.1 TEMPERATURE - ADAPTIVE COMFORT ZONE USING ET GRAPH [11]

- The comfort zone is between 26°C and 23°C
- From November to February, the effective temperature is within the comfort range.
- Hottest month – May 35°C
- Coldest month – January 23°C

Months	T (Max) °C	T (Min) °C	Tc (Max) °C	Tc (Min) °C
Jan	27	23	26.2	22.5
Feb	28	24	25	23.5
Mar	31	26	26.5	25.2
Apr	33	28	28.2	27
May	35	30	29	28.5
Jun	34	29	28	27.2
Jul	33	29	27.8	27.2
Aug	32	28	27.2	26.8
Sep	32	28	27.5	27
Oct	31	27	26.8	26.2
Nov	29	26	25.6	25.4
Dec	28	24	24	23.5

Table 7.1 Monthly Temperature

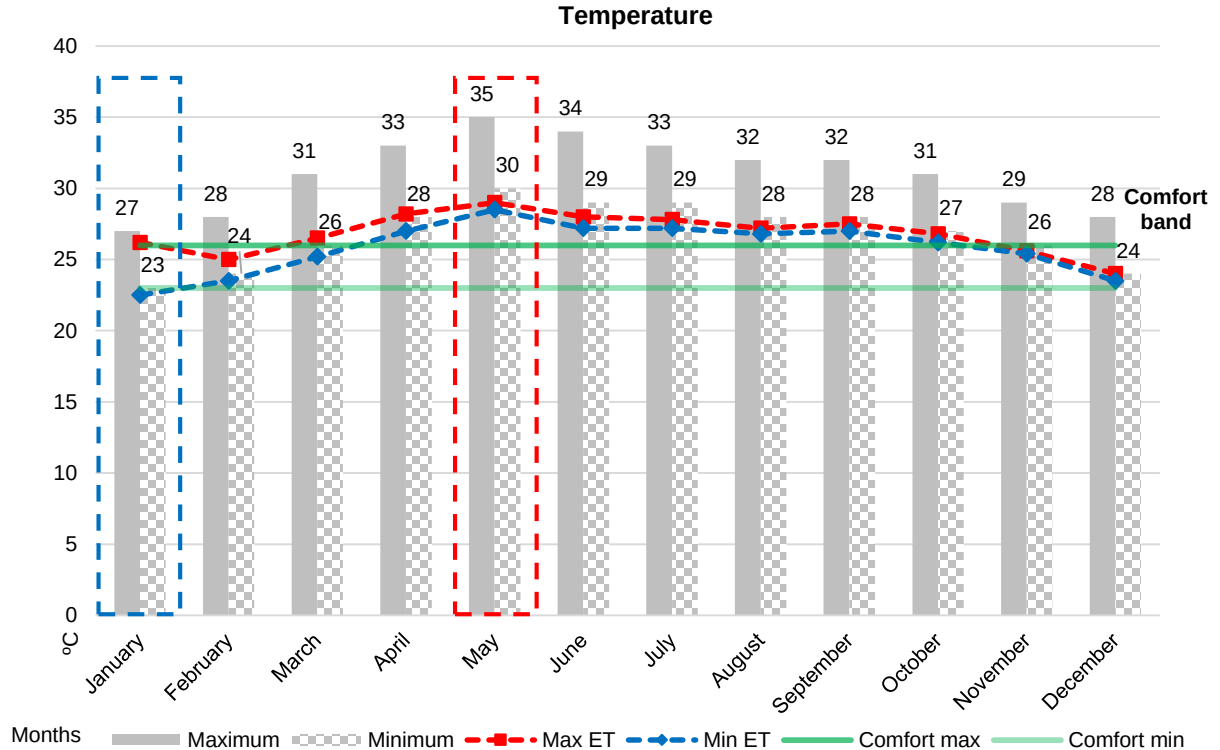


Fig 7.1 Temperature graph

- Chennai is located on the southeast coast of India, in the northeast corner of Tamil Nadu, at 13.04°N 80.17°E.
- Chennai has a tropical climate that is both wet and dry. The weather is hot and humid most of the year.

7.2 RELATIVE HUMIDITY AND DBT - RELATIONSHIP BETWEEN RH & DBT [12]

- The greater the RH, the lower the DBT.
- RH is highest in November and December and lowest from May to July.
- DBT is highest from May to July, and lowest from November to December.

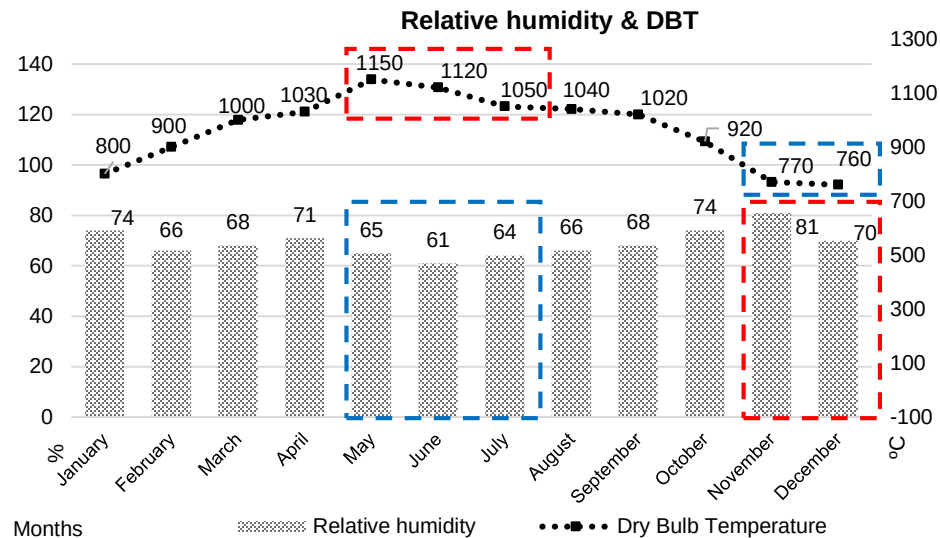


Fig 7.2 RH & DBT graph

7.3 PRECIPITATION - MONTHLY VARIATION IN RAINFALL [12]

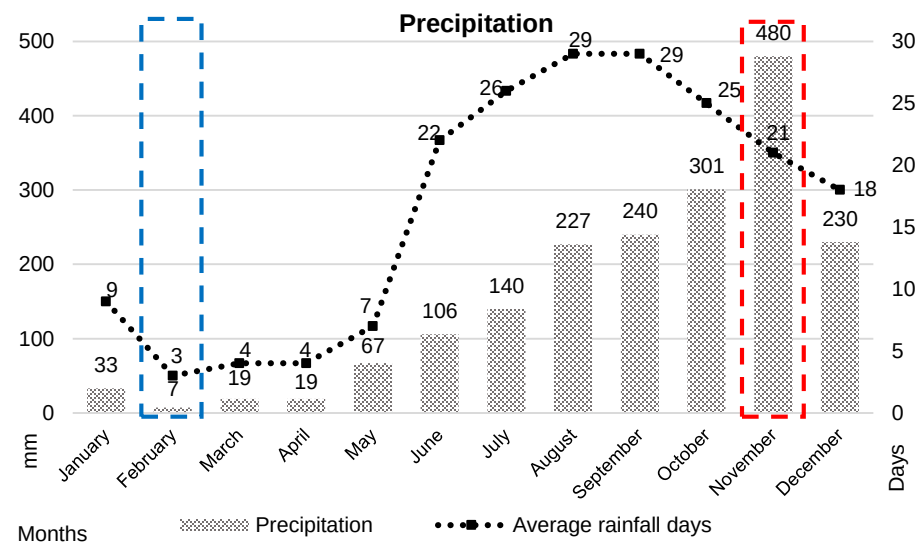


Fig 7.3 Precipitation graph

- Madhavaram receives around 1,880 mm of rainfall each year on average.
- In November, the maximum rainfall reached 480mm. In February, the average minimum rainfall was 7mm.
- From mid-September to mid-December, the city receives the majority of its seasonal rainfall from the north-east monsoon wind.

7.4 WIND VELOCITY - MONTHLY VARIATION IN WIND VELOCITY [13]

- May has the highest wind velocity of 5.8m/s, with temperatures ranging from 27 to 38°C and humidity levels usually above 70%.
- January has the minimum wind velocity is 3.9m/s, with temperatures ranging from 21 to 27°C and humidity levels usually above 70%.

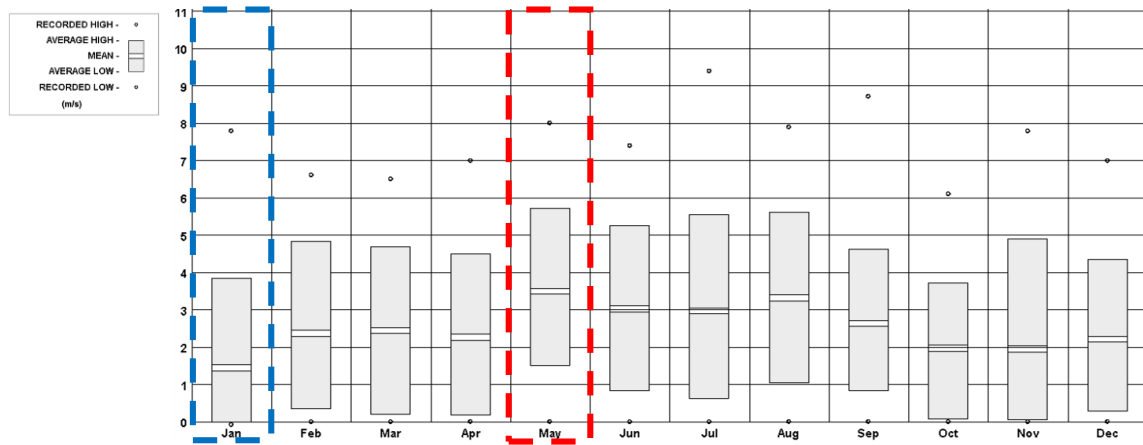


Fig 7.4 Wind velocity

7.5 RADIATION - MONTHLY VARIATION IN RADIATION [13]

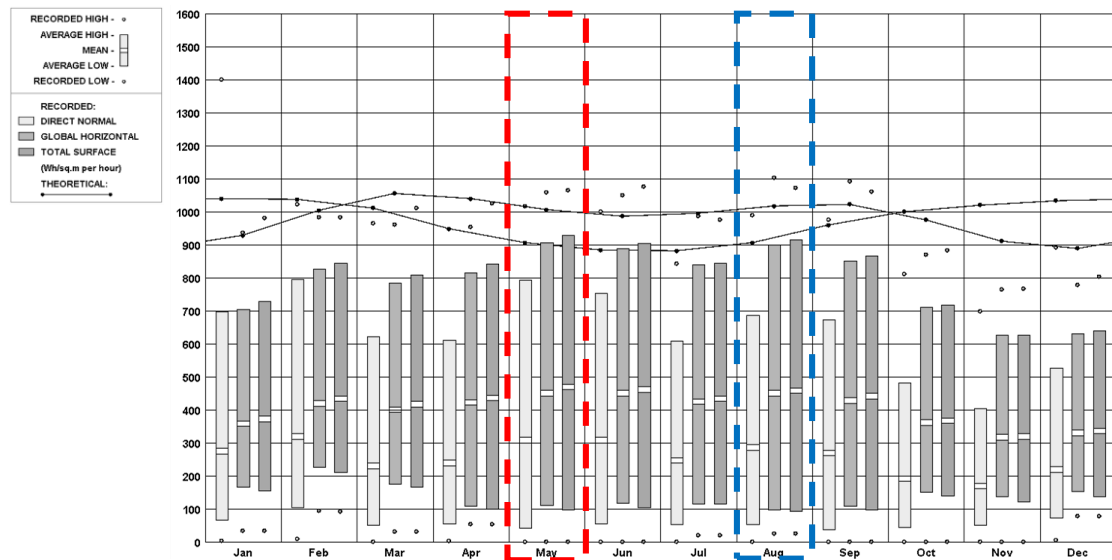


Fig 7.5 Radiation

- The month of May has the maximum surface radiation of 920Wh/m², and the month of August has the lowest surface radiation of 98Wh/m².

7.6 WIND DIRECTION - MONTHLY VARIATION IN DIRECTION [13]

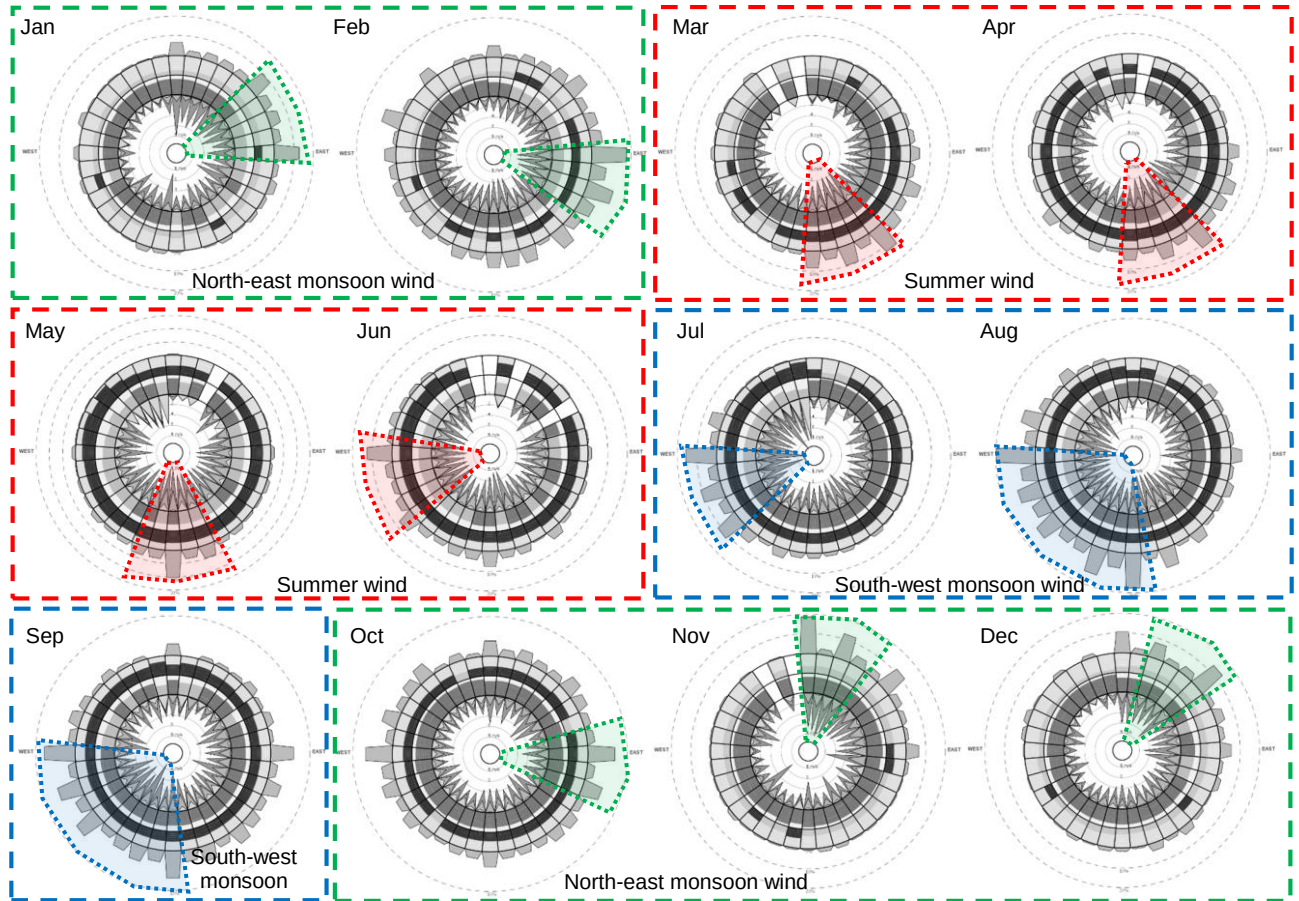


Fig 7.6 Wind rose diagram

- From mid-September to mid-December, the city receives the majority of its seasonal rainfall from the north-east monsoon winds.
- The most common winds in Chennai are south-westerly from the end of May to the end of September and north-easterly the rest of the year.
- Summer winds stream from the southeast and southwest directions from March to June.
- South-west monsoon prevailing winds from July to September.
- During October to February, the north-east monsoon prevailing winds from the western disturbances.

7.7 SKY COVER - CLOUD PERCENTAGE [14]

- Madhavaram has the highest amount of sky cover in the month of November, with 67%. The average amount of sky cover is lowest in March with 4%.

- The average number of sunshine hours is directly related to the amount of sky cover. The lower the sky cover, the higher the sunshine.

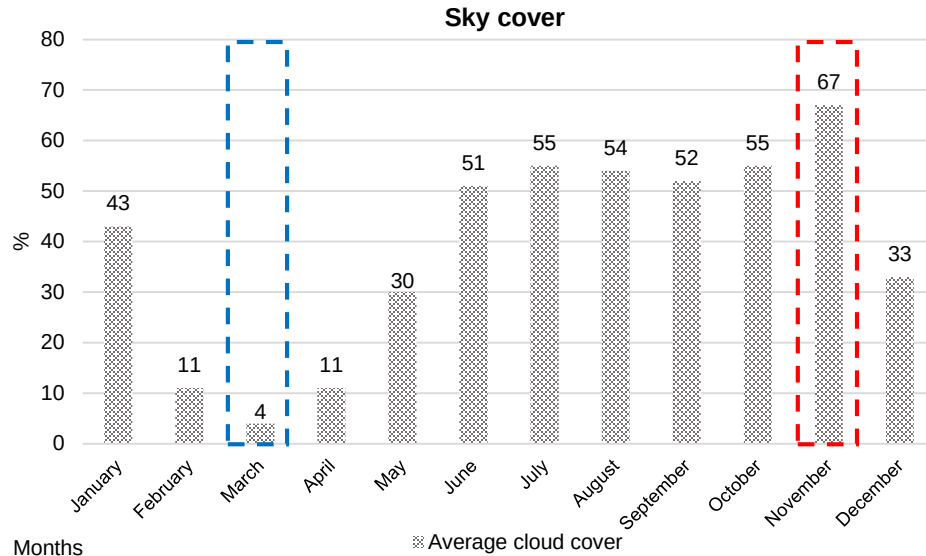


Fig 7.7 Sky cover

7.8 SUN HOURS - DAYLIGHT AND SUNSHINE HOURS [14]

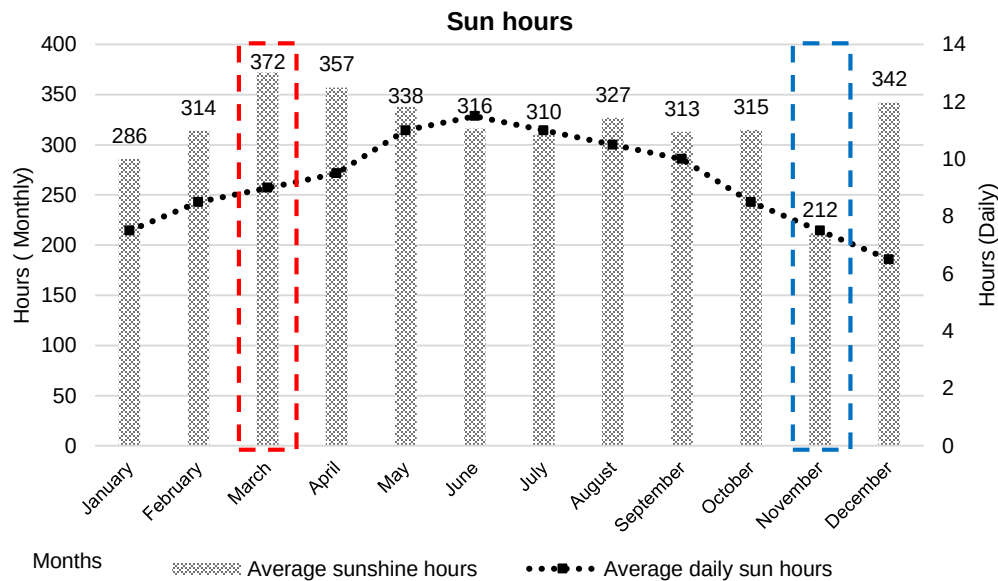


Fig 7.8 Sun hours

- Madhavaram has the highest amount of average sunshine hours in March, with 372 hours and lowest in November with 212 hours.
- June has highest daily sunshine hours with an average of 11 hours. December has the lowest daily sunshine hours with an average of 6.5 hours.
- Throughout the year, Madhavaram receives around 3800 hours of sunlight.

7.9 MAHONEY TABLE

	J	F	M	A	M	J	J	A	S	O	N	D	HIGH	AMT
M.M.Max	27	29	31	33	35	34	33	32	32	31	29	27	35	29
M.M.Min	23	24	26	28	30	29	29	28	28	27	26	24	23	12
M.M.Range	4	5	5	5	5	5	4	4	4	4	3	3	LOW	AMR

Table 7.2 Air temperature °C

	J	F	M	A	M	J	J	A	S	O	N	D
M.M.Max	93	92	90	89	86	82	80	86	90	92	94	93
M.M.Min	53	50	52	55	48	44	50	52	54	54	58	59
M.M.Range	73	71	71	72	67	63	65	69	72	73	76	76
H.Group	4	4	4	4	3	3	3	3	4	4	4	4

Table 7.3 Relative humidity %

	J	F	M	A	M	J	J	A	S	O	N	D	Total
Rainfall	33	17	19	19	67	106	140	227	240	301	480	230	1879

Table 7.4 Rainfall mm

	J	F	M	A	M	J	J	A	S	O	N	D
Monthly Mean.Max	27	29	31	33	35	34	33	32	32	31	29	27
Day Comfort: Upper	27	27	27	27	29	29	29	29	27	27	27	27
Lower	22	22	22	22	23	23	23	23	22	22	22	22
Monthly Mean.Min	23	24	26	28	30	29	29	28	28	27	26	24
Night Comfort:Upper	21	21	21	21	23	23	23	23	21	21	21	21
Lower	17	17	17	17	17	17	17	17	17	17	17	17
Thermal Stress: Day	O	H	H	H	H	H	H	H	H	H	H	O
Night	H	H	H	H	H	H	H	H	H	H	H	H

Table 7.5 Diagnosis °C

Comfort limits Humidity Group	AMT over 20 °C		Indicator from above table					
	Day	Night						
1	26-34	17-25	H1	H2	H3	A1	A2	A3
2	25-31	17-24	10	2	5	4	0	0
3	23-29	17-23						
4	22-27	17-21						

Table 7.6 Indicators

CRITERIA	SL.NO.	INFERENCE	REASON
Layout	1	Orientation north & south (long axis east-west)	To minimize sun exposure, the longer side should face north-south
Spacing	3	Open spacing for breeze specification	Open planning to take advantage of the prevailing wind and shade
Air movement	6	Rooms single banked permanent provision for air movement	To allow for cross ventilation, rooms should be single-banked, with a minimum of windows on the east and west facades.
Openings	9	Large openings 40-80%	Larger apertures on the north and south walls, with overhangs on the south side.
Walls	13	Heavy external and internal walls	Walls should be thick enough to defend against the radiation from the sun.
Roofs	14	Light insulated roofs	To avoid heat ingress, the roof can be well insulated.
Rain protection	17	Protection from heavy rain necessary	Heavy rainfall is possible during the North-East monsoon, so proper rain protection is required.

Strategies

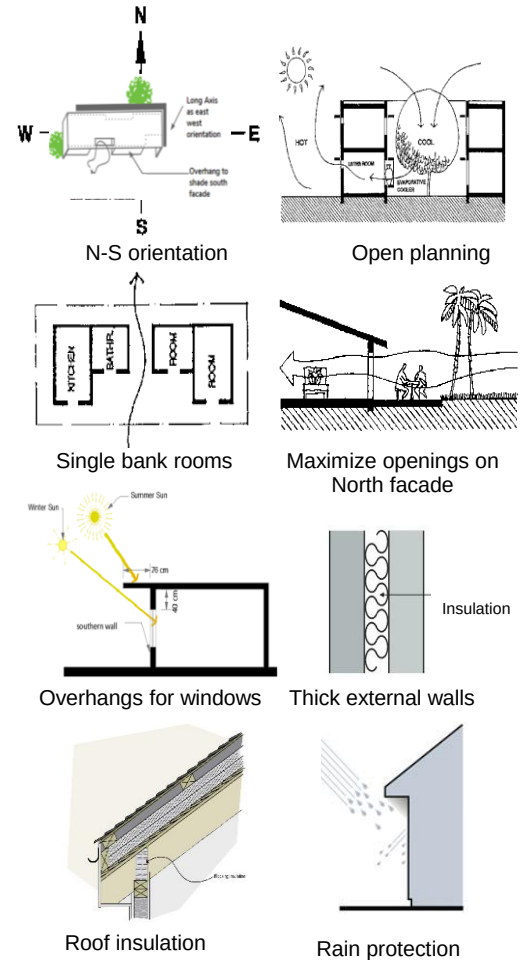
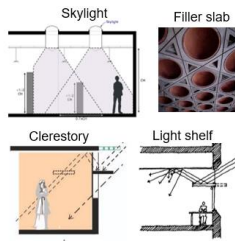


Table 7.7 Inference

7.10 RECOMMENDED PASSIVE STRATEGIES [15]

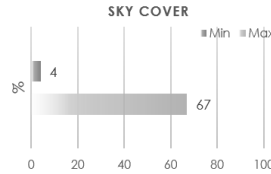
Inference - Strategies	PARAMETERS	CLIMATE DATA	CONSEQUENCES	STRATEGIES TO BE INCORPORATED
Shading by plants Green roof Jaali wall Courtyard planning	Dry bulb temperature (Day) Max temperature May (35°C) Min temperature Jan (27°C)	DRY BULB TEMPERATURE	If shading is not provided - High levels of radiation on the pavement and walls. - Upper levels have a high heat gain and a low thermal mass.	- Tree shading saves 2°C to 5°C. - Cool and green roof – decreases temperatures by 6°C - 8°C. - Secondary façade, Jaali wall, and cavity wall – decrease 2°C - 5°C.
	Wet bulb temperature (Night) Max temperature May (30°C) Min temperature Jan (23°C)	WET BULB TEMPERATURE	- Direct heat gain as well as visual glare. - Inadequate thermal and acoustic insulation. - In the summer, hot and dry air enters the building.	- Courtyard planning may save up to 25% on energy use. - Filler slab – lowers the temperature by 6°C - 8°C. - Heavy walls and roof – decreases temperatures by 2.8°C - 7°C.



Sky cover

Max Sky cover
Nov (67%)

Min Sky cover
Mar (4%)



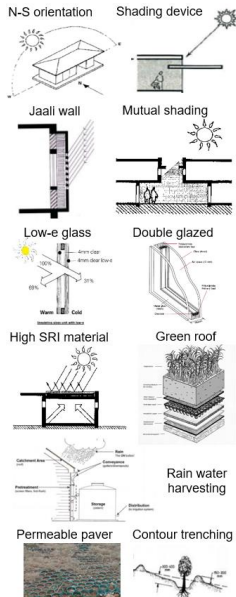
If daylight strategies are not implemented

- Low light penetration into the deeper parts of room.

Because the sky cover here exceeds 50% for more than half of the year, daylighting penetration may be hindered to some extent.

Some of the Daylighting Techniques

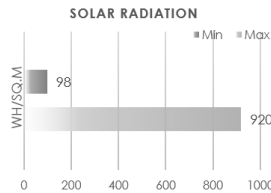
- Skylights - reduction in energy savings by 77 %
- Clerestory window
- Light shelves and light tubes
- Light wells & Courtyard



Solar radiation

Max Direct radiation May (920 Wh/sq.m)

Min Direct radiation Aug (98 Wh/sq.m)



If shading is not provided

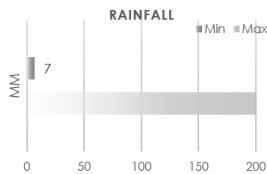
- East and west are subjected to intense sun radiation.
- Penetration of hot summer wind.
- The greatest amount of radiation can be absorbed.

- Longest façade with a north-south orientation.
- Trees and a shading device to provide shade.
- Jaali & double facade to keep heat out.
- Mutual shading by building forms -courtyard planning.
- Reflective glass, Low-e glass, double glazing, and glass with a low SHGC to limit heat penetration.
- High SRI roof, reflective coating, white paint, ceramic tile, and insulation (XPS, EPS). Cool and green roofs are used to decrease heat gain via the roof.
- Materials with light colours reflect more heat.

Rainfall

Max rainfall Nov (480mm)

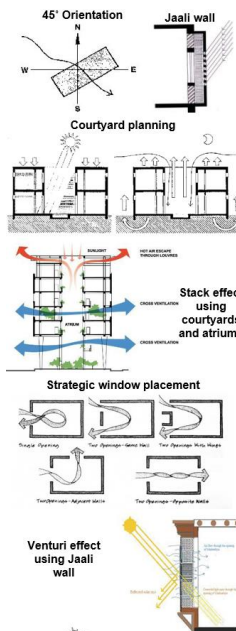
Min rainfall Feb (7mm)



If rainwater harvesting is not implemented

- Storm-water runoff can be a problem.
- During the monsoon season, heavy rains wash away fertile topsoil.
- There won't be enough groundwater recharge.

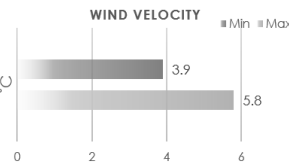
- Rain water catchment area and recharge tank
- Permeable pavement to enable groundwater recharge.
- Surface runoff can be prevented via contour trenching, bio swales.



Wind velocity

Max wind velocity May (5.8m/s)

Min wind velocity Jan (3.9m/s)



If proper wind movement is not allowed

- In the summer, the entry of hot and humid air can raise indoor temperatures.
- Reduced air circulation into the spaces might be undesirable.
- If not adequately vented, the indoor temperature might rise owing to heat absorption via the walls and roofs.

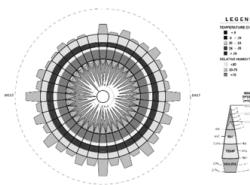
- Orienting 30° – 45° – Wind movement is enhanced when the orienting the building towards the direction of the prevailing wind.
- Cross ventilation, courtyard and appropriate window size – improve air flow, which greatly reduces indoor temperature.
- Open and spacious layout – aids wind movement.
- Stack ventilation and venturi effect –aids in the removal of hot air while allowing cold breezes to enter the building.

Wind direction

March to June – SE, SW

July to September – SW

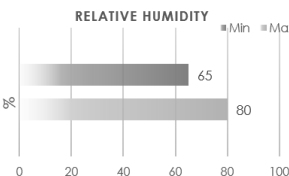
October to February – NE



Relative humidity

Max humidity Nov and Dec (above 80%)

Min humidity May to July (65%)



- If humid air is not appropriately cooled during the summer months, it may cause discomfort to the occupants..

- Cross ventilation
- Courtyard – stack effect
- Strategic window placement

Table 7.8 Passive strategies recommended

7.11 SITE ANALYSIS – SUN & WIND PATH

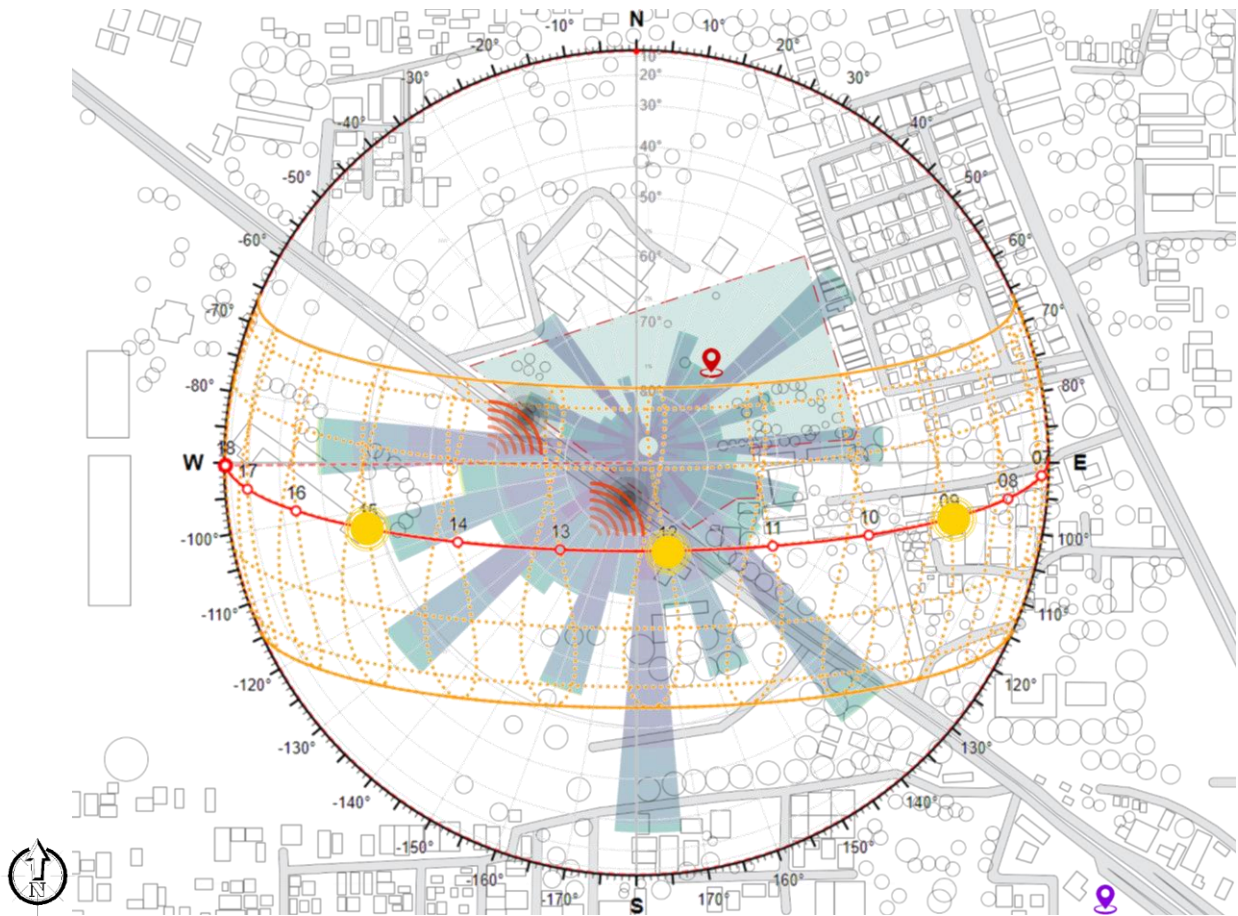


Fig 7.9 Sun & Wind path

Throughout the year, wind flows mostly from the south east to the south west, with wind speeds of less than 3.4m/s.

7.12 MICRO CLIMATE ANALYSIS

7.12.1 RADIATION ANALYSIS

Throughout the day, a cluster of trees covers the southeast side, resulting in 34.67% low radiation – 980Wh/m² – when compared to regions with no trees (1500Wh/m²).

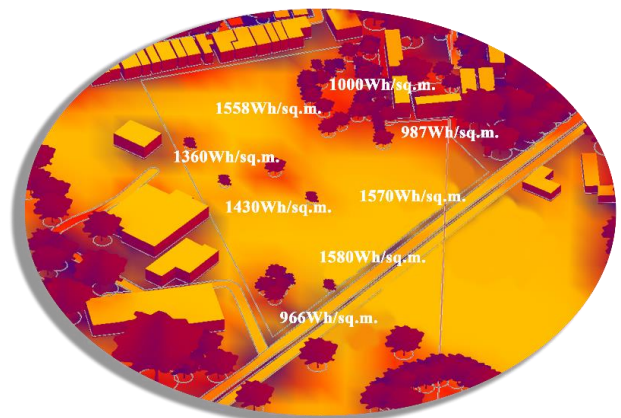


Fig 7.10 Annual cumulative radiation

7.12.2 WIND ANALYSIS

The predominant North East and South West airflow may not be affected because there are no residential clusters or high-rise structures in the direction of the prevailing wind.

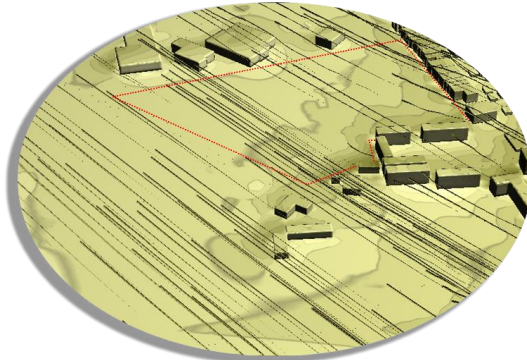


Fig 7.11 North east wind

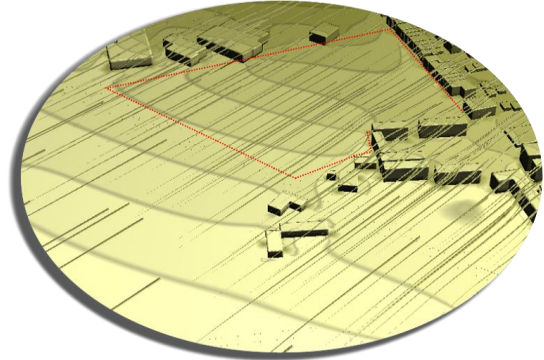
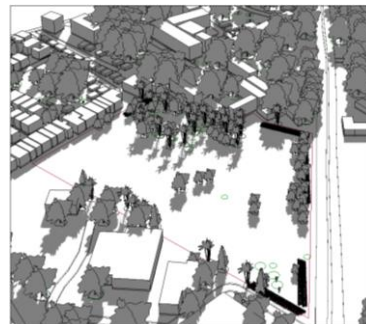


Fig 7.12 South west wind

7.12.3 SHADOW ANALYSIS

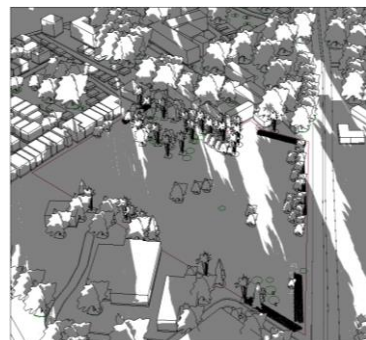
- Throughout the day, a cluster of trees shades the south east side.
- There are bushes and grasses to the west; extensive vegetation may be required to minimize noise pollution and severe west radiation.
- The north side features tall trees that do not block off the sunlight.



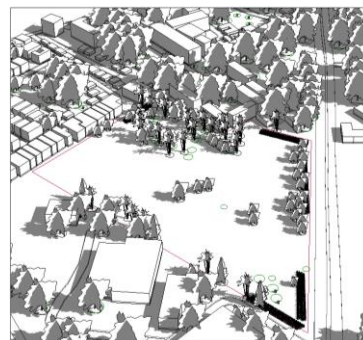
09.00 AM



12.00 PM



06.00 PM



03.00 PM

Fig 7.13 Shadow analysis

7.13 SWOT ANALYSIS - CLIMATE SPECIFIC

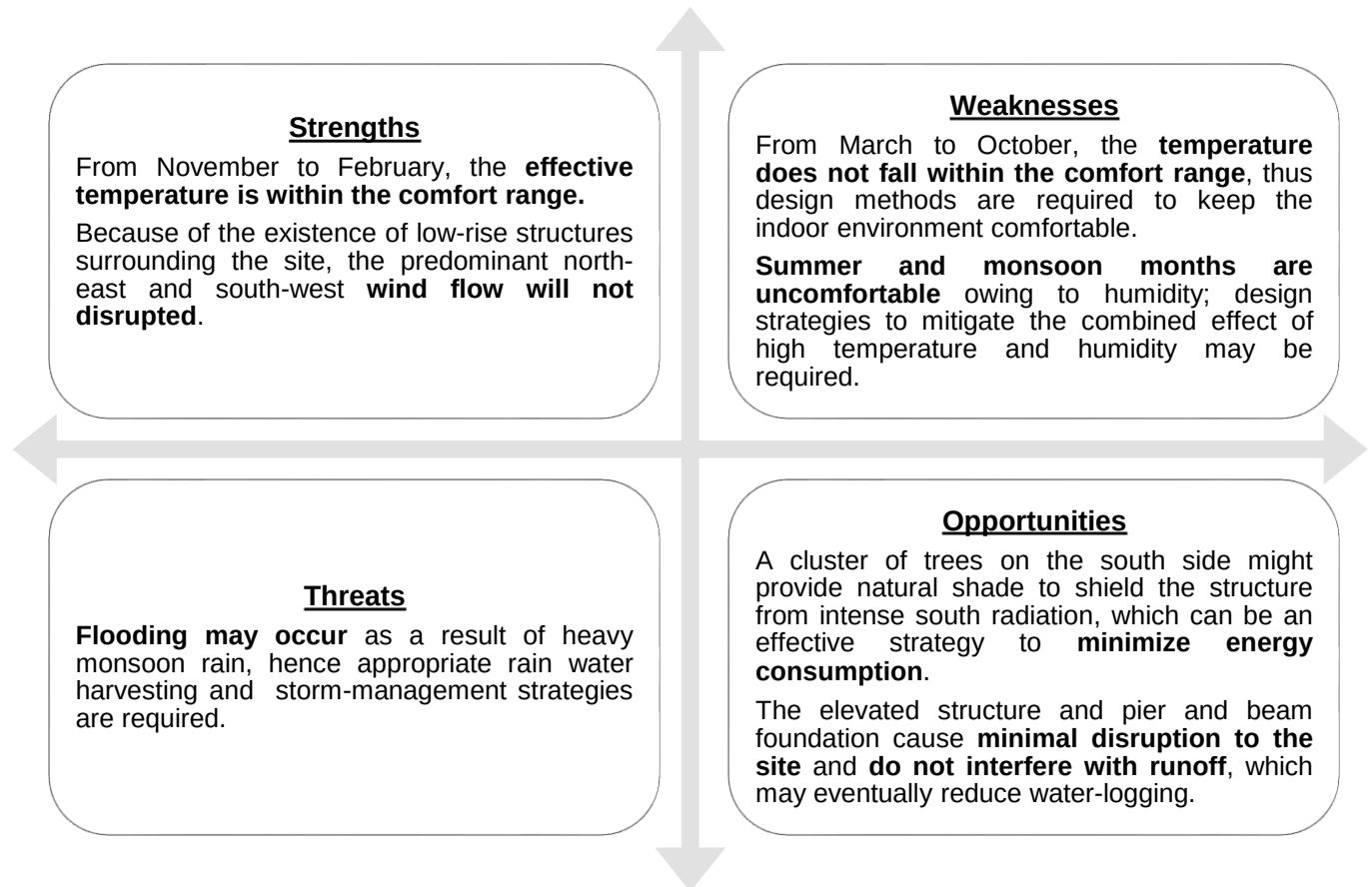


Fig 7.14 SWOT analysis

7.14 SITE INVENTORY - SITE SYNTHESIS OF POTENTIAL SPOTS

1. Parking can be given there to prevent intense south-west radiation from affecting container buildings.
2. Shrubs, which should be removed, obscure the view of the container building from the entrance.
3. Potential spot for a vehicle entry.
4. Possibility of constructing a major entrance.
5. Possibility of constructing a additional public entrance.
6. Possible spot for a service entrance.
7. Possibility of creating more usable rooms to the north in order to enjoy glare-free illumination all of the time.
8. Potential spot to create open spaces like restaurant, café, street shops as there are more trees to provide shade throughout the day.
9. Possibility of creating a sports facility over to the east, where it will not be harmed by radiation for the rest of the day.
10. Covered water-body can be created on the site's lowest slope, which serves as a natural drainage area.

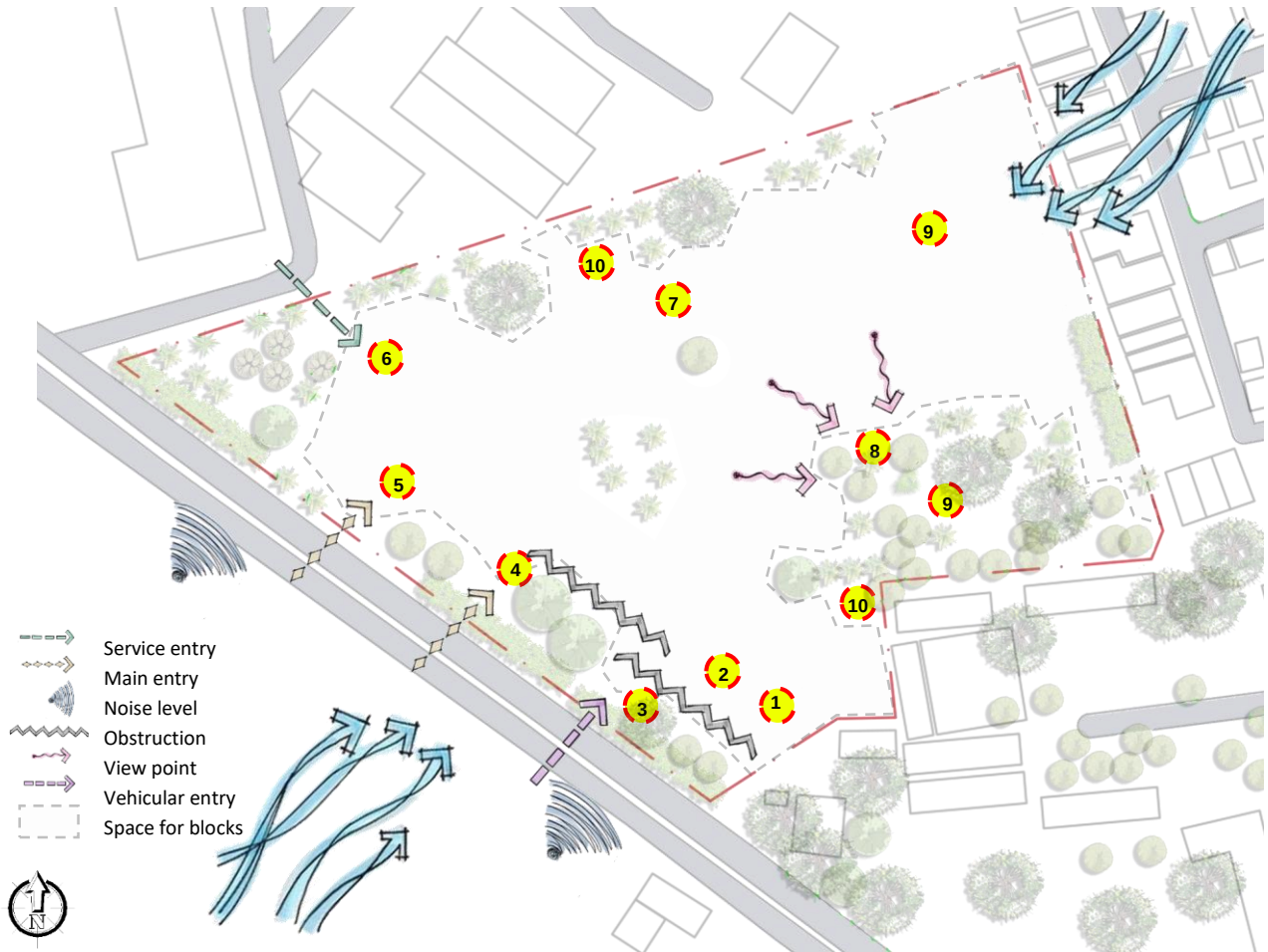


Fig 7.15 Site inventory map

CHAPTER 8 AREA PROGRAMME

8.1 SCALE FOR THE STUDY - WALKING DISTANCE – COMMUNITY LEVEL [16]

- The 5-minute walk, often known as the "pedestrian shed," is the distance that people are willing to walk before driving.
- A five-minute walk is represented by a radius measuring $\frac{1}{4}$ of a mile or about 400 meters, based on average walking speed.
- The standard measure for walking distance is 80 meters for 1 minute of walking time

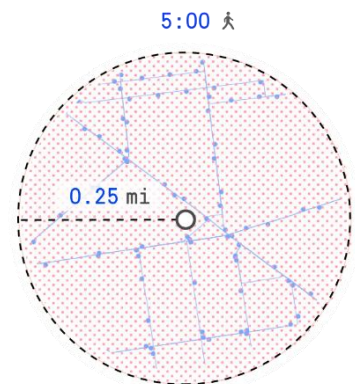


Fig 8.1 Pedestrian shed

- Residents may access a variety of community services within 5-10 minutes (400-800 meters/0.25-0.5 miles) walking distance of residential areas in walkable communities.
- Area – 5.54 km²
- Population (2020) – 43320
- Population density – 7814 people/km²

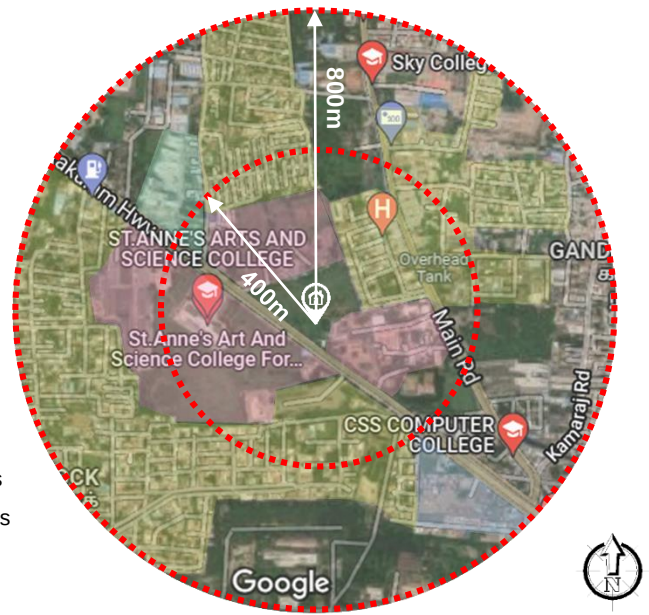


Fig 8.2 Walking distance

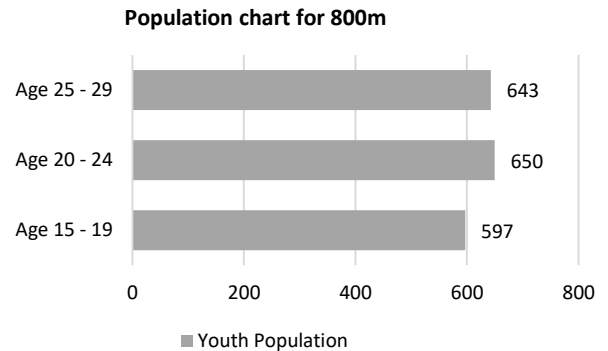
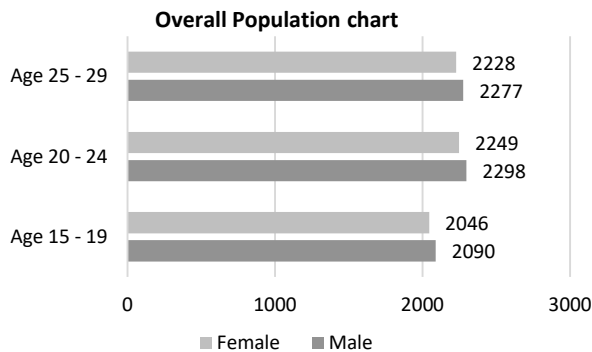


Fig 8.3 Population chart

- Population density (800m radius) – 6251 people
- Youth population (for 800m) – 1890
- 25% of 1890 – 470 (approx.)**

8.2 USER GROUP DATA - AGE GROUP AND ACTIVITY BASED ON SURVEY

- Late teens – Music (50%), Art and crafts (43%), Gardening, Gym (36%), Indoor game, Movie and Dance (29%)
- Youth – Music (69%), Gardening, Movies (56%), Dance, Arts and crafts (44%), Indoor games (31%)
- Late youth – Outdoor games, Movies (60%), Art and crafts, Music (53%), Yoga/Meditation (47%), Gym, Gardening (40%)

Primary users



Late teens
Age – 15 - 19



Youth
Age – 20 - 24



Late youth
Age – 25 -29



Coaches



Mentors



Other workers

Secondary users

Fig 8.4 User group

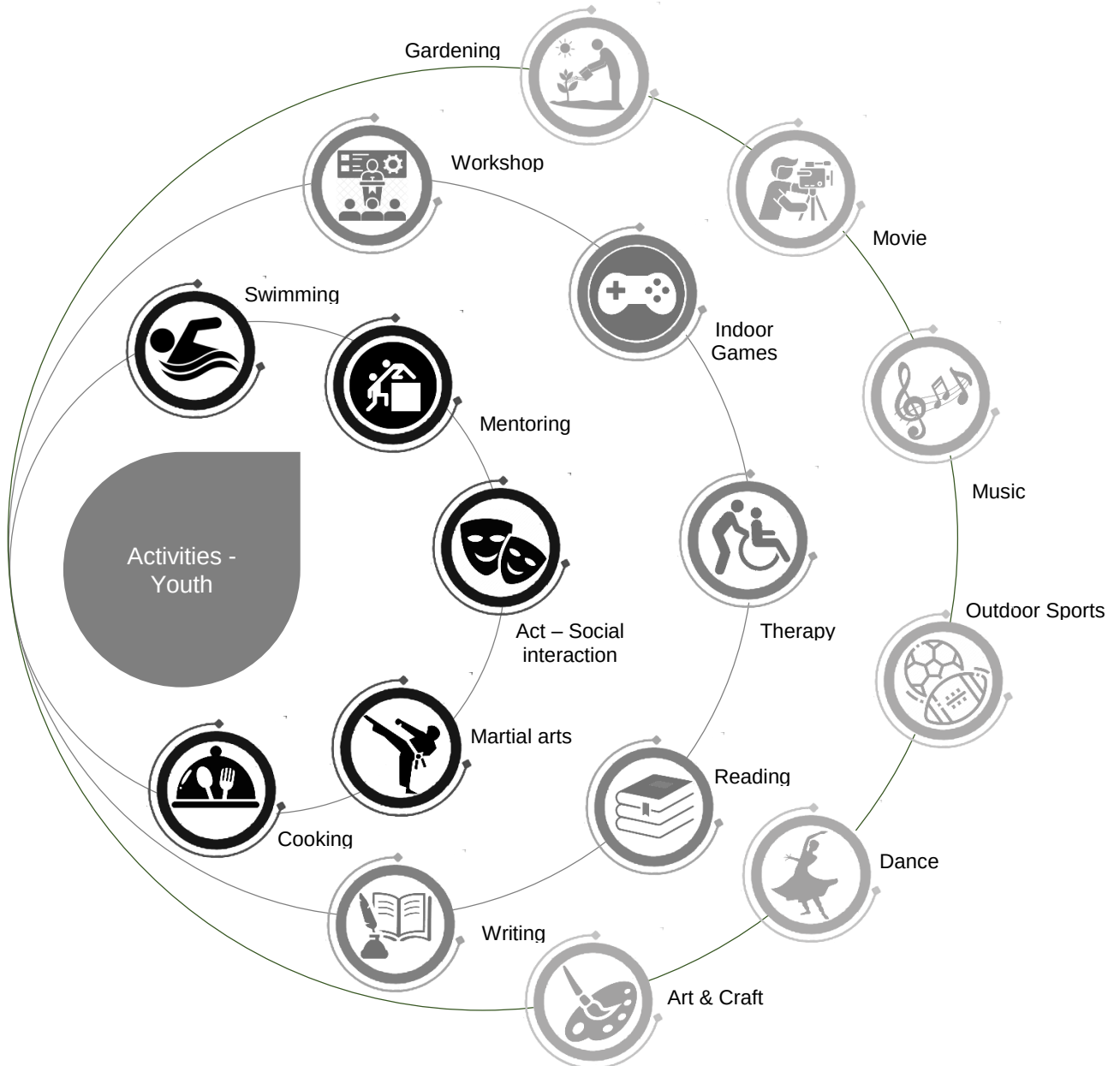


Fig 8.5 Recreational facilities

8.3 HYPOTHETICAL PROGRAMME - PROGRAMME ELEMENTS AND FUNCTION



- There are limited facilities available for youth development.
- Because of their unhealthy lifestyles, today's youth become physically inactive.
- Youth mental health is deteriorating, due to work stress.



- Possibility of developing a youth centre.
- Because of the nearby educational facilities, it has the potential to become a great attraction in the future.

8.3.1 NEED FOR THE USERS

- Given the demographics and survey results for the space, there is an obvious need for a basic sports and recreation facility for teenagers in Madhavaram.
- However, instead of being discrete components, they are re-envisioned as a major anchor connecting an active, healthy, and productive younger generation.

Basic sports facility + Recreation center (for youth)

=

Youth center

8.3.2 POTENTIAL ROLE FOR THE CENTER

- Furthermore, considering that the majority of users are young people, the center must become a place where they can learn and grow in order to captivate their interest.
- It must become a place where knowledge and well-being are imparted via observation and experience.

Learning + Entertainment

8.3.3 HYPOTHESIS



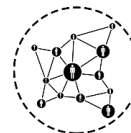
Increasing the
number of users



Supporting and
fostering a healthier
generation of youth



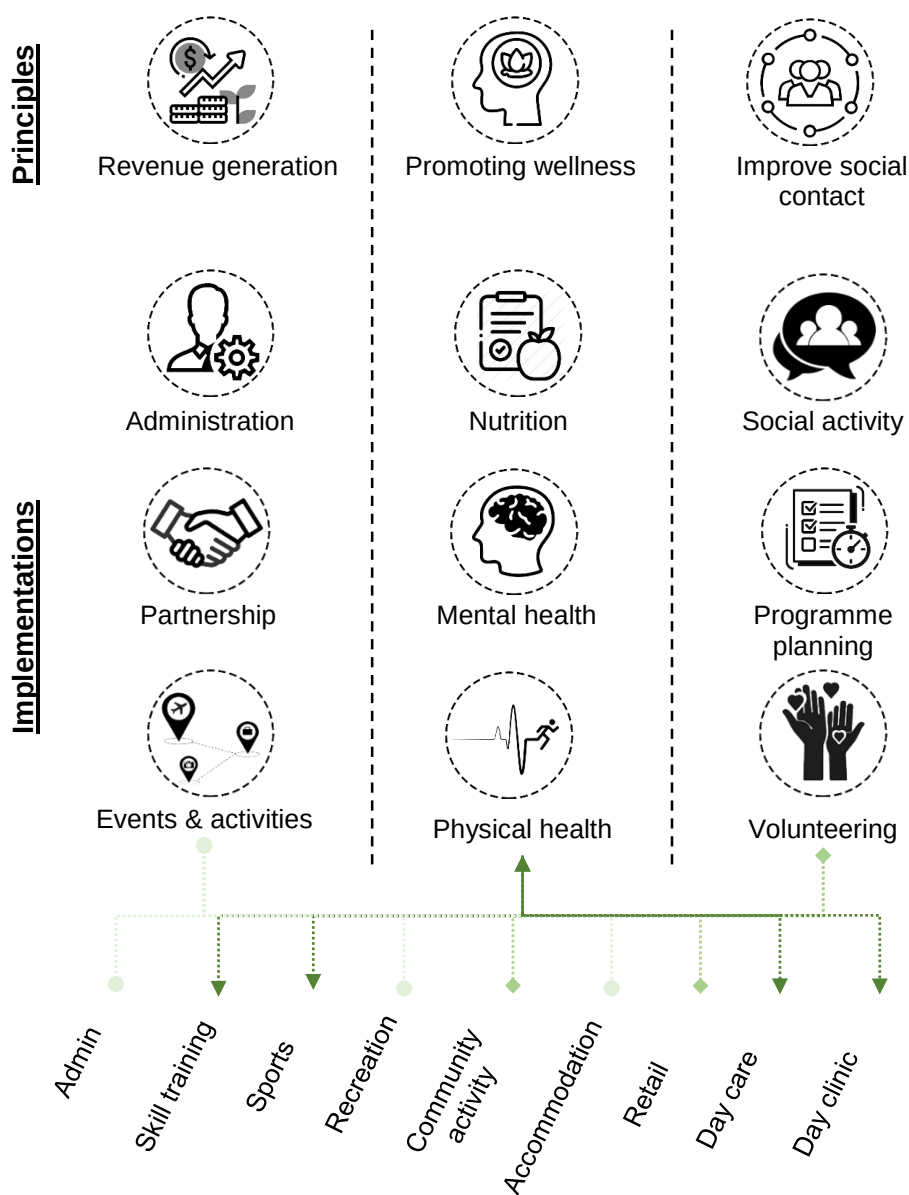
Promoting an
active youth
lifestyle



Promoting social cohesiveness
among young people from
diverse backgrounds

Fig 8.6 Design hypothesis

8.4 PROGRAMME COMPONENTS - NEED AND DESIGN ELEMENTS



8.4.1 DESIGN ELEMENTS

Learning by exposure

Knowledge center - Library, Reading rooms, Music room, Informal classrooms

Learning by experience

Performing arts center – Auditorium, Performance halls, Open air theatre, Music hall, Dance hall, Multi-purpose court

Learning by observing

Visual arts center – Exhibition gallery, Open courts/ plaza, gathering plaza, Craft street

Learning by doing

Collaborative studios – Workshops, Computer labs, Conference halls

Learning by interaction

In between spaces – Lounges, Food court, Restaurants, Café, Small shops, Departmental stores

Healing area

Therapy spaces – Counselling rooms, Mentor rooms, therapy rooms, Wellness room, Meditation rooms, Day care center, Day clinic

Supporting facilities

Administration – Guest house, Staff facilities, Services

8.5 MATRIX DIAGRAM - PROXIMITY OF SPACES

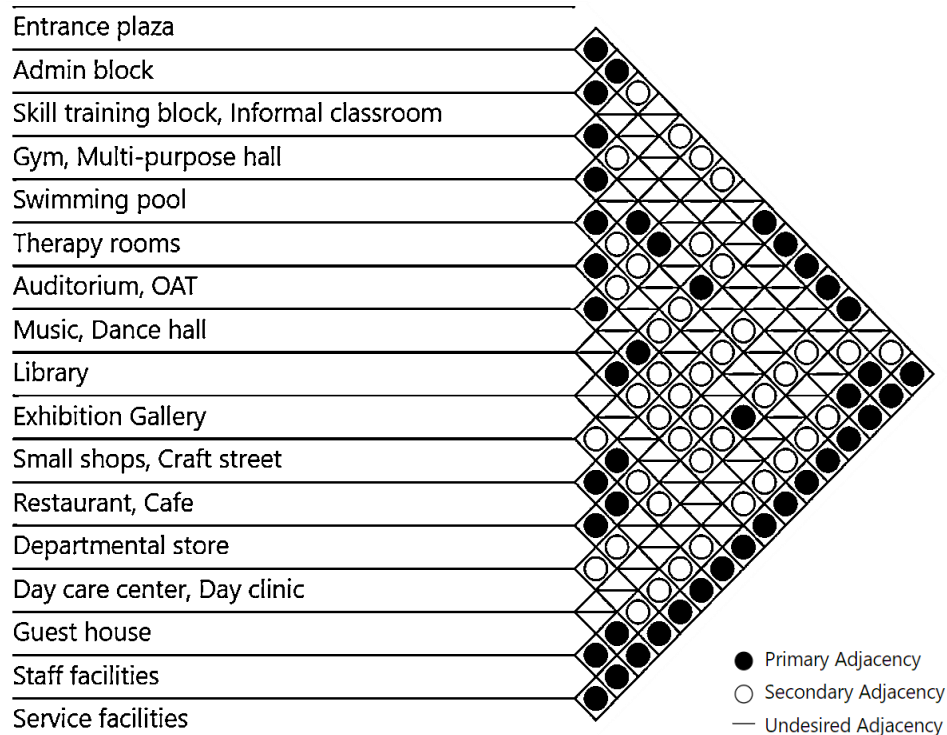


Fig 8.7 Matrix diagram

8.6 STANDARDS - ENERGY STANDARDS

Daylight Requirement	
Building Category	Percentage of above grade floor area meeting the UDI requirement
Educational	40%
Roof Assembly U-factor (W/m2.K) Requirements	
All building types	0.33
Opaque Assembly Maximum U-factor (W/m2.K) Requirements	
All building types	0.40
Vertical Fenestration	
Maximum allowable Window Wall Ratio (WWR)	40%
Minimum allowable Visual Light Transmittance (VLT)	0.27
Maximum U-factor (W/m ² .K)	3.0
Maximum SHGC Non-North	0.27
Maximum SHGC North for latitude ≥ 15°N	0.50

Table 8.1 ECBC [17]

Concert (Lux)	
Foyers, auditoria	100 to 150
Platforms	450
Corridors	70
Stairs	100
Libraries	
Shelves (stacks)	70 to 150
Reading rooms	150 to 300
Reading tables	300 to 700
Art galleries	
General	100 to 150
Paintings	200
Office	
Entrance hall	150
Reception	150
Meeting rooms	300
General office	300

Table 8.2 IS Standards [18]

8.7 AREA PROGRAMME

Programme	Area / person (m ²)	No. of users	No. of units	Total area (m ²)
1. ENTRANCE PLAZA - 270m² [19]				
Reception	0.6	4	1	2.4
Lobby	0.6	100	1	60
Gathering space (semi open)	2	100	1	200
Information centre	0.6	10		6
2. ADMINISTRATION BLOCK - 330m²				
Lounge	2	10	1	20
Management office	1(15)	6	2	180
Meeting room	1.5	10	2	30
Pantry	1.5	20	1	30
Store room	-	-	1	30
Security room	1.5	5	1	7.5
Trainer's room	3	1	4	12
Toilet + Wash area	1.5	-	3+2	(7.5+10) 17.5

3. SKILL TRAINING CENTRE - 540m²

Indoor workshops	4	35	1	150
Outdoor workshops	4	35	1	150
Store room	-	-	2	60
Maintenance room	-	-	1	30
Informal Classrooms	2	25	2	100
Counselling room	1(10)	3	3	30
Toilet + Wash area	1.5	-	3+4	(10+10) 20

4. SPORTS(INDOOR) - 960m²

Gym	1.5	30	-	60
Changing rooms	1	-	15	15
Swimming pool	4	40	2	160
Changing rooms	1	-	10	10
Shower/Bath	1	-	10	10
Training studio	1.5	50	2	120
Equipment storage	-	-	2	60
Toilet + Wash area	1.5	-	6+10	(10+15) 25
Multi-purpose court	0.6	250	1	500

5. SPORTS (OUTDOOR) - 250m²

Changing rooms	1	-	15	15
Equipment storage	-	-	2	60
Toilet + Wash area	1.5	-	4+5	(14+10) 24
Multi-purpose court	0.75	200	1	500

6. RECREATION BLOCK - 3430m²

Gathering plaza	2	100	1	200
Therapy rooms	1 (10)	2	5	50
Mentor rooms	1 (10)	2	5	50
Open air theatre	0.6	500	1	300
Dance hall	2	20	5	200
Pre-function hall	0.6	100	1	60
Performance hall	0.6	500	1	300
Green room	1.5	20	2	60
Changing rooms	1	-	10	10
Equipment storage	-	-	1	50
Library	2.5	80	1	200
Storage	-	-	1	50
Computer lab	1	60	1	60
Wellness rooms	6	1	10	60

Yoga room	2	25	1	50
Meditation room	2	25	1	50
Exhibition gallery	1	60	1	60
Toilet + Wash area	1.5	-	10+15	(37+20) 57
7. RETAIL BLOCK - 1370m²				
Small shops	2 (15)	-	10	150
Craft street	1	-	-	150
Outdoor restaurant	1.5	100	1	150
Indoor Restaurant	1.5	100	1	150
Departmental store	1	150	1	150
Food court	1.5	120	1	180
Café	1.5	80	1	120
Kiosks	2 (15)	-	10	150
Kitchen	4	10	1	40
Preparation area	2	15	1	30
Packing/Dispatch area	2	15	1	30
Store room	-	30	1	30
Toilet +Wash area	1.5	-	7+10	(26+15) 41
8. DAY-CARE CENTRE (FOR STAFF'S KIDS) - 2600m²				
Information desk	0.6	3	1	1.8
Crèche	2	25	2	100
Play area	2	25	2	100
Dining area	1.5	25	1	37.5
Toilet +Wash area	1.5	-	4+2	(9+10) 19
9. DAY CLINIC - 180m² [20]				
Waiting area	0.6	20	1	12
Consultation room	1.5 (10)	2	3	30
Emergency beds	4	10	1	40
Minor OT	4	10	1	40
Treatment area	2	2	3	12
Pharmacy	-	1	1	30
Toilet +Wash area	1.5	-	3+2	(7.5+10) 17.5
10. GUEST HOUSE (ACCOMMODATION FOR ARTISTS/PROFESSIONALS) - 190m²				
Lobby	0.6	10	1	6
Guest rooms	1 - (15)	1	10	150
Canteen	1.5	20	1	30
11. COMMUNITY AVTIVITY - 150m²				
Gardening (Semi open)	1.5	100	1	150

12. STAFF FACILITIES - 70m²

Staff lounge	2	20	1	40
Pantry	1.5	20	1	30

13. SERVICES (10%) of total area - 170m² [21]

Electrical & AHU room	-	-	2	60
Plumbing & fire fighting system room	-	-	1	30
Waste treatment plant	-	-	1	30
Sewage treatment plant	-	-	1	50

Total area

8,170

Circulation area (30%) of Total area

2,540

Overall building area

10,710

Table 8.3 Area programme

CHAPTER 9 DESIGN DETERMINANTS

9.1 SITE ZONING

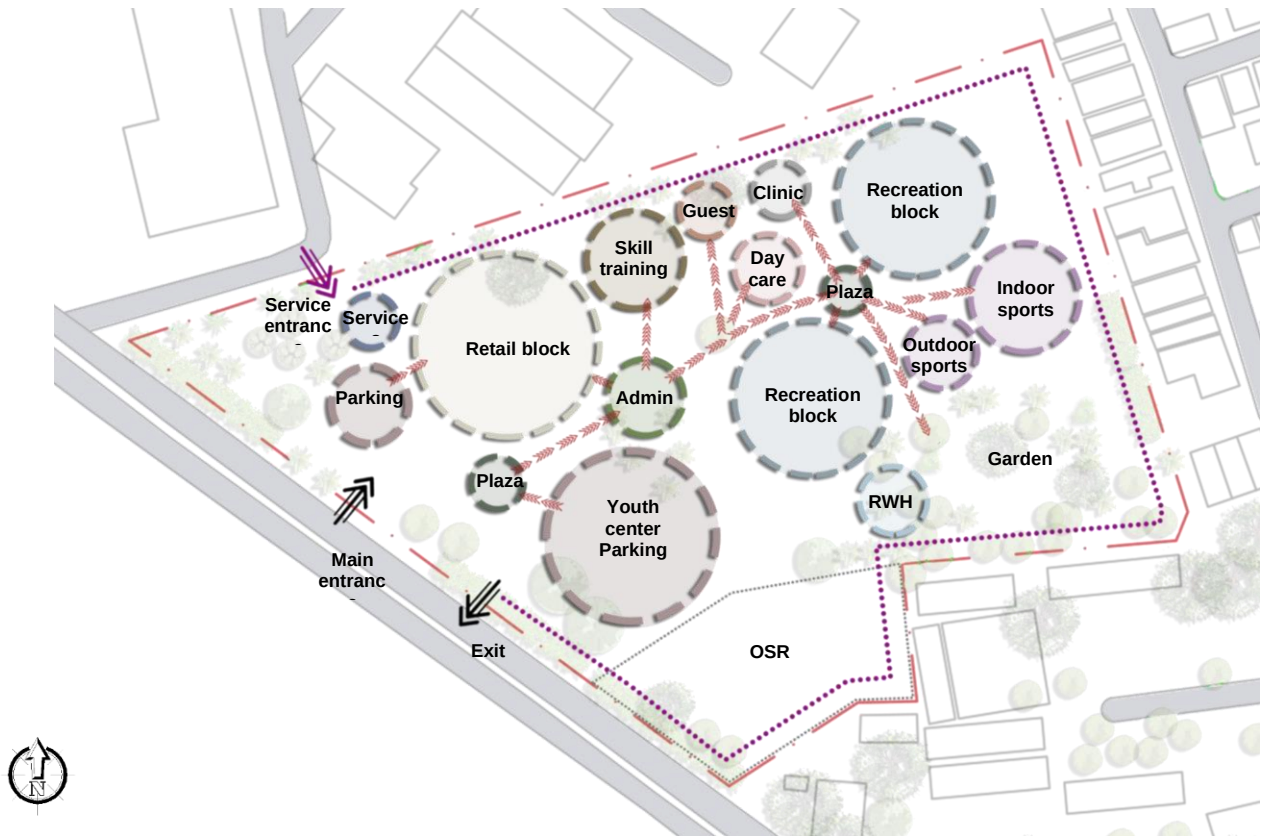


Fig 9.1 Site zoning

- Retail block is located near the service road to have independent access so that the general public, in addition to those attending the youth centre, may access it.
- There is separate parking for retail and public access towards the north-west.
- Parking for the youth center is provided to the west, with trees to protect from intense radiation.
- Admin is placed in the middle so that all other blocks may quickly reach it.
- Skill training, day-care, and clinic that require management oversight are positioned closer to the admin block.
- Staffs will be accommodated in guest rooms near the skill training facility.
- The recreation block, which is the main focus, is located in the center to draw attention to it.
- The indoor sports complex is located in the east, and outdoor sports block is located closer to the indoor sports block and will be shaded by it.
- In the south, there is a provision for rainwater harvesting (lowest slope)

9.2 BLOCK MASSING

9.2.1 ORIENTATION

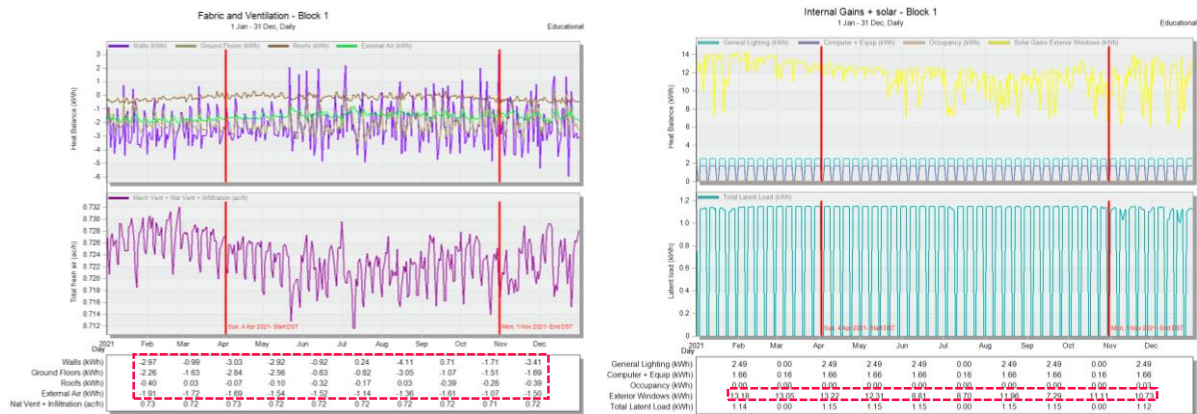


Fig 9.2 30° N-S

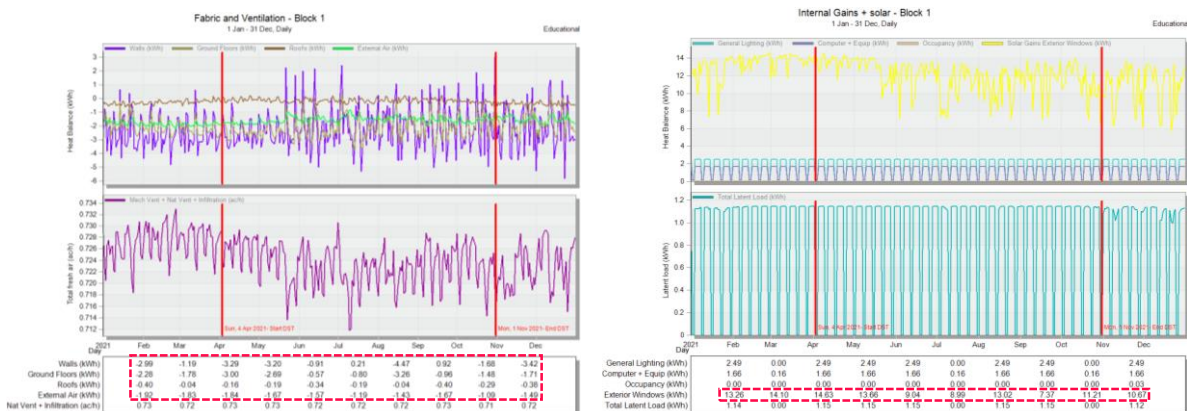


Fig 9.3 45° N-S

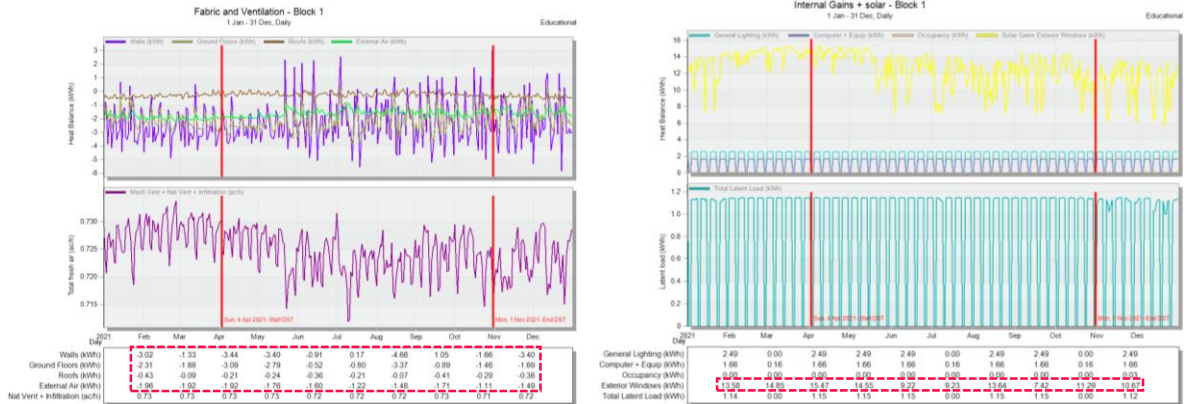


Fig 9.4 60° N-S

When compared to 45° N-S and 60° N-S orientations, 30° N-S orientation shows reduced heat gain and via walls, floors, windows, glazing, and roofs.

9.2.2 3D MASSING ITERATIONS

- The shape of a building can drastically affect its energy efficiency.
- Heat from a building escapes from external faces – such as walls, roofs and terraces – so the larger the area of these faces, the more opportunity for heat to break through.
- If the Form Factor is high, thicker insulation will be required. So an inefficient form needs thicker insulation and more of it and becomes more expensive.

Heat Loss Form Factor (HLFF) [22]

- The Heat Loss Form Factor is a measure of compactness and an indication of how much insulation will be required.
- Heat Loss Form Factor (HLFF) is the ratio between the building's envelope area (EA) and it's net floor area (NFA). It is calculated as $HLFF = EA / NFA$.
- HLFF is a number generally between 0.5 and more, with a lower number indicating a more compact building.

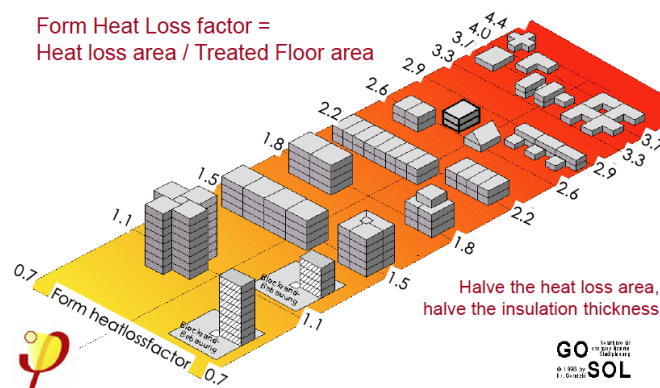


Fig 9.5 Heat Loss Form Factor

Surface to Volume Ratio (SVR)

- Surface to Volume Ratio is an important factor in determining heat loss and gain. So, smaller S/V ratios imply minimum heat gain and heat loss.
- Surface to Volume Ratio (SVR) is the ratio between the building's envelope area (EA) and it's volume (V), it is calculated as $SVR = EA / V$.
- In warm-humid climates the prime concern is creating airy spaces. This might not necessarily minimize the S/V ratio.

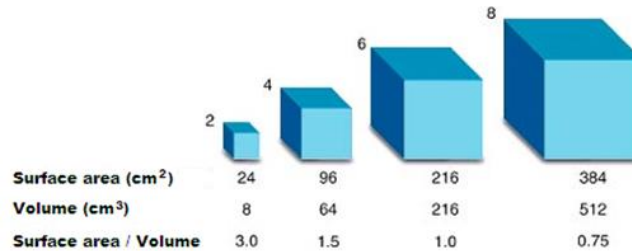
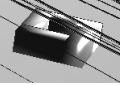
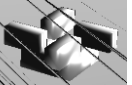
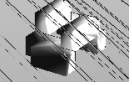


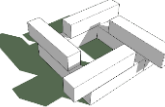
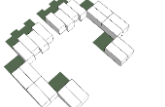
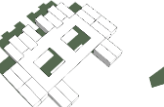
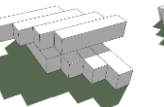
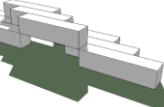
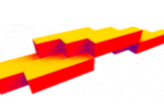
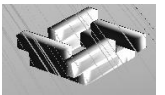
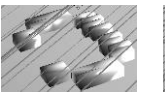
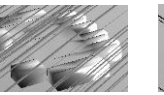
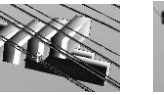
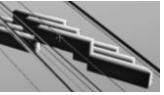
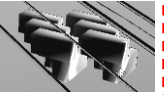
Fig 9.6 Surface to Volume Ratio (SVR)

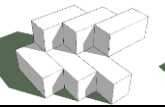
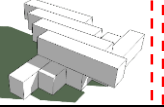
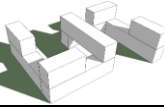
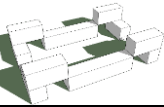
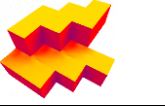
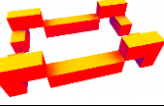
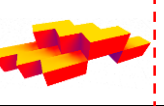
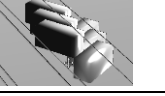
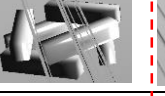
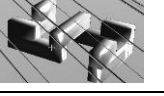
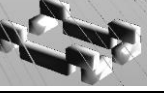
9.2.3 ITERATION - ANALYSIS

Parameters	Form 1	Form 2	Form 3	Form 4	Form 5	Form 6	Form 7
Forms							
Radiation analysis							
Wind analysis							
Heat loss form factor	2.31	6.0	5.43	5.97	6.86	6.27	6.27
Surface to volume (1/m)	0.6	1.66	1.31	1.44	1.66	1.51	1.51
Envelope area m²	866.8	144.1	342.3	752.1	720.5	526.39	526.4

Parameters	Form 8	Form 9	Form 10	Form 11	Form 12	Form 13	Form 14
Forms							
Radiation analysis							

Wind analysis							
Heat loss form factor	6.02	5.23	5.9	6.17	4.82	6.15	6.91
Surface to volume (1/m)	1.45	1.26	1.42	1.49	1.16	1.48	1.67
Envelope area m ²	505.9	769.49	495.2	259.2	708.49	516.4	435.2

Parameters	Form 15	Form 16	Form 17	Form 18	Form 19	Form 20
Forms						
Radiation analysis						
Wind analysis						
Heat loss form factor	5.44	5.45	3.21	4.05	4.97	5.02
Surface to volume (1/m)	1.31	1.32	1.3	0.98	1.2	1.21
Envelope area m ²	931.92	1,145.2	1,141.15	679.7	939.99	632.7

Parameters	Form 21	Form 22	Form 23	Form 24	Form 25	Form 26
Forms						
Radiation analysis						
Wind analysis						
Heat loss form factor	6.26	6.18	4.37	5.87	6.93	5.97
Surface to volume (1/m)	1.51	1.49	1.06	1.42	1.67	1.44
Envelope area m ²	931.92	1,145.2	1,141.15	679.7	939.99	632.7

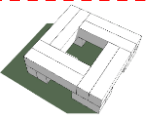
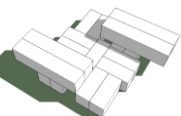
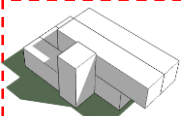
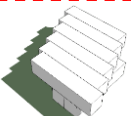
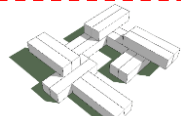
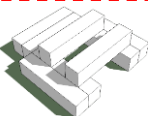
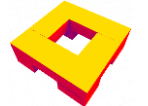
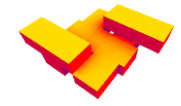
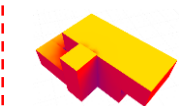
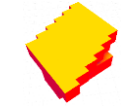
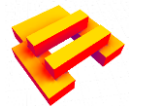
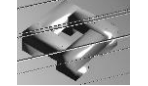
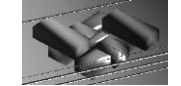
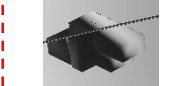
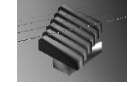
Parameters	Form 27	Form 28	Form 29	Form 30	Form 31	Form 32
Forms						
Radiation analysis						
Wind analysis						
Heat loss form factor	4.02	6.86	4.37	3.33	4.37	5.15
Surface to volume (1/m)	0.97	1.66	1.06	0.8	1.06	1.24
Envelope area m ²	1,013.4	144.1	734.6	699.1	1,469.4	865

Table 9.1 3d massing iterations

These are some of the combinations that have an HLFF less than 6 and a minimal SVR. Other forms can be explored while developing spatial functions.

CHAPTER 10 SUSTAINABLE MEASURES

10.1 BIO-CHAR FILTER - WATER TREATMENT MEASURES

Rainwater collected at site level is filtered through biochar system. Biochar, like all activated carbon, will filter many types of organic and inorganic impurities from water.

10.1.1 HOW DOES BIO-CHAR FILTER WORKS?

- Biochar can be used as an adsorbent to remove different pollutants in water and wastewater.
- Charcoal removes impurities from water by a process called adsorption, meaning that the contaminants adhere to the charcoal's surface. Because it is porous, however, water can flow through and permeate the charcoal.

10.1.2 BENEFITS OF BIO-CHAR

- Biochar can improve water quality, reduce soil emissions of greenhouse gases, reduce nutrient leaching, reduce soil acidity, and reduce irrigation and fertilizer requirements.

- Biochar is a boon for sustainable growth and maintenance of lawns. It is a hygroscopic product that can retain nutrients and water in the soil and plants, which leads to the healthy growth of grass and plants in your backyard.

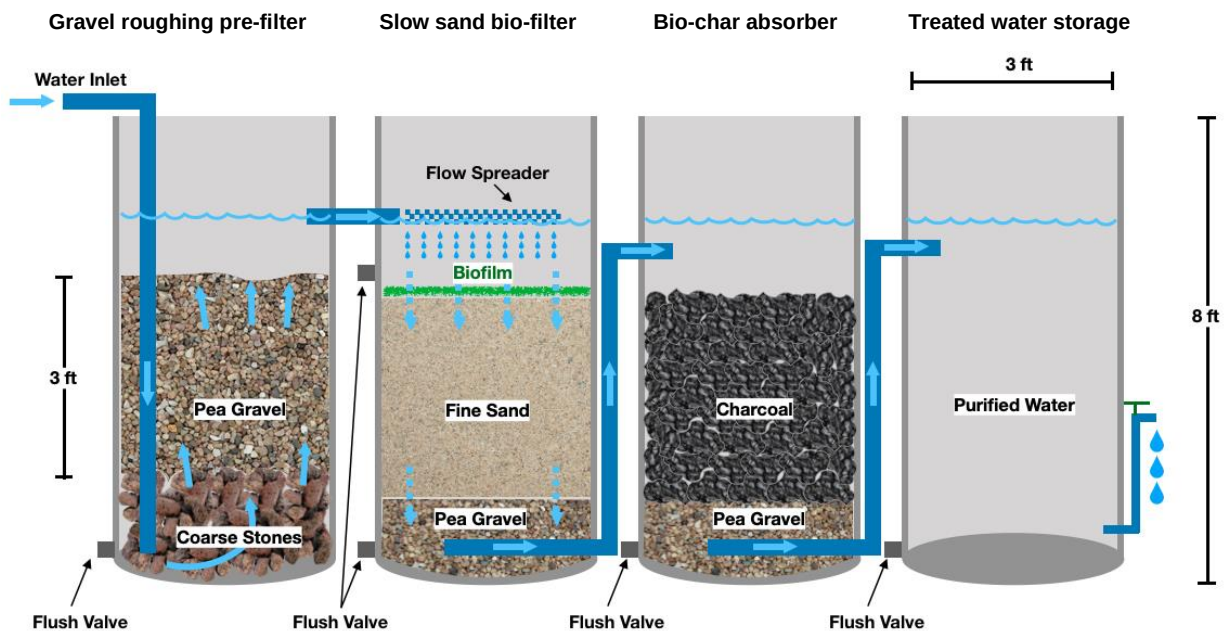
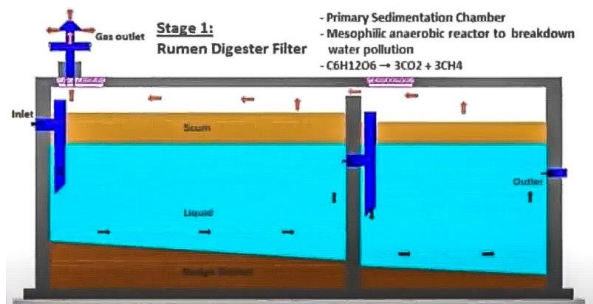


Fig 10.1 Bio-char filter

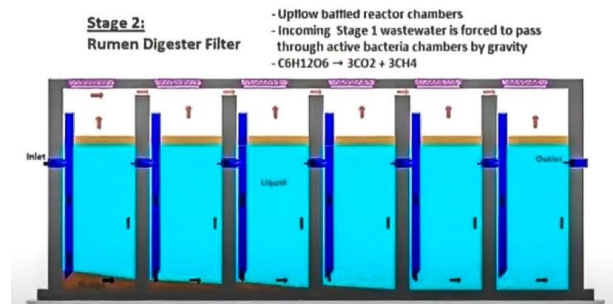
10.2 ECO STP - WASTE-WATER TREATMENT MEASURES [23]

- ECOSTP Technologies converts "bad water into good water using the cow stomach mechanism".
- An anaerobic bacteria catalyst seed made from cow dung substrate is added (one-time addition) and the end result is that sewage is converted into water, some gas, and very little sludge (digester).

10.2.1 HOW DOES ECO STP WORKS?



Stage 1, is where **all sewage lands and get settled** at the bottom.



Stage 2, has **multiple mini chambers** and **water flows using gravity** with series of pipes.

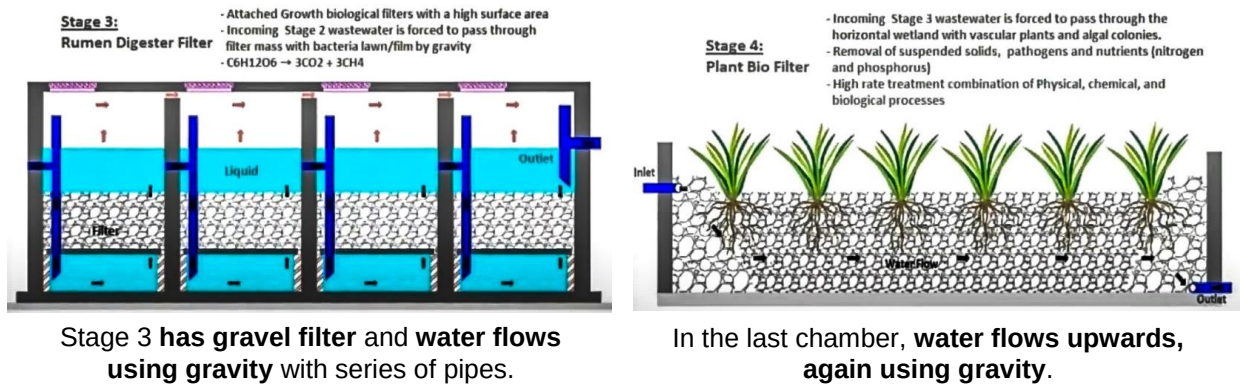


Fig 10.2 Eco STP stages

10.2.2 ADVANTAGES OF ECO STP

- Eco STP's are 90% more cost effective than regular STP. 20% lower capital expenditure (such as cost of building the STP) and 93% lower operational costs (since power, chemicals and operators are not needed).
- Even the operational costs are minimal as there is no maintenance staff needed.

10.3 HYDROPONIC SYSTEM - WATER EFFICIENT USAGE MEASURES [24]

Hydroponics is the cultivation of plants without using soil. Hydroponic flowers, herbs, and vegetables are planted in inert growing media and supplied with nutrient-rich solutions, oxygen, and water.

10.3.1 HOW DOES HYDROPONICS WORK?

- Hydroponics operates under a very simple principle: provide plants exactly what they need when they need it.
- If a plant's root system is exposed directly to water and nutrition, the plant does not have to exert any energy in sustaining itself.

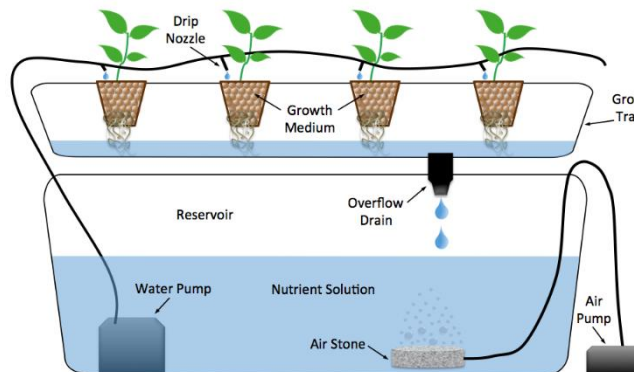


Fig 10.3 Hydroponic system

10.3.2 HYDROPONICS IN HOT AND HUMID CLIMATE

- Crops cannot handle high humidity and temperature levels, thus in order to grow them outside in tropical and subtropical locations, measures to decrease humidity and temperature levels must be sought.

Shade-cloth

- The use of a Shade-cloth over a crop is beneficial for many reasons:
- Reduces heat stress
- Promotes the cooling of a growing area
- Reduces the intensity of sunlight, which can be harmful for seedlings and crops that are normally suited to shady conditions or cooler climates
- Allows plants to be grown in regions they are not normally found in.
- In hydroponics, the water is used and re-used multiple times, over periods of up to several weeks.

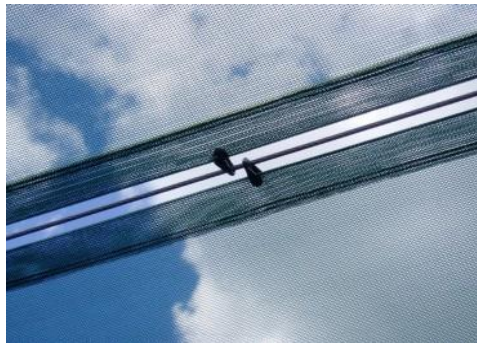


Fig 10.4 Cloth shade

10.4 EXTERIOR – INSULATION - SUPER THERM CERAMIC PAINT [25]

Super Therm® is an energy efficient, highly advanced insulation coating system that contains 4 unique ceramics that block solar heat entering a structure, which is amazingly non-toxic, has received Cradle to Cradle certification.



Fig 10.5 Container vs super therm coated container

10.4.1 BENEFITS OF SUPER THERM

- Cost efficient – ₹ 40/m²
- U-value – 0.070 W/m².K
- Blocks 96.1% of Heat Load (blocks the absorption and transfer of heat)
- Blocks Water and Moisture Penetration – certified and tested water barrier
- Safe and non-toxic, Environmentally Friendly water based and Energy Star rated
- Prevents Mould and Mildew
- Blocks 68% of All Sound Waves, Flame Spread and Smoke
- Saving you up to 40% in electricity costs

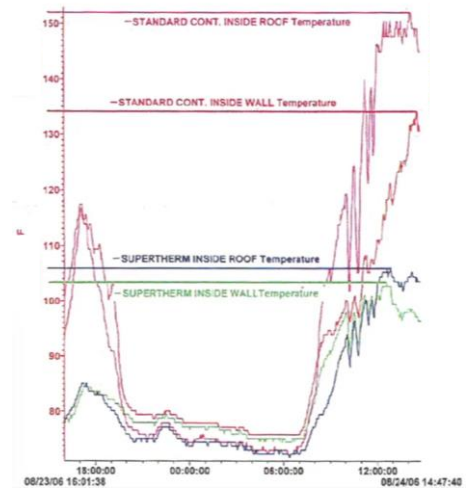


Fig 10.6 Container wall & roof performance

10.5 INTERIOR - CORK INSULATION AND MDF BOARDS [26]

- According to the research conducted during the dissertation, cork insulation has superior thermal performance, is a little more cost-effective, and is more environmentally friendly than spray foam insulation, which is not.

10.5.1 CONTAINER WALL MATERIAL LAYERS

Insulation	Cost (₹) (per square meter)	Thickness (mm)	k-value (W/m.K)	Image of the material	Property
Cork Insulation	150	10 - 60	0.035		• Eco-friendly • Renewable and biodegradable • Has acoustic properties

Table 10.1 Cork insulation

Dry wall	Cost (₹) (per square meter)	Thickness (mm)	k-value (W/m.K)	Image of the material	Property
Gypsum board	130	5	0.25		• Low cost • Ease of installation and finishing • Fire resistance • Sound control

Table 10.2 Gypsum drywall

10.5.2 TO TREAT WET-ZONE INSIDE CONTAINER BUILDING

- Moisture-resistant Gypsum board, also known as MR board or Green board, has superior moisture and water resistance.
- It is hence appropriate for regions exposed to water, moisture, and humidity.
- It may be used as a base for wall tile in bathrooms, showers, and other moist spaces in a container building.



Fig 10.7 MR gypsum board

CHAPTER 11 DESIGN DEVELOPMENT

11.1 SCHEME PLANS

11.1.1 FLOOR PLANS



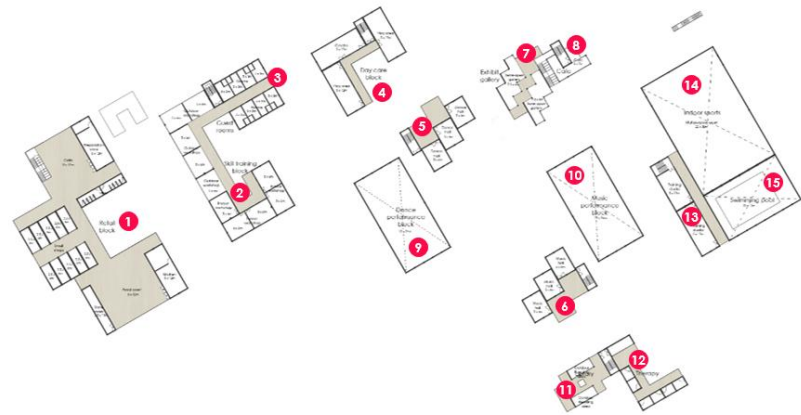
Fig 11.1 Ground floor plan

- 20) Retail entrance & exit
- 21) Main entrance & exit
- 22) Security gate
- 23) Service entrance
- 24) Retail block
- 25) Service block
- 26) Four wheeler Parking
- 27) Two wheeler Parking
- 28) Gathering Plaza
- 29) Administration block

- 10) Day care center
- 11) Clinic
- 12) Skill training block
- 13) Outdoor sports
- 14) Indoor sports block
- 15) Swimming pool
- 16) Dance performance hall
- 17) Music performance hall
- 18) Computer lab
- 19) Café

- 1) Library
- 2) Yoga and meditation block
- 3) Hydroponics
- 4) Rainwater harvesting tank
- 5) Eco STP
- 6) Bio-char filter
- 7) Community garden
- 8) Open Amphitheatre
- 9) Permeable pavers

1. Retail block
2. Workshop
3. Guest rooms
4. Crèche and play area
5. Dance floor
6. Music floor
7. Exhibit gallery
8. Café
9. Dance hall below
10. Music hall below
11. Outdoor reading area
12. Therapy rooms
13. Training studio
14. Multipurpose court below
15. Swimming pool below



Scale – 1:500

Fig 11.2 First floor plan

Ground floor area – 4435 m²

First floor area – 1425 m²

Total built-up area – 5860 m²

Site coverage – 15%

FSI – 0.23

11.2 WINDOW WALL RATIO - WWR CALCULATION

Administration block		
Orientation	Opaque area	Non-opaque area
North	21.6 m ²	190.61 m ²
South	10.8 m ²	
West	10.56 m ²	
East	10.08 m ²	
	53.04 m ²	WWR = 27.8%

Skill training block		
Orientation	Opaque area	Non-opaque area
North	56.35 m ²	295 m ²
South	24 m ²	
West	27.8 m ²	
East	8.52 m ²	
	116.67 m ²	WWR = 39%

Recreation block		
Orientation	Opaque area	Non-opaque area
North	81.8 m ²	972 m ²
South	132.6 m ²	
West	54.7 m ²	
East	55.1 m ²	
	324.4 m ²	WWR = 33.3%

Administration block			Skill training block			Recreation block		
Orientation	Opaque area	Non-opaque area	Orientation	Opaque area	Non-opaque area	Orientation	Opaque area	Non-opaque area
North	21.6 m ²	190.61 m ²	North	56.35 m ²	295 m ²	North	81.8 m ²	972 m ²
South	10.8 m ²		South	24 m ²		South	132.6 m ²	
West	10.56 m ²		West	27.8 m ²		West	54.7 m ²	
East	10.08 m ²		East	8.52 m ²		East	55.1 m ²	
	53.04 m ²	WWR = 27.8%		116.67 m ²	WWR = 39%		324.4 m ²	WWR = 33.3%

Table 11.1 WWR calculation

Vertical Fenestration (ECBC)		Vertical Fenestration (ECBC)	
Maximum allowable Window Wall Ratio (WWR)	40%	Achieved Window Wall Ratio (WWR)	36.16%

Inference:

Window Wall Ratio (WWR) satisfies ECBC requirement – 39.16%

11.3 SUSTAINABLE SITE FEATURES - INTERPRETING PASSIVE STRATEGIES

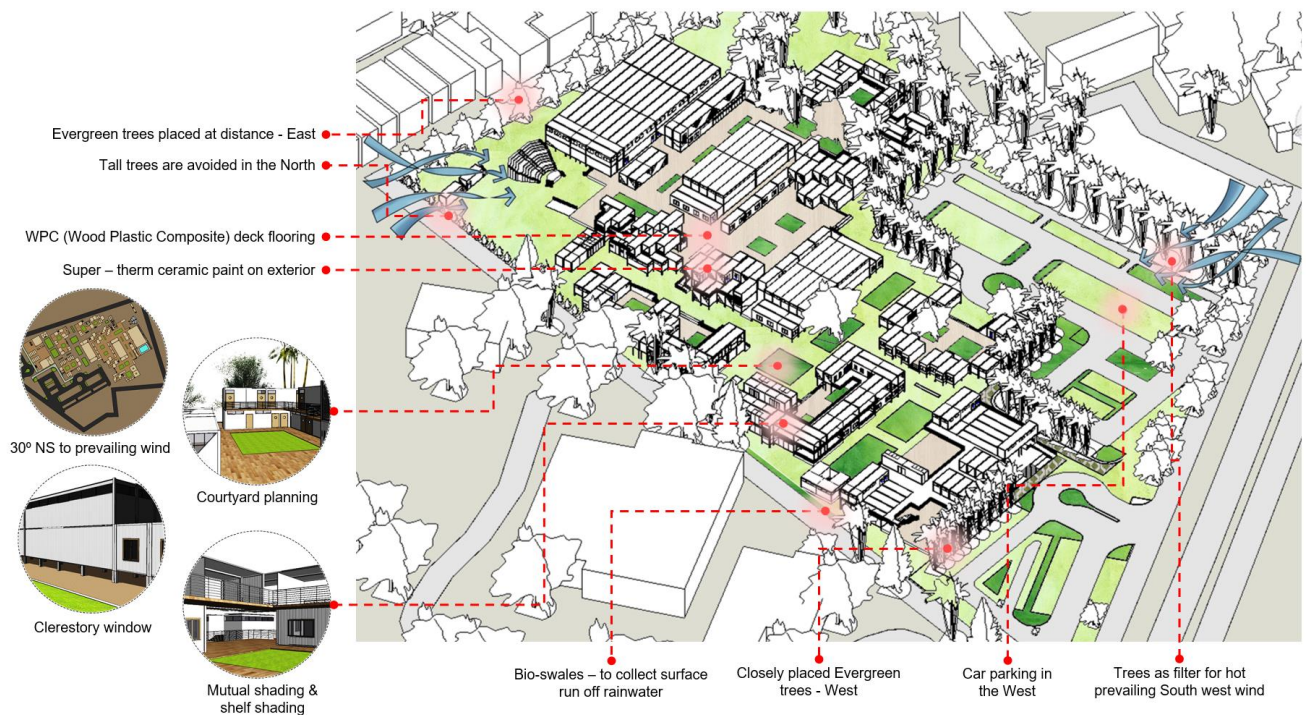


Fig 11.3 Passive strategies incorporated - 1

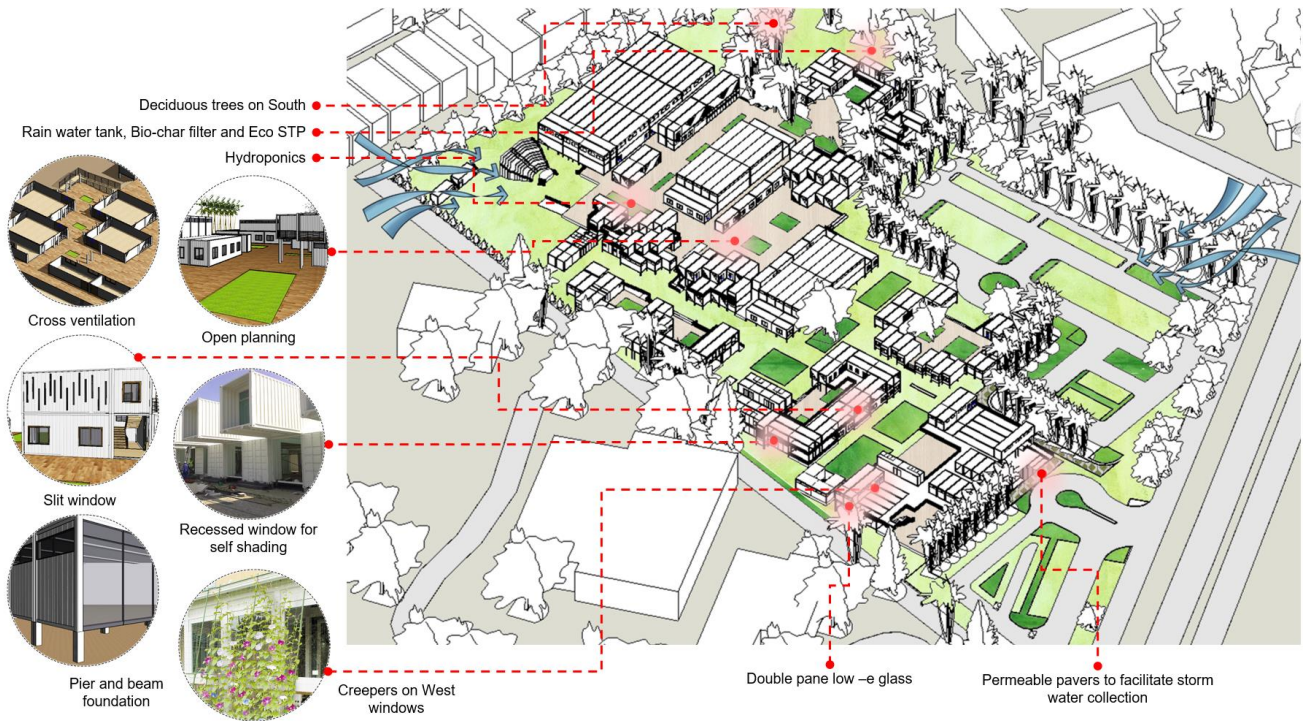


Fig 11.4 Passive strategies incorporated - 2

11.4 DETAILED FLOOR PLAN

11.4.1 ADMINISTRATION BLOCK



Fig 11.5 Administration block

11.4.2 RETAIL BLOCK

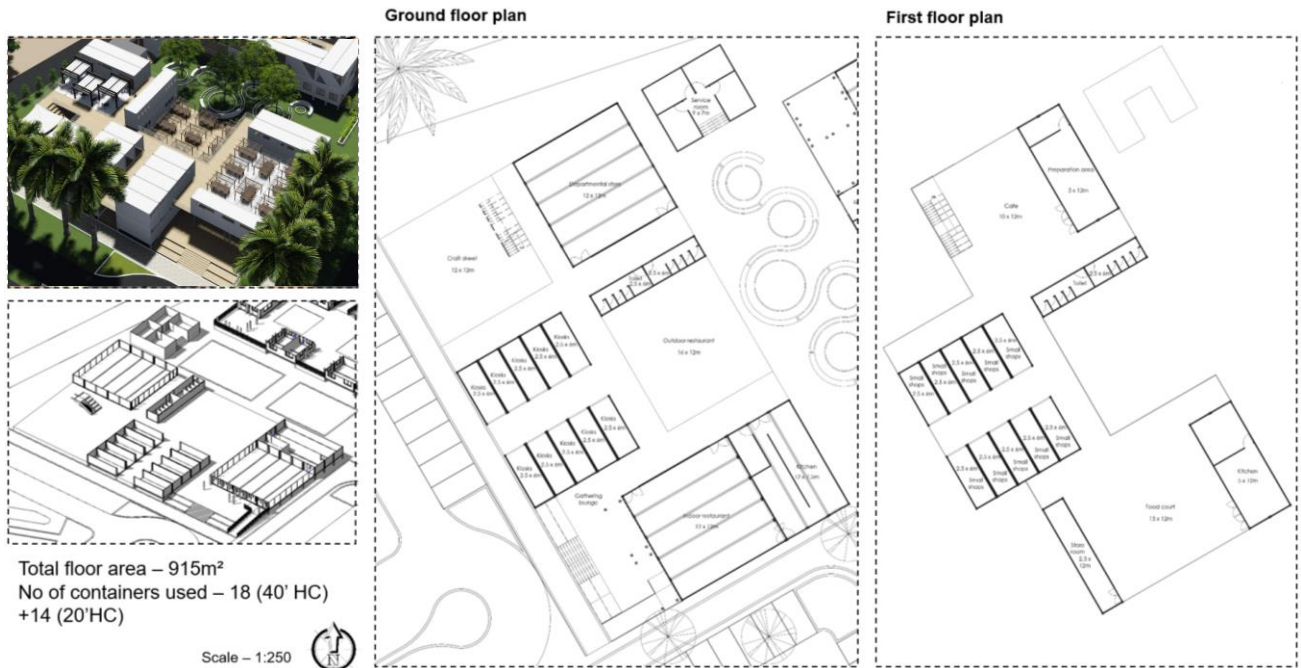


Fig 11.6 Retail block

11.4.3 SKILL TRAINING BLOCK

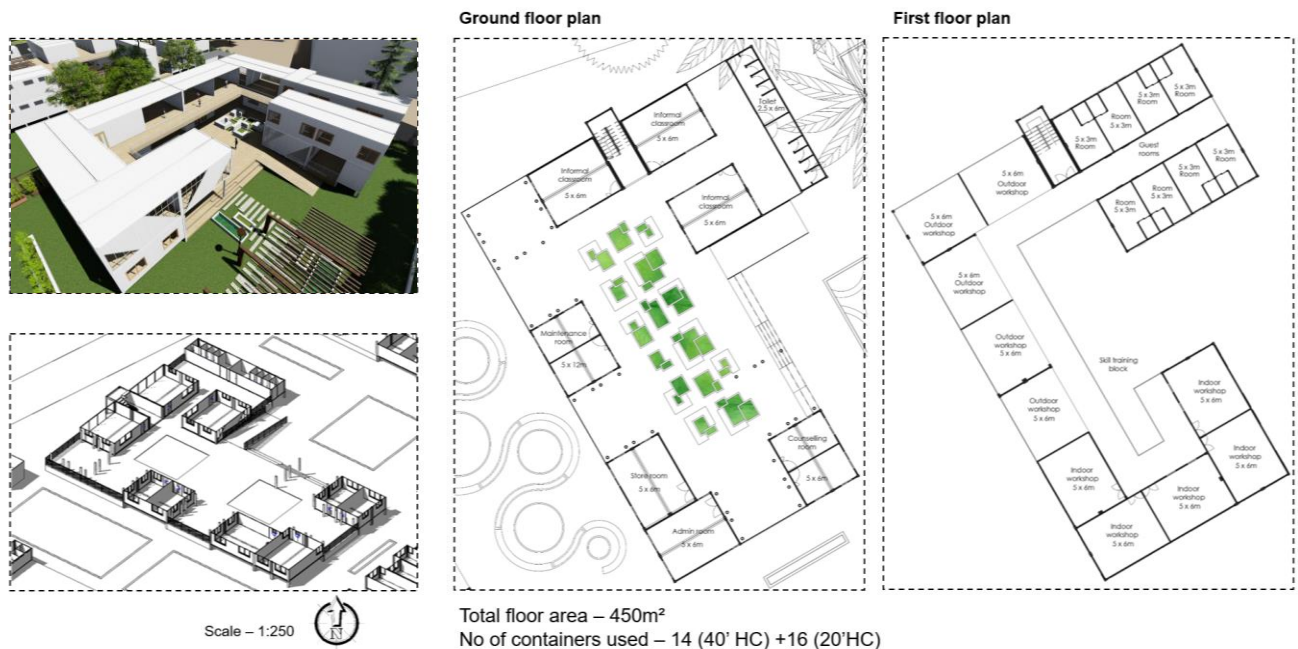


Fig 11.7 Skill training block

11.4.4 DAY-CARE AND CLINIC BLOCK

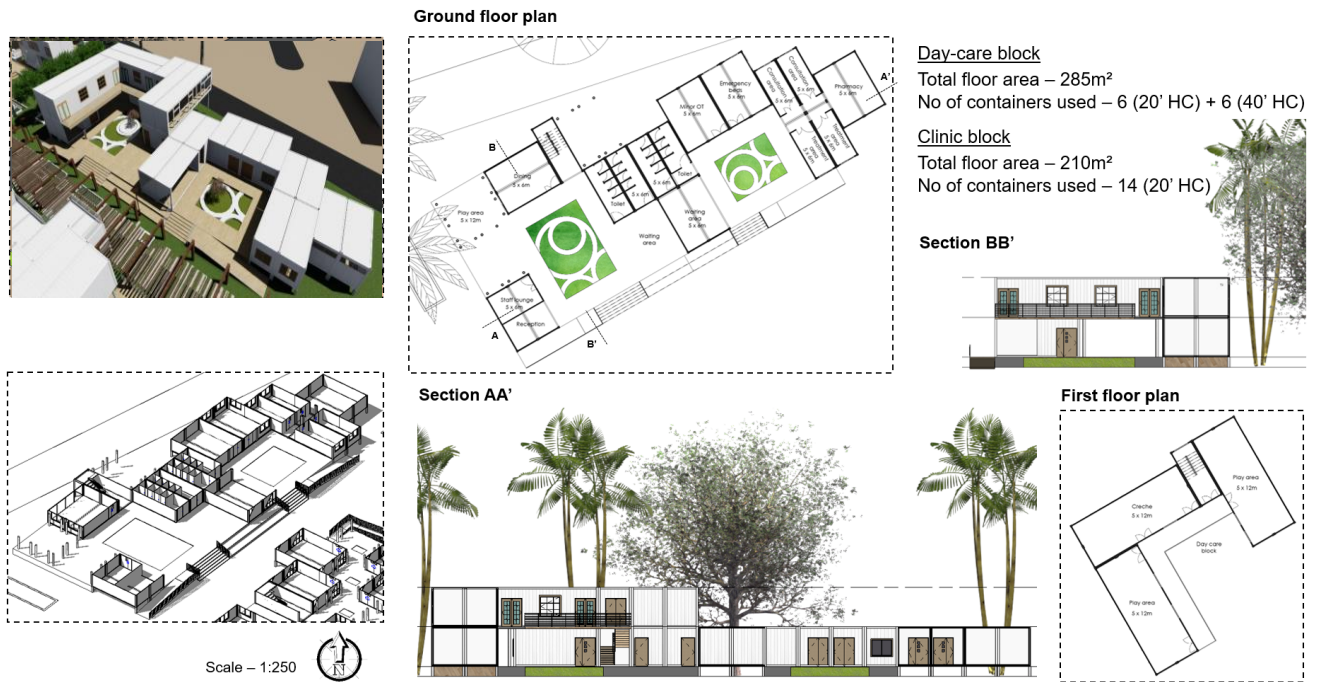


Fig 11.8 Day-care and clinic block

11.4.5 DANCE AND MUSIC HALL



Fig 11.9 Dance and Music hall - 1

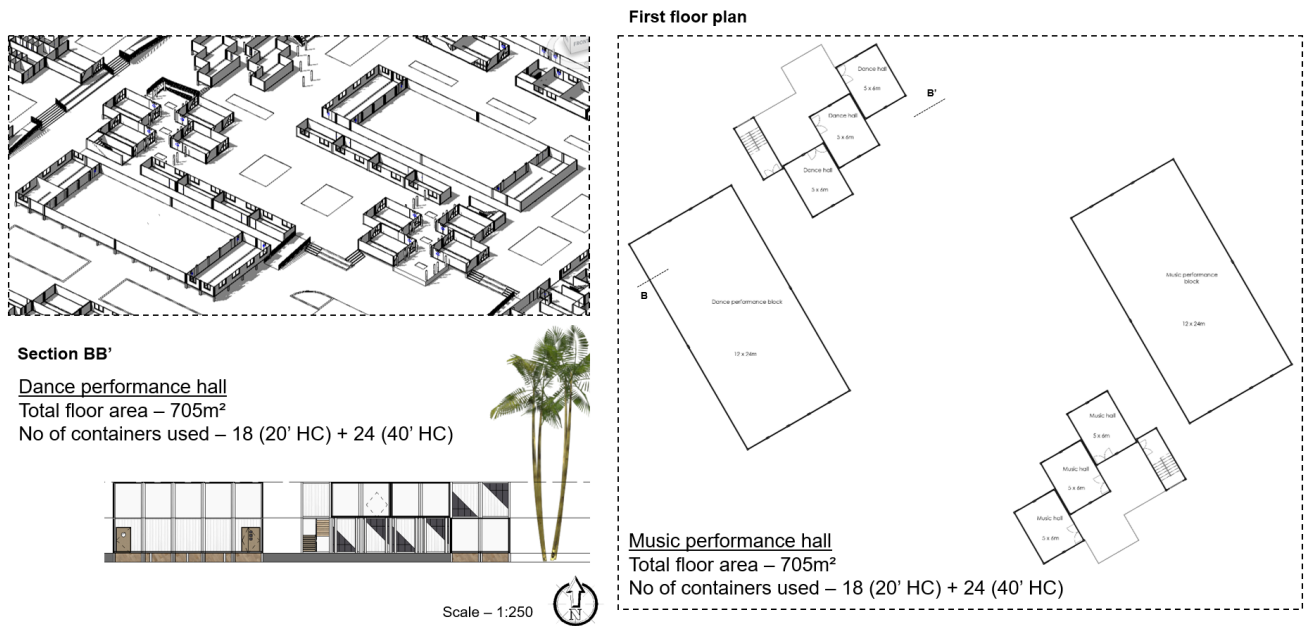


Fig 11.10 Dance and Music hall - 2

11.4.6 COMPUTER LAB AND EXHIBIT GALLERY BLOCK

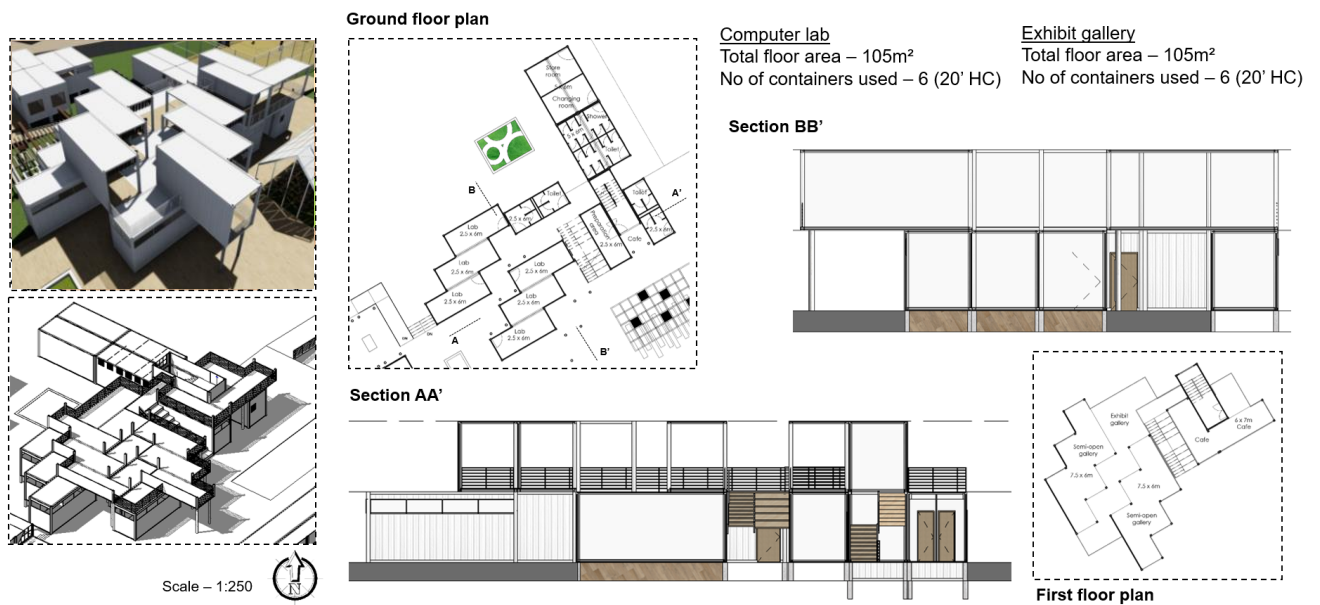


Fig 11.11 Computer lab & exhibit gallery block

11.4.7 INDOOR SPORTS BLOCK

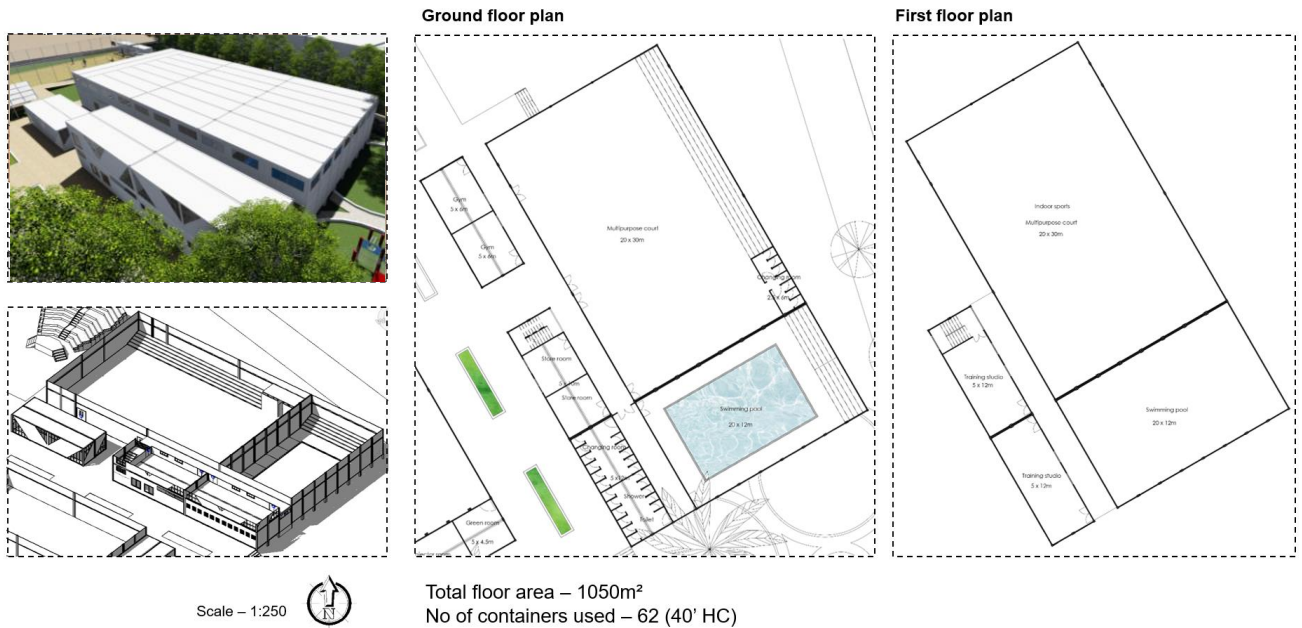


Fig 11.12 Indoor sports block

11.4.8 LIBRARY, YOGA AND MEDITATION BLOCK

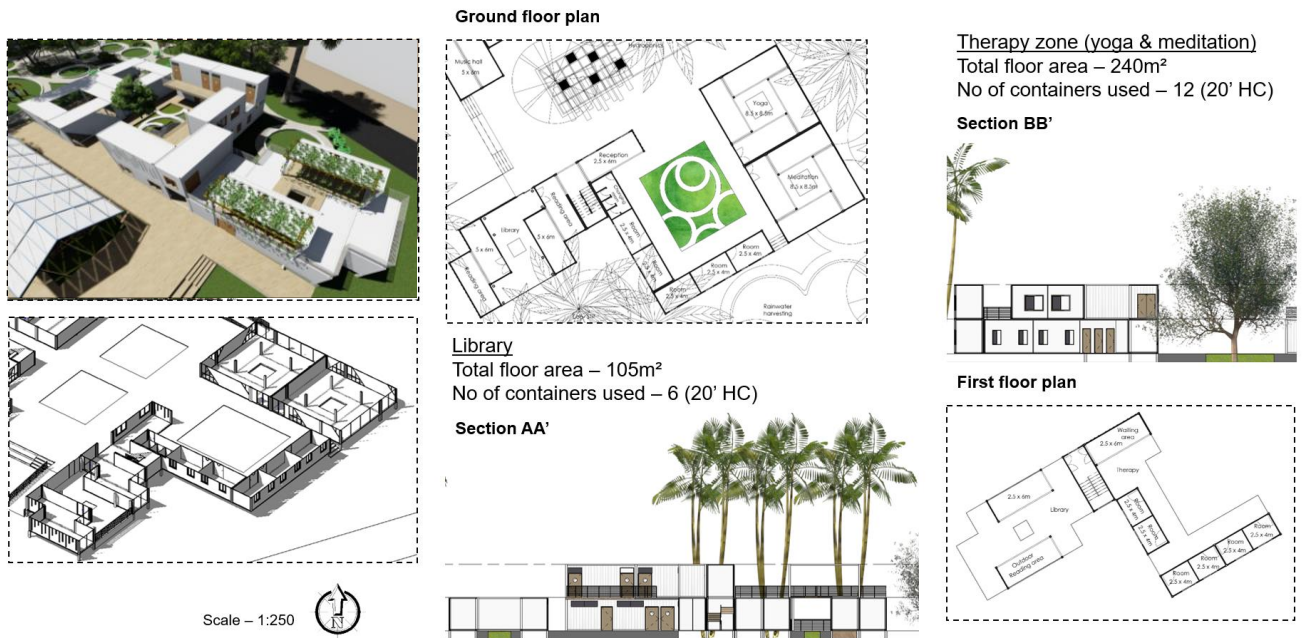


Fig 11.13 Library, yoga and meditation block

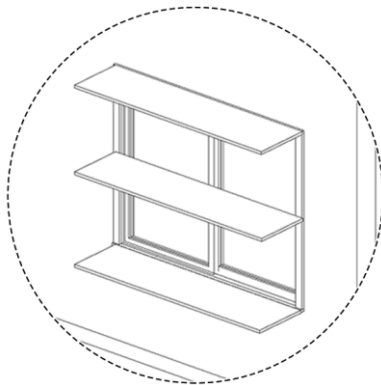
11.5 SHADING DEVICE

11.5.1 DESIGN OF BASIC SHADING DEVICE

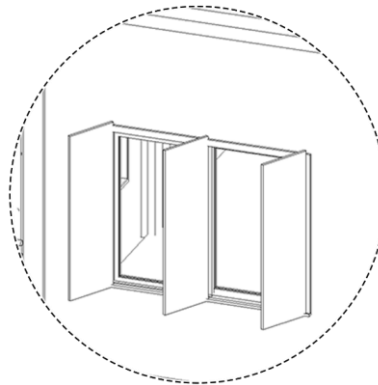
- Shading devices are designed according to SP 41 design recommendations.
- Window types,
 - W1 = 1.2 m x 1.5 m
 - W2 = 1.5 m x 1.5 m

For South-West and South-East

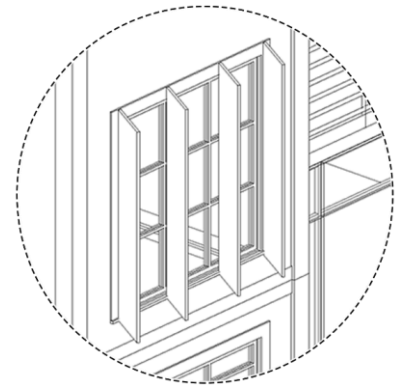
- According to Table 10 of SP 41, Horizontal member works effectively for SW & SE windows.
- For W1, H (B=0°), $H = P$, where P is the length of the projection.
 $150 = P$
3 horizontal members of 50cm width is recommended.



Horizontal shade for
W1 = 1.2 m x 1.5 m



Vertical fins for
W1 = 1.2 m x 1.5 m



Vertical fins for
W2 = 1.5 m x 1.5 m

Fig 11.14 Shading device - Windows

For North-West and North-East

- According to Table 10 of SP 41, Vertical member works effectively for NW & NE windows.
- For W1, V (B=30°), $0.63P = 0.63 \times 60$, where P is the length of the projection.
 $37.8 = P$
 $120/37.8 = 3.1$
3 vertical members of 60cm width is recommended.
- For W2, V(B=30°), $0.63P = 0.63 \times 60$, where P is the length of the projection.
 $37.8 = P$
 $150/37.8 = 3.9$
4 vertical members of 60cm width is recommended.

11.5.2 DESIGN OF SHADING DEVICE – CRAFT STREET

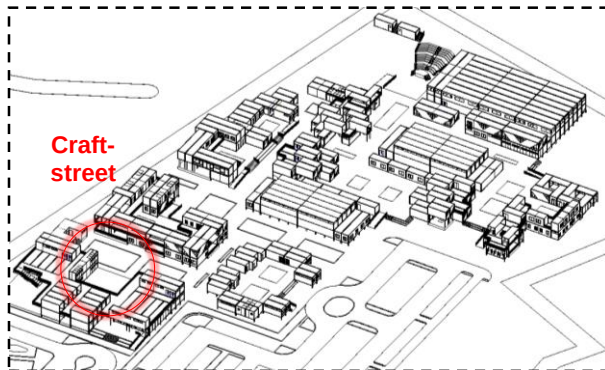


Fig 11.15 Key plan



Fig 11.16 View – Craft street

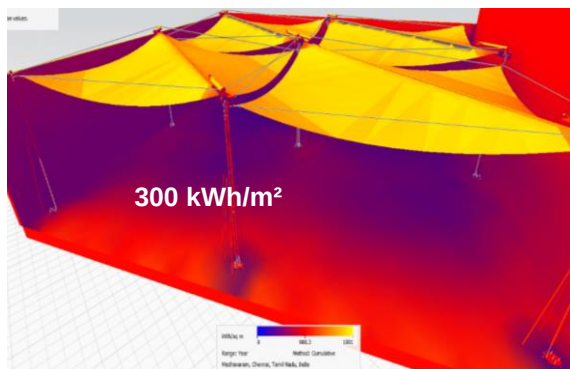


Fig 11.17 Radiation analysis

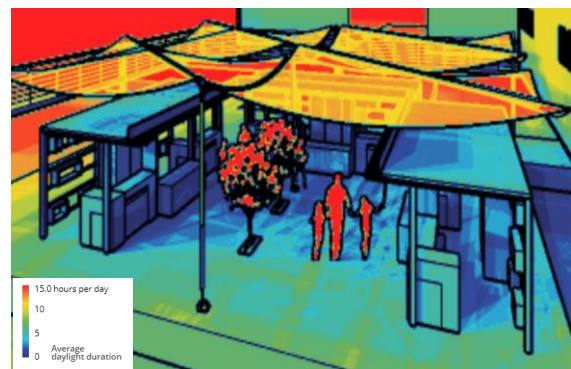


Fig 11.18 Daylight analysis

Inference:

This fabric shade effectively **shades the space by 80%** while allowing for 5 hours of daylight.

11.5.3 DESIGN OF SHADING DEVICE – HYDROPONIC GARDEN

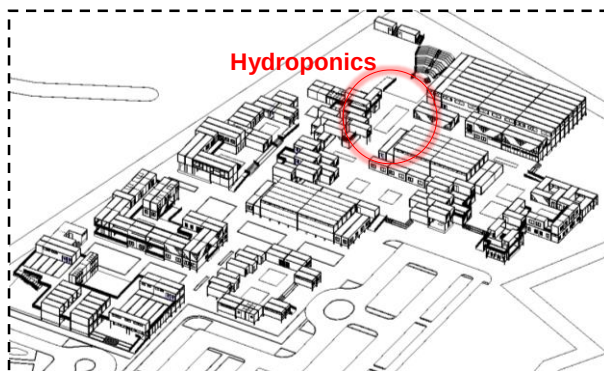


Fig 11.19 Key plan

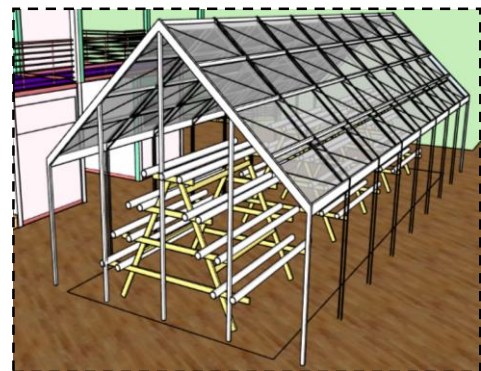


Fig 11.20 View – Hydroponics

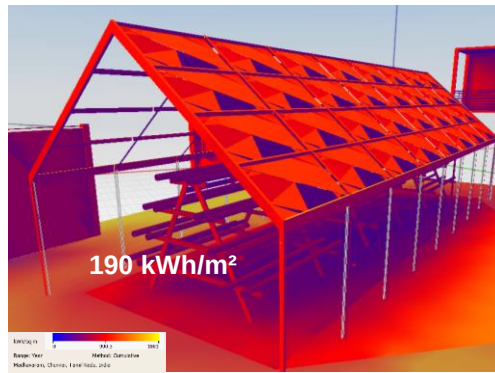


Fig 11.21 Radiation analysis

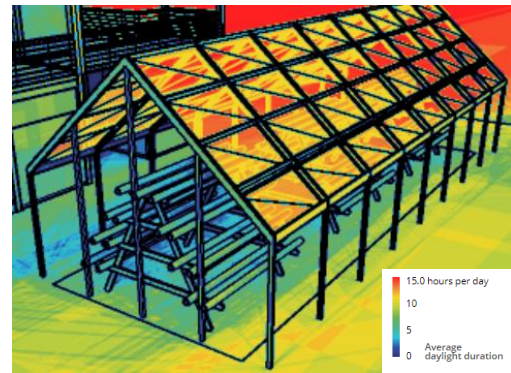


Fig 11.22 Daylight analysis

Inference:

This effectively shades the space by **87.33%** while allowing for **7 hours** of daylight.

11.5.4 DESIGN OF SHADING DEVICE – GATHERING PLAZA

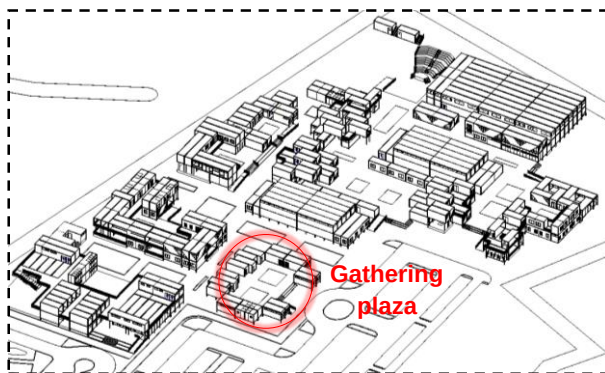


Fig 11.23 Key plan



Fig 11.24 View – Gathering plaza

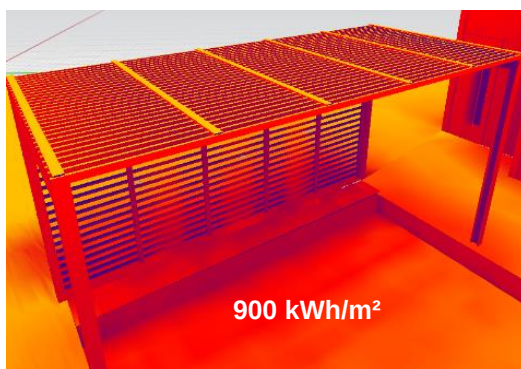


Fig 11.25 Radiation analysis

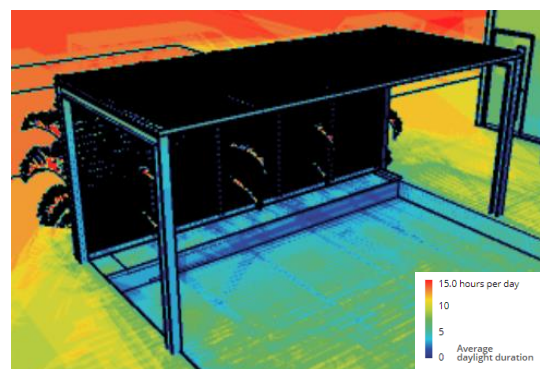


Fig 11.26 Daylight analysis

Inference:

This effectively shades the space by **40%** while allowing for **7 hours** of daylight.

11.5.5 DESIGN OF SHADING DEVICE – OUTDOOR READING AREA

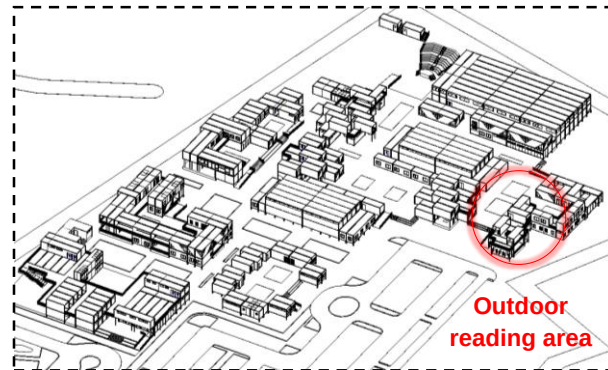


Fig 11.27 Key plan

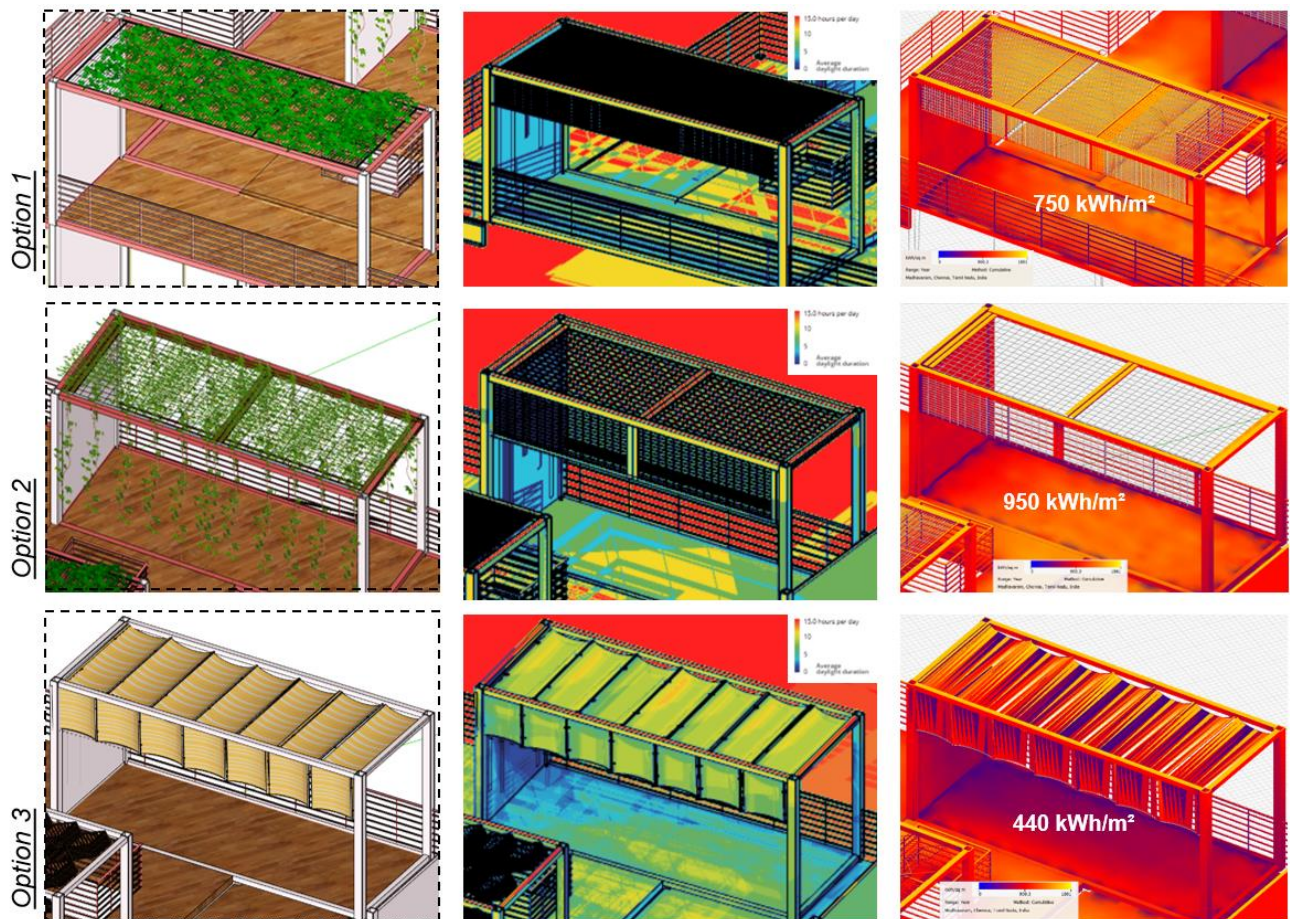


Fig 11.28 View

Fig 11.29 Daylight

Fig 11.30 Radiation

Inference:

This adjustable fabric effectively shades the space by **70.66%** while allowing for **8 hours** of daylight.

11.5.6 DESIGN OF SHADING DEVICE – WALL GLAZING

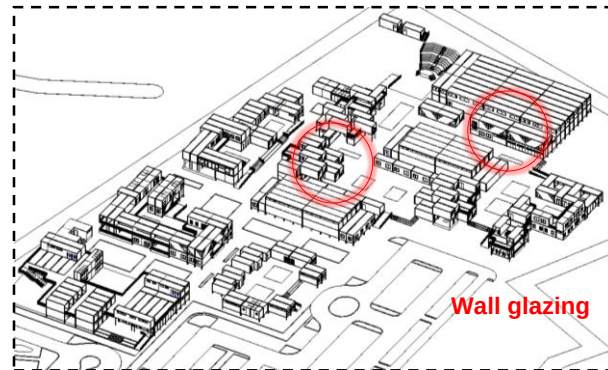
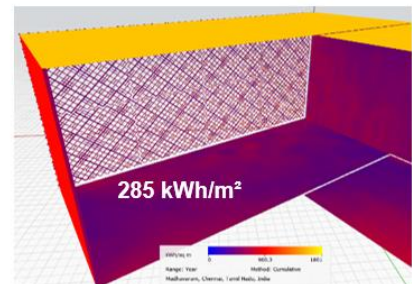
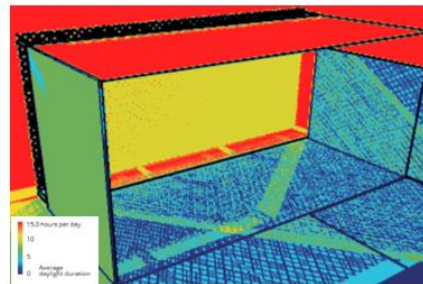
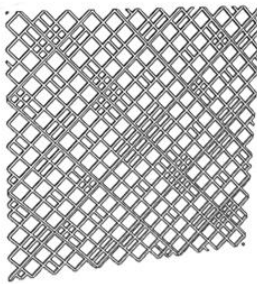
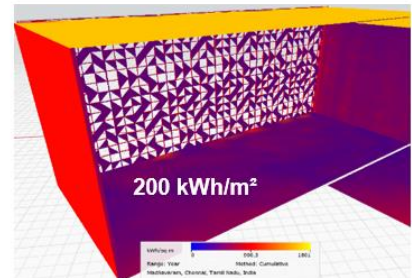
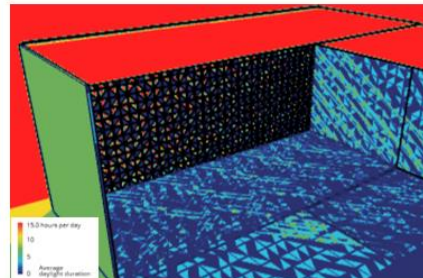
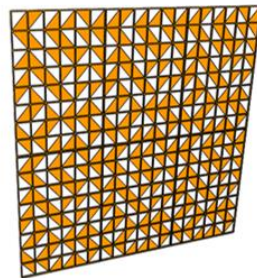


Fig 11.31 Key plan

Option 1 - 60% opening



Option 2 - 50% opening



Option 3 - 65% opening

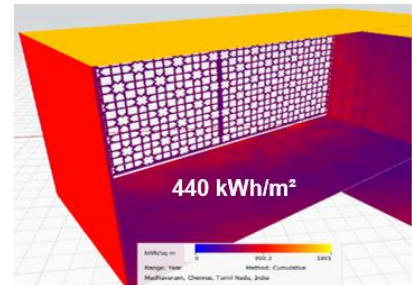
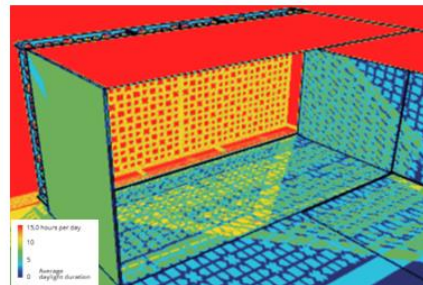
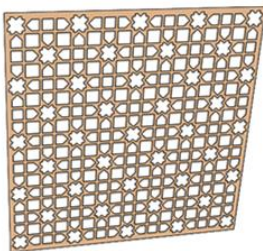


Fig 11.32 View

Fig 11.33 Daylight

Fig 11.34 Radiation

Inference:

Jaali with 50% opening effectively shades the space by **86.66%** while allowing for **5 hours** of daylight.

11.5.7 DESIGN OF SHADING DEVICE – OUTDOOR RESTAURANT

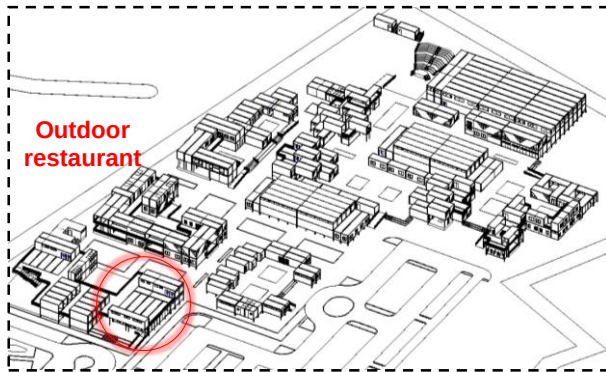


Fig 11.35 Key plan



Fig 11.36 View – Outdoor restaurant

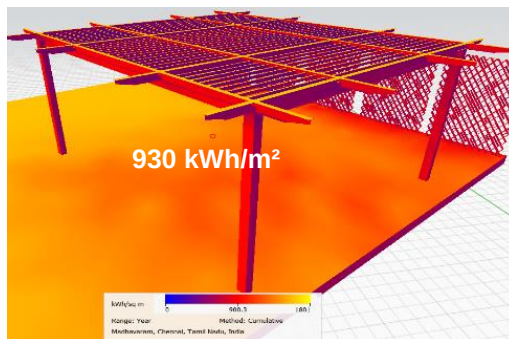


Fig 11.37 Radiation analysis

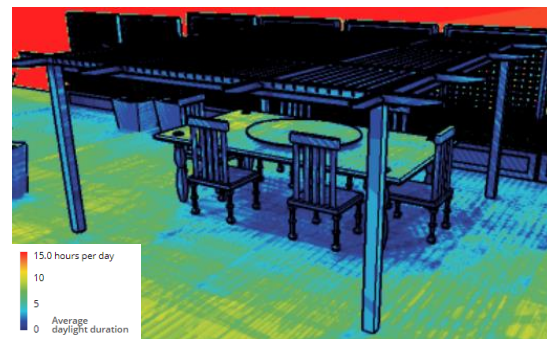


Fig 11.38 Daylight analysis

Inference:

This effectively shades the space by **38%** while allowing for **6 hours** of daylight.

11.5.8 DESIGN OF SHADING DEVICE – SEMI-OUTDOOR WORKSHOP

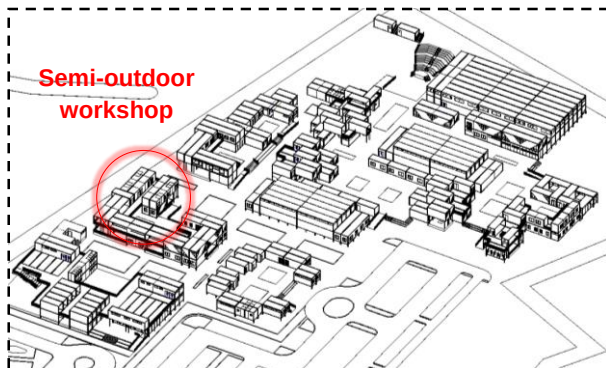


Fig 11.39 Key plan



Fig 11.40 View – Outdoor Workshop

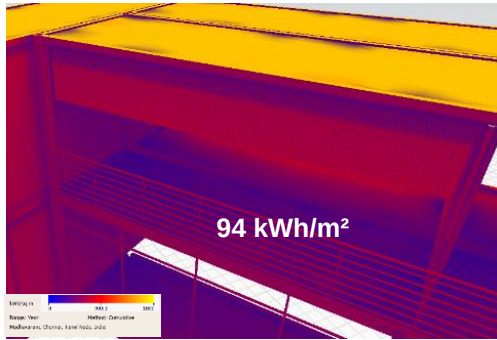


Fig 11.41 Radiation analysis

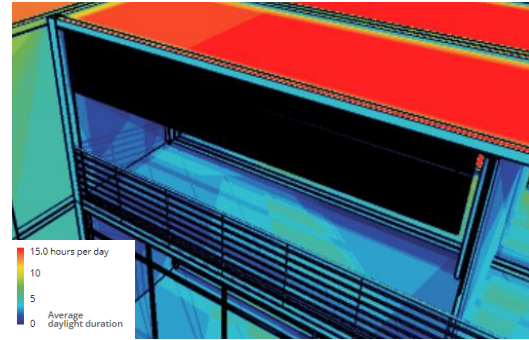


Fig 11.42 Daylight analysis

Inference:

This effectively shades the space by **94%** while allowing for **5 hours** of daylight.

11.6VOLUMETRIC ANALYSIS

FIRST FLOOR – 1425 m²

GROUND FLOOR - 4435 m²

SITE COVERAGE – 15%

FSI – 0.23

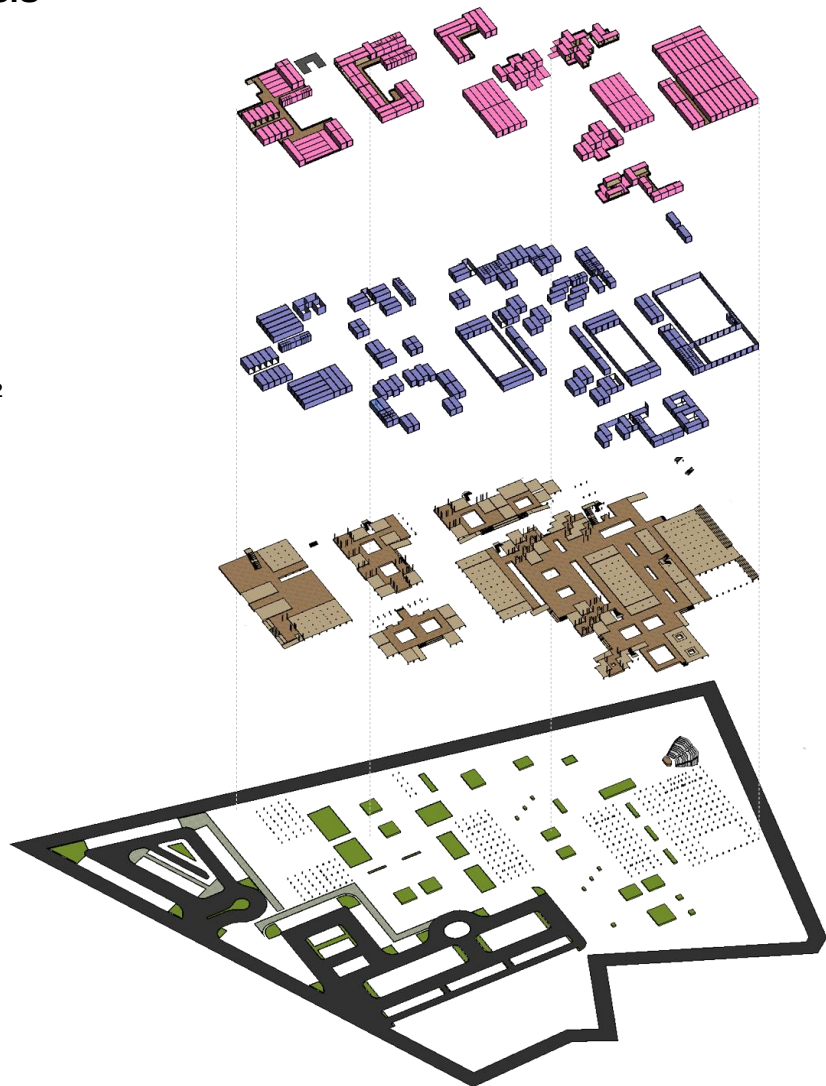


Fig 11.43 Exploded site plan

11.7 VEGETATION LAYOUT - PROPOSED TREES AND SHRUBS ACCORDING TO CLIMATE AND VASTU



Fig 11.44 Vegetation layout

	Trees	Spacing	Ht.	Dia.
SE	Tamarindus indica (Tamarind)	8 - 10m	2m	3 - 5m
S	Albizia lebbeck (Vaagai tree)	3m	18 - 30m	15 - 20m
	Azadirachta indica (Neem)	10m	15 - 30m	10 - 20m
NW, W	Saraca asoca (Ashoka tree)	3m	7 - 10m	8 - 12m
SW	Cocos nucifera (Coconut tree)	7.5m	25 - 30m	8 - 9m
	Polyalthia longifolia (False Ashoka tree)	1.8m	15 - 20m	3m
N,NE	Hibiscus rosa-sinensis (Hibiscus)	1m	1 - 2m	1m
	Bambusa vulgaris (Bamboo)	4m	10m	20 -30cm

Table 11.2 Vegetation proposed

11.8 STRUCTURAL DETAILS - DESIGN AND JOINERY DETAILS

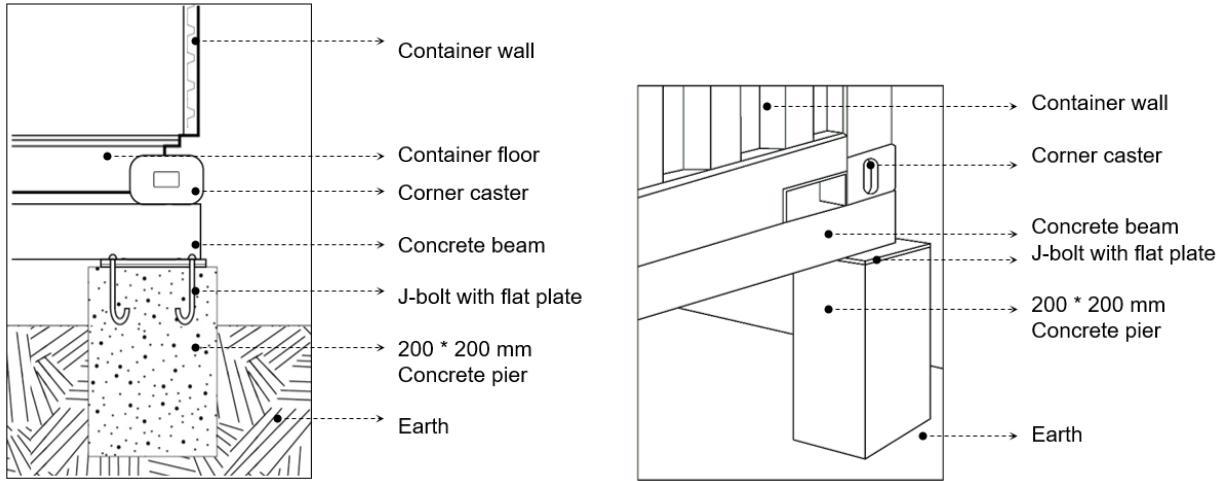


Fig 11.45 Container to Foundation detail

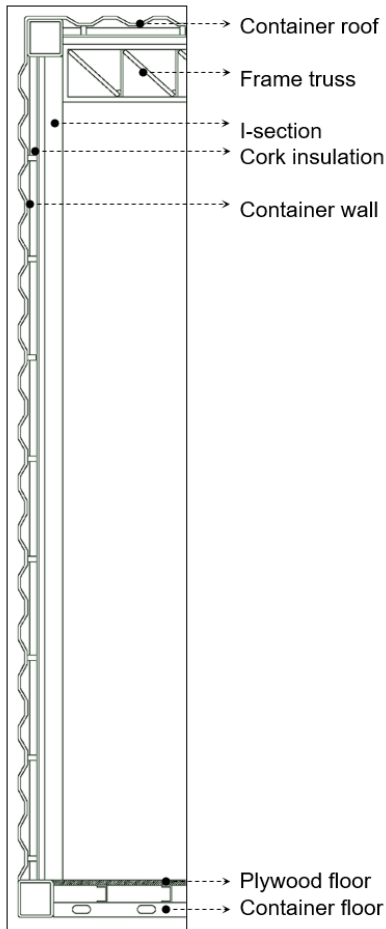


Fig 11.48 Container to truss detail

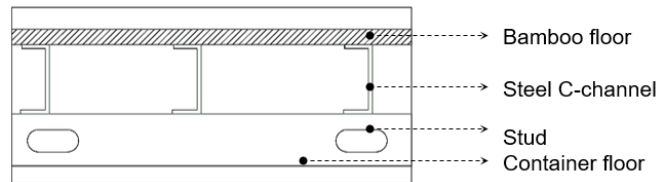


Fig 11.46 Container to Flooring fixing detail

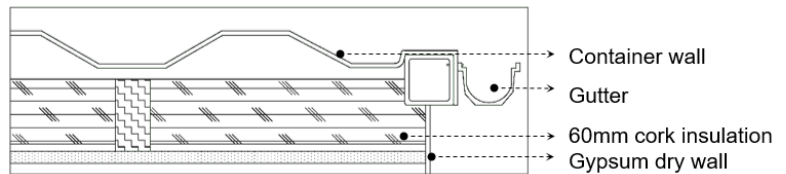


Fig 11.47 Container roof to Gutter detail

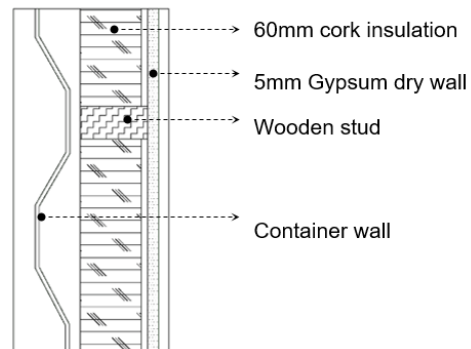


Fig 11.49 Container to Dry wall fixing detail

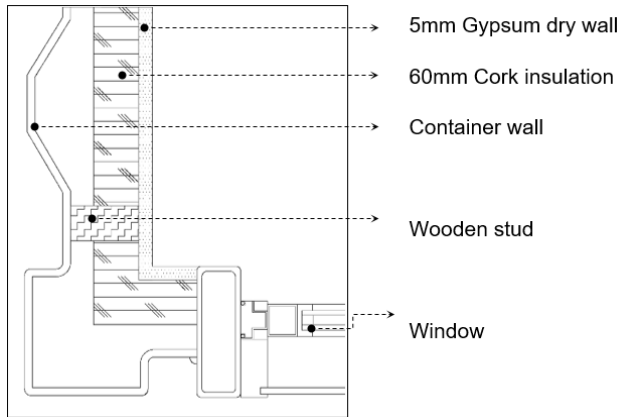


Fig 11.50 End to end welding detail

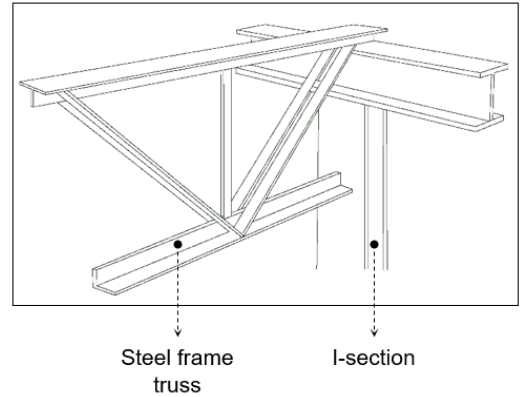


Fig 11.51 Truss joinery detail

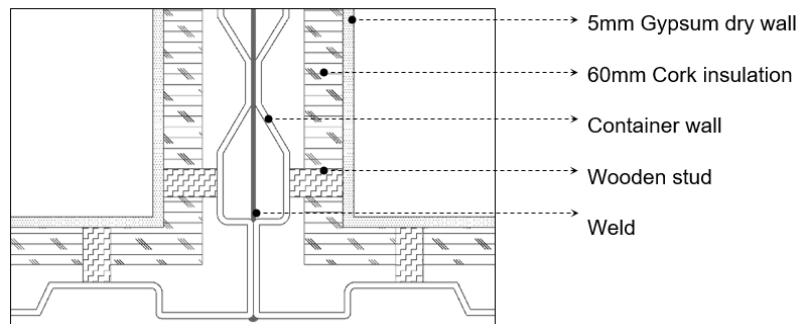


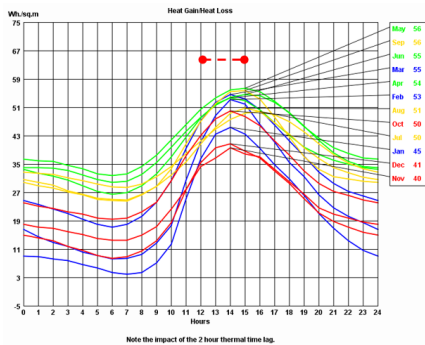
Fig 11.52 Container to Dry wall fixing detail

CHAPTER 12 SUSTAINABLE DESIGN PERFORMANCE

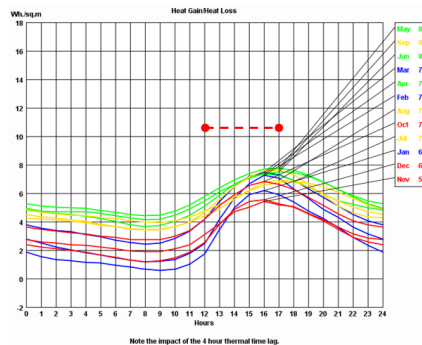
12.1 PRELIMINARY MATERIAL ANALYSIS

12.1.1 TIME LAG FOR WALL MATERIALS

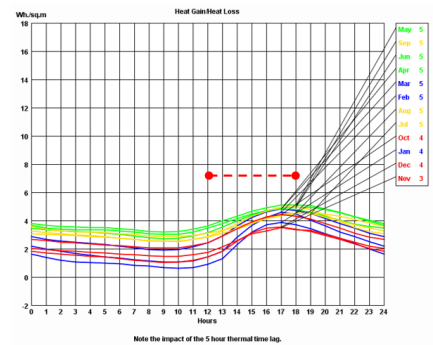
Conventional Brick wall



Steel wall with 60mm cork insulation



Steel wall with Super therm ceramic paint and 60mm cork insulation



Time lag – 2hrs
Heat gain – 56 Wh/m²
U-Value – 3.637 W/m².k

Time lag – 4hrs
Heat gain – 8 Wh/m²
U-Value – 0.503 W/m².k

Time lag – 5hrs
Heat gain – 5 Wh/m²
U-Value – 0.34 W/m².k

Fig 12.1 Wall – Time lag

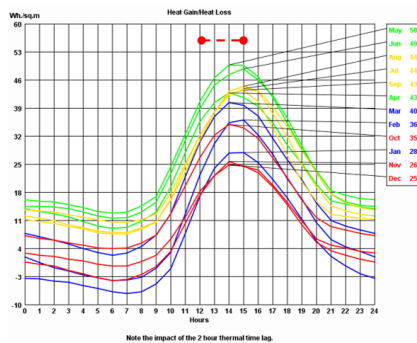
Inference:

The U-value of a steel wall with super therm ceramic paint and cork insulation is **15% less than the value specified by ECBC standards.**

	Maximum U-factor (W/m ² .K) Required	Achieved (W/m ² .K)
Wall assembly	0.40	0.34

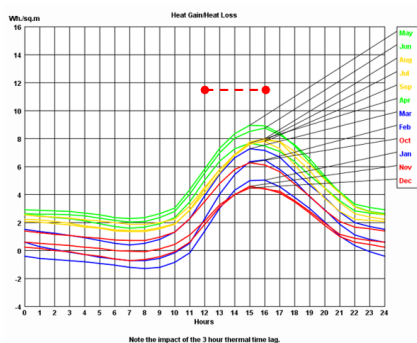
12.1.2 TIME LAG FOR ROOF MATERIALS

Conventional RCC roof



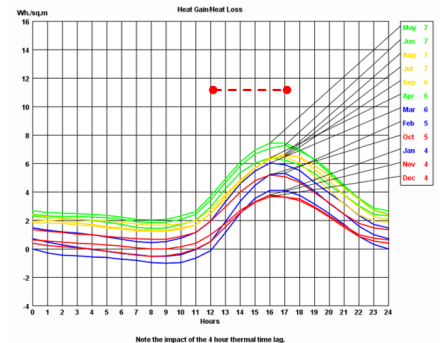
Time lag – 2hrs
Heat gain – 50 Wh/m²
U-Value – 2.553 W/m².k

Steel roof with 60mm cork insulation



Time lag – 3hrs
Heat gain – 9 Wh/m²
U-Value – 4.99 W/m².k

Steel roof with Super therm ceramic paint and 60mm cork insulation



Time lag – 4hrs
Heat gain – 7 Wh/m²
U-Value – 0.293 W/m².k

Fig 12.2 Roof – Time lag

Inference:

The U-value of a steel wall with super therm ceramic paint and cork insulation is **15% less than the value specified by ECBC standards.**

	Maximum U-factor (W/m ² .K) Required	Achieved (W/m ² .K)
Roof assembly	0.33	0.293

12.2 DAYLIGHT ILLUMINANCE ANALYSIS

Spaces	Standard	Achieved	Spaces	Standard	Achieved
Auditorium	100 - 150	500 - 2000	Reception	150	500
Platforms	450	500	Meeting rooms	300	450 - 500
Corridors	70	200	General office	300	200 - 300
Stairs	100	100 - 200	Computer lab	300	300 - 500

Reading rooms	150 - 300	400 - 500	Dining	100	500
Gallery	200	300 - 500	Toilet	100	70 - 100
Entrance hall	150	500 - 1000	Restaurant	100	500-1000
Workshop	200	400 - 1000	Kitchen	200	120 - 500

Table 12.1 Daylight achieved

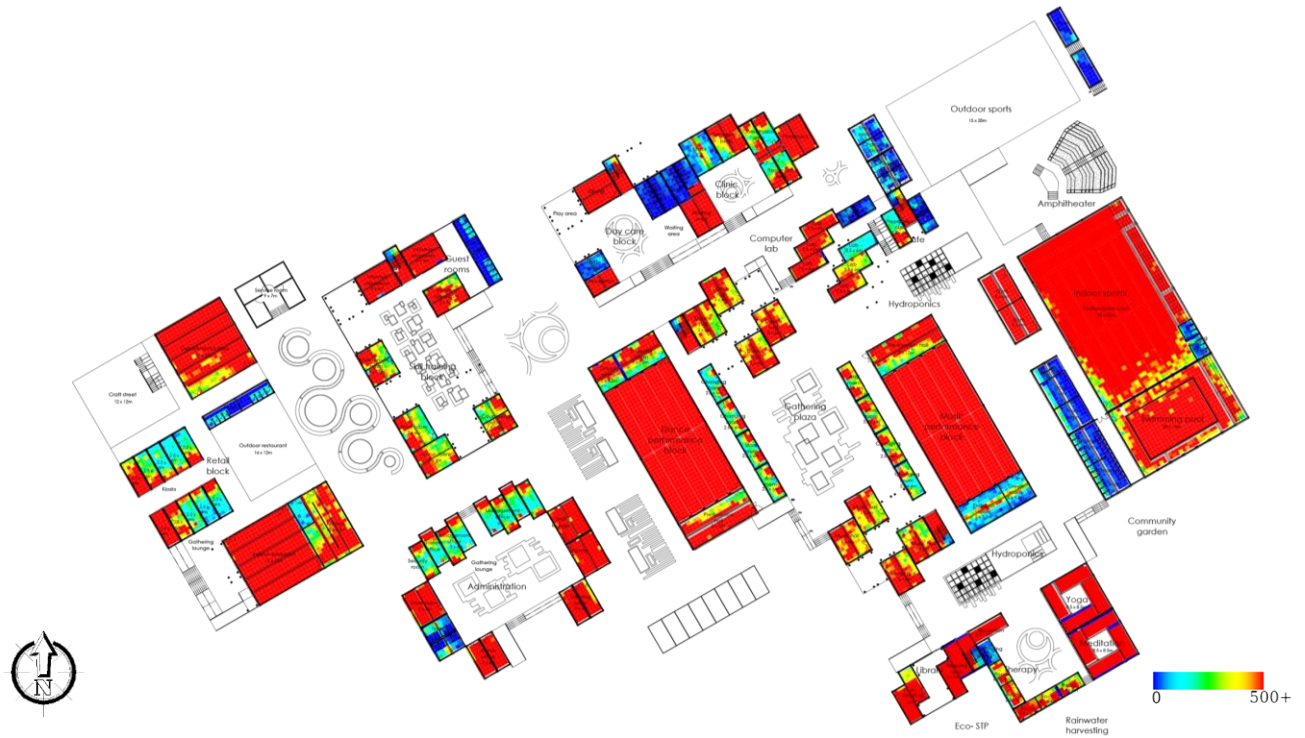


Fig 12.3 Ground floor daylight plan

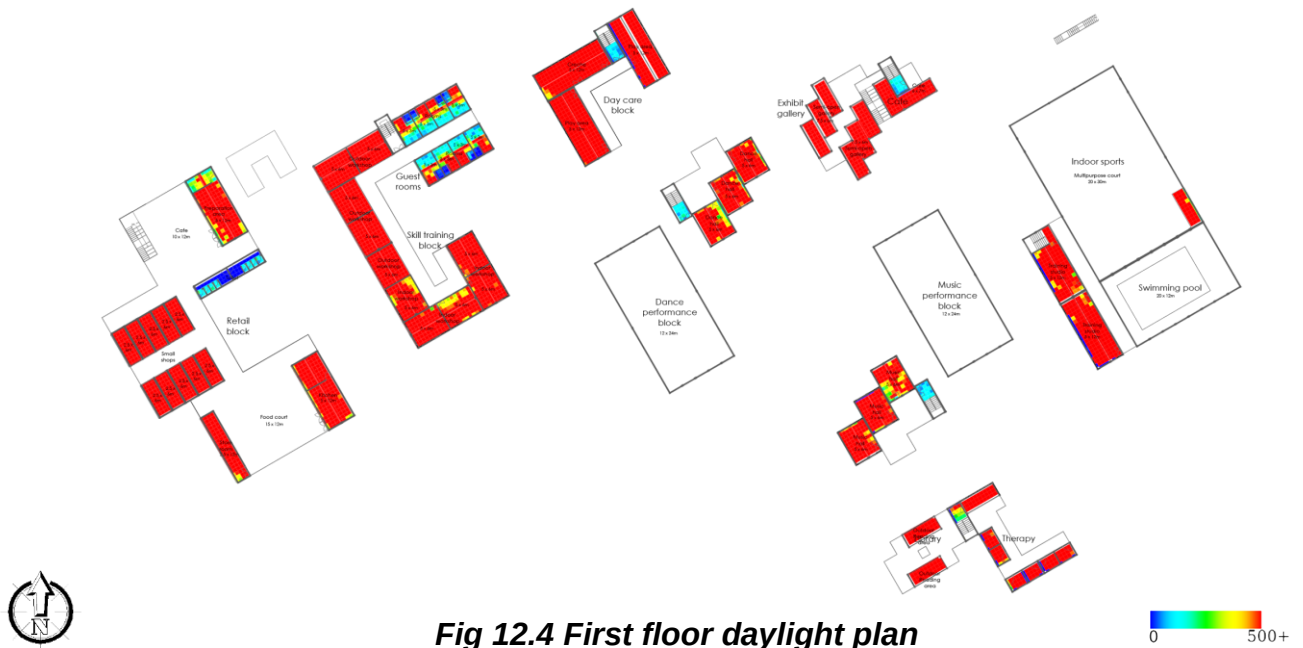


Fig 12.4 First floor daylight plan

Inference:

All habitable spaces receive adequate daylight that meets ECBC standards.

12.3 USEFUL DAYLIGHT ILLUMINANCE (UDI) ANALYSIS

12.3.1 GROUND FLOOR UDI

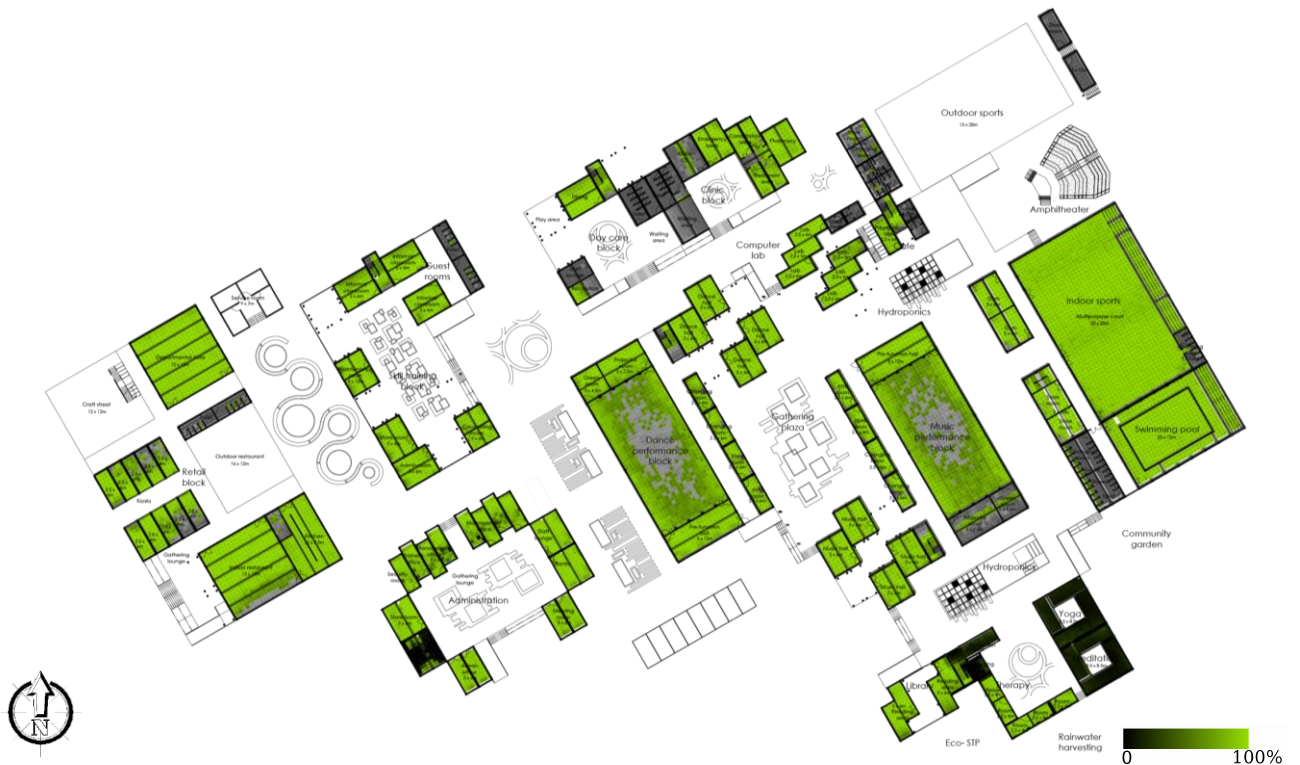


Fig 12.5 Ground floor UDI plan

Spaces	UDI (100-3000lux)
Administration	80.56%
Retail block	86.6 %
Day care & Clinic	74.32
Dance & Music hall	76.48%
Sports block	93.93 %
Library & therapy	45.62%

Daylight Requirement (UDI)

UDI	Minimum 40% of above grade floor area meeting the UDI requirement (ECBC)
-----	--

Inference:

All regularly occupied spaces on the **ground floor receive more than 40% of UDI** (Useful Daylight Illuminance) expected by ECBC standards.

12.3.2 FIRST FLOOR UDI

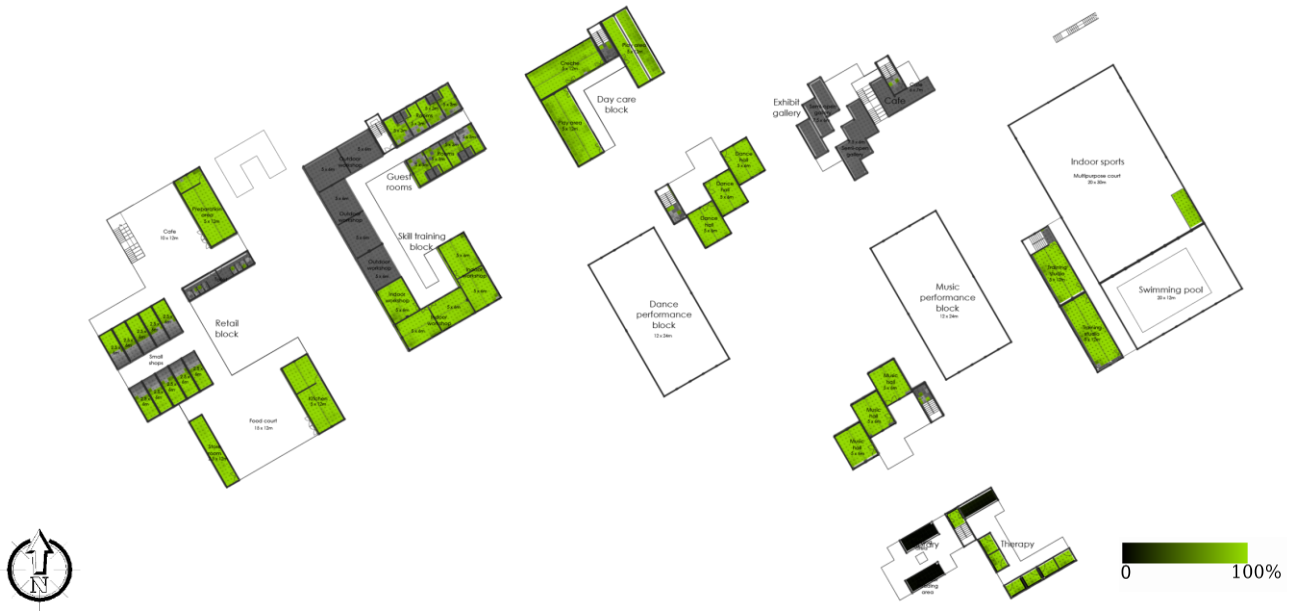


Fig 12.6 First floor UDI plan

Spaces	UDI (100-3000lux)
Administration	-
Retail block	63.7%
Day care & Clinic	91.32%
Dance & Music hall	41.07%
Sports block	84.76%
Library & therapy	39.93%

Daylight Requirement (UDI)	
UDI	Minimum 40% of above grade floor area meeting the UDI requirement (ECBC)

Inference:

All regularly occupied spaces on the **first floor receive more than 40% of UDI** (Useful Daylight Illuminance) expected by ECBC standards.

12.4ANNUAL SOLAR EXPOSURE (ASE) ANALYSIS

12.4.1 GROUND FLOOR ASE

- Annual sunlight exposure (ASE1000, 250) is achieved for no more than 10% of regularly occupied space.
- In other words, no more than 10% of the area can receive more than 1,000 lux for 250 hours each year.

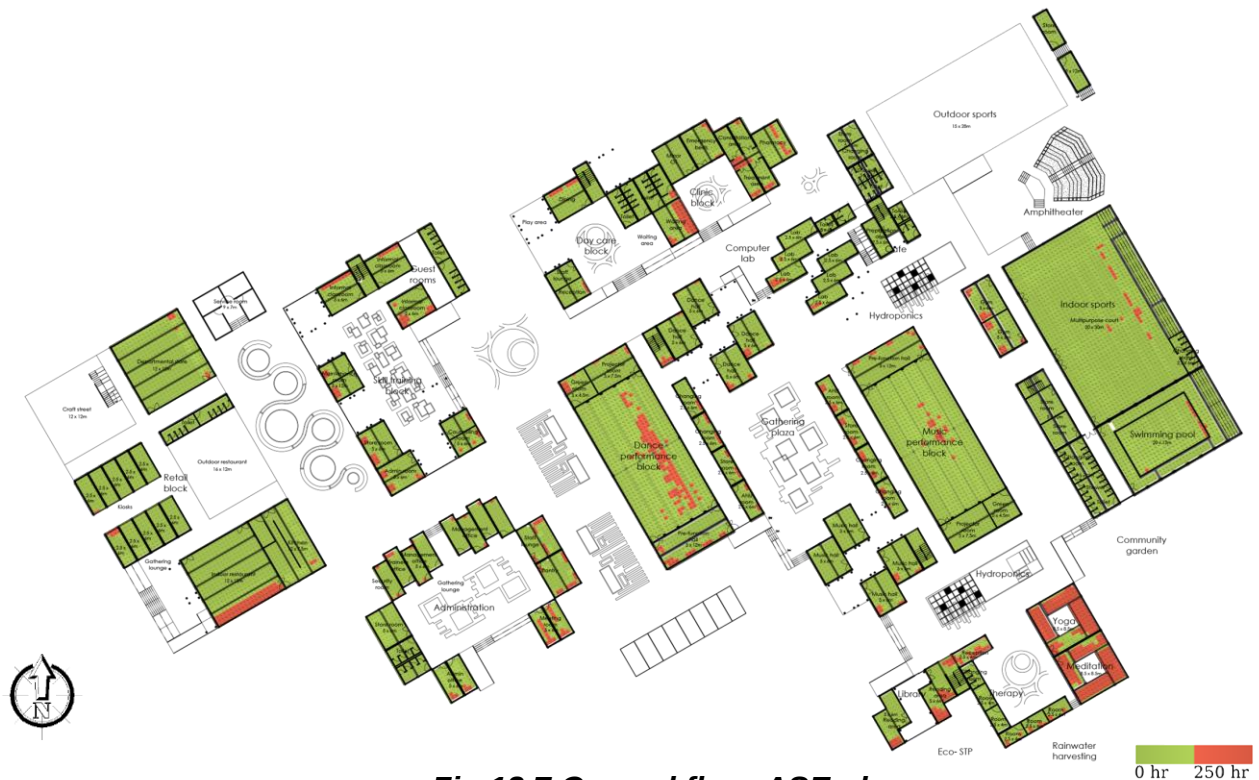


Fig 12.7 Ground floor ASE plan

Inference:

All regularly occupied spaces on the **ground floor receive less than 10% of ASE** (Annual Solar Exposure) expected by standards.

Spaces	ASE %
Administration	7.32 %
Retail block	6.67 %
Skill training block	8.80 %
Day care & Clinic	10.71 %
Dance & Music hall	4%
Sports block	1.93

12.4.2 FIRST FLOOR ASE

Inference:

All regularly occupied spaces on **the first floor receive more than 10% of ASE** (Annual Solar Exposure) expected by standards, proper shading needed.

Spaces	ASE %
Administration	-
Retail block	30.10 %
Skill training block	30.50 %
Day care & Clinic	17.49 %
Dance & Music hall	49.19%
Sports block	22.36 %

Wind speed – 5.8m/s (maximum)

Inference:

The prevailing wind is not disturbed and is evenly dispersed towards the indoor space due to the spacious layout and strategic positioning of blocks.

12.6 RAINWATER HARVESTING - RWH CALCULATION [27]

- IS standards for water supply demand = 15 litres per head
- Over-all water demand = $450 \times 45 \times 365 = 73,91,250$ litres annually

Surface	Run-off co-efficient
Roof	0.75
Pavement	0.3
Hardscape	0.7
Rainfall	
Annual rainfall	1870mm
Maximum rainfall (Nov.)	480 mm

Table 12.2 Run off



Fig 12.10 Run off surface

Roof-top draining area calculation

- Annual Rain Water harvesting potential = $3745 \times 0.6 \times 1.87 = 5,252.3 \text{ m}^3 = 52,52,300$ litres
- Rain Water harvesting potential for highest rainfall month (November) = $3745 \times 0.6 \times 0.48 = 1,348.2 \text{ m}^3 = 13,48,200$ litres

Surface draining area calculation

- Annual Rain Water harvesting potential = $4300 \times 0.7 \times 1.87 = 5,628.7 \text{ m}^3 = 56,28,700$ litres
- Rain Water harvesting potential for highest rainfall month (November) = $4300 \times 0.7 \times 1.87 = 1,444.8 \text{ m}^3 = 14,44,800$ litres

Rain Water harvesting potential = Amount of Rainfall x Area of catchment x Runoff coefficient

Annually Total Rain water Harvested = Total Rain water harvesting by Roof-top + Total Rain Water harvesting by Surface drainage

Over-all Total Rain water Harvested calculation

- Annual Rain Water harvesting potential = $52,52,300 + 56,28,700 = 1,08,81,000$ litres
- Rain Water harvesting potential for highest rainfall month (November) = $13,48,200 + 14,44,800 = 27,93,000$ litres

12.6.1 RWH FLOW LINES

- Size of bio swale – minimum 1% total draining area
- Total draining area = $3745 + 4300 = 8,045 \text{ m}^2$
- Total bio swale area = 765 m^2 (9.5% of total draining area)



Fig 12.11 Bio swales RWH flow lines

Rain Water tank capacity

- RWH tank 1 = 15m diameter x 5m depth = 8,83,572 litres
- RWH tank 2 = 6m diameter x 5m depth = 1,41,371 litres

Rain percolation pit capacity

- RWH pit 1 = 15 x 10 x 3 = 4,50,000 litres
- RWH pit 2 = 12 x 8.5 x 3 = 3,06,000 litres
- RWH pit 3 = 12 x 5.5 x 3 = 1,98,000 litres

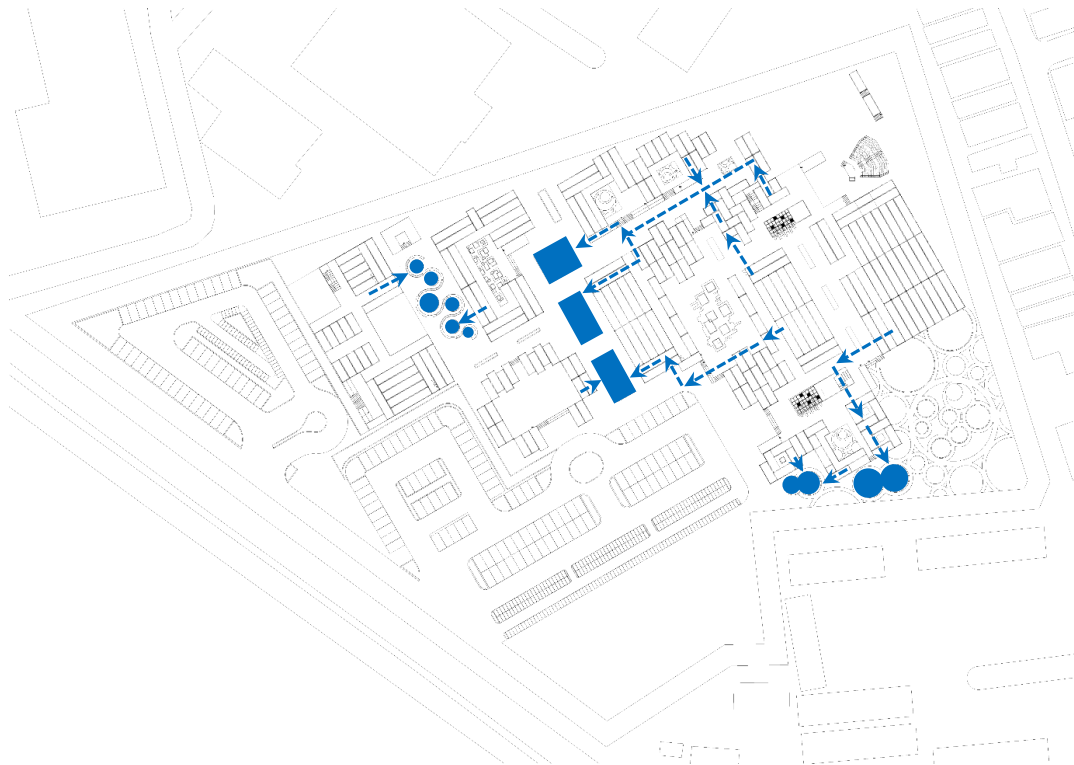


Fig 12.12 Roof top RWH flow lines

Over-all RHW tank capacity = **21,76,943 litres**

12.7 GREY AND BLACK WATER MANAGEMENT [28]

Fixtures		Product details	Flow rate	Rating
Faucet	Hindware	Contessa Pillar Cock body	4 lpm	WEP-3 Star rated
Urinal	Eco 365 Falcon	Waterfree Urinals	Waterless	Member of IGBC

Closet	Hindware Mario Starwhite WC	3 lpf	WEP-3 Star rated
Shower	Eco 365 Water Saving Showers	6lpm	Member of IGBC

Table 12.3 Fixtures selected

Spaces	WC	Urinal	Faucet (1min)	Shower (10mins)	Total (l)
Admin	8	3	5	-	47
Litres used	32	-	15		
Retail	16	4	16	-	112
Litres used	64	-	48		
Skill training	8	2	3	-	41
Litres used	32	-	9		
Day care	8	2	3	-	41
Litres used	32	-	9		
Clinic	7	2	3	-	37
Litres used	28	-	9		
Gallery	4	3	1	-	19
Litres used	16	-	3		
Café	4	3	1	-	19
Litres used	16	-	3		
Sports	6	2	4	6	396
Litres used	24	-	12	360	
Pool	8	3	5	6	407
Litres used	32	-	15	360	
Therapy	2	1	1	10	611
Litres used	8	-	3	600	
Total waste water collected per fixture (litres)					1730
Total black water collected per fixture (litres)					284
Total grey water collected per fixture (litres)					1446

Table 12.4 Amount of waste water generated

Total waste water collected per day = 17,300 litres

Total black water collected per day = 2,840 litres

Total grey water collected per day = 14,460 litres

83% of total waste water produced in grey water, which can be treated and reused, only 17% is black water

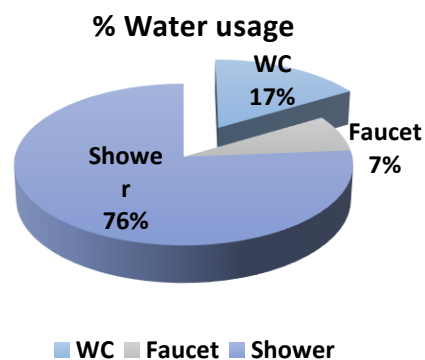


Fig 12.13 Water usage

12.7.1 TANK CAPACITY FOR ECO – STP [29]

- Black water generated per month = $2,840 \times 30 = 85,200$ litres
- For septic tank (black water) = $3 \times 5 \times 7 = 105 \text{ m}^3 \times 1000 \text{ litres} = 1,05,000 \text{ litres}$
- Grey water generated per day = 14,460 litres
- For grey tank = $3 \times 3 \times 3 = 27 \text{ m}^3 \times 1000 \text{ litres} = 27,000 \text{ litres}$
- ECOSTP needs 2.6 m^2 per KLD for underground stages 1, 2 and 3. Stage 4 Tertiary treatment Plant Bio Filter needs 1.2 m^2 per KLD.
- For 14.46 KLD, stage 1-3 (treatment) requires 38 m^2 and stage 4 (tertiary treatment) requires 17 m^2 .
- **Over all Eco- STP tank capacity = 55 m^2**



Fig 12.14 STP flow lines

ROI for Eco-STP [30]

- When an ECOSTP is implemented in place of a Conventional STP, the Return of Investment (ROI) is substantially less than two years.
- ECOSTP helps you save each year ₹1.15 lakhs for a 10 KLD unit and up-to ₹ 47.5 lakhs for a 1 MLD unit.

- For 14.46 KLD capacity, annual savings = ₹1,22,992, ROI achieved in = 2 years

$$ROI = \frac{\text{Net Return on Investment}}{\text{Cost of Investment}} \times 100\%$$

- Net Return on Investment → Total Profits Received
- Cost of the Investment → Total Amount Spent

Year	Conventional STP OPEX	Eco STP OPEX	Annual savings	Eco STP savings
1	₹86,760	₹21,690	₹75,915	
2	₹95,436		₹84,591	₹15,906
3	₹1,14,523	₹21,690	₹1,03,678	₹1,19,584
4	₹1,25,975		₹1,15,130	₹2,34,714
5	₹1,38,573	₹23,859	₹1,26,644	₹3,61,358
6	₹1,52,430		₹1,40,501	₹5,01,858
7	₹1,67,673	₹23,859	₹1,55,744	₹6,57,602
8	₹1,84,440		₹1,72,511	₹8,30,112
9	₹2,02,884	₹26,245	₹1,89,762	₹10,19,874
10	₹2,23,172		₹2,10,050	₹12,29,923
	₹14,91,866	₹1,17,343	₹13,74,526	₹12,29,923

Table 12.5 ROI for eco STP

12.8 ENERGY EFFICIENT FIXTURES - LIGHTING AND CEILING FAN FIXTURES [31]

Parameters	Base case	Proposed case
Fixtures	PHILIPS B22 GLS Incandescent Bulb (60 W)	Orient Eternal Shine LED Bulb 9W 5 Star Cool White B22
Cost/fixture	₹ 15	₹ 200
Wattage	60W	9W
Hourly electricity consumption	0.06 kWh	0.009 kWh
Daily (6 hrs) electricity consumption	0.36 kWh	0.054 kWh
Annual electricity consumption	131.4 kWh	19.71 kWh
Cost per annum	₹ 720	₹ 110
Savings per annum	₹ 0	₹ 610
Savings after 3 years	₹ 0	₹ 1,830

Table 12.6 Cost saving for light fixture

- Considering a 40 ft (12m x 2.5m) HC container,
- To calculate the lumen required,
- Area x required lux = 30 x 200 = 6000 lumen
- Number of fixtures required = 6000/800 = 7.5 = 8 nos.
- To calculate the required number of fans,
- According to standards, for area more than 20m², minimum 2 number of fans should be provided.

Parameters	Base case	Proposed case
Fixtures	Usha Racer 1200MM Ultra High Speed 400RPM Ceiling Fan	Atomberg Ozeo 1200mm BLDC 5 Star Rated Ceiling fan
Cost/fixture	₹ 2130	₹ 2895
Wattage	78W	28W
Hourly electricity consumption	0.078 kWh	0.028 kWh
Daily (8 hrs) electricity consumption	0.624 kWh	0.224 kWh
Annual electricity consumption	227.76 kWh	81.76 kWh
Cost per annum	₹ 1,250	₹ 450
Savings per annum	₹ 0	₹ 800
Savings after 3 years	₹ 0	₹ 2,400

Table 12.7 Cost saving for ceiling fan

Inference

- Initial investment cost for light fixtures are 92.5% higher than base case, while **overall energy savings 89.89% higher than initial investment** over 3 years period.
- Initial investment cost for fan is 26.42% higher than base case, while **overall energy savings 68.12% higher than initial investment** over 3 years period.

12.9 LIFE CYCLE COST ANALYSIS

Criteria	Specification	Base case	Proposed case
		Brick wall, RCC roof	Shipping container, cork insulation & gypsum dry wall
Construction cost	Total cost including material & labour cost and construction time	₹ 2,100/ft ² (for materials) - GF ₹ 1,600/ft ² (for materials) - FF ₹ 22,000/m ² (for materials) - GF ₹ 17,000/m ² (for materials) - FF Time - 12 months	₹ 75,000/container [32] ₹ 100 (for labour) for 2 months ₹ 150/m ² (for insulation) ₹ 130/m ² (for dry wall) ₹ 12/m ² (for flooring) ₹ 40/m ² (for ceramic coating)

		₹ 6,66,000	₹ 1,85,040
	For total area	₹ 12,17,95,000	₹ 4,07,08,800
Cost of electrical fixtures	8 light fixtures and 2 fans	PHILIPS B22 GLS Incandescent Bulb (60 W)	Orient Eternal Shine LED Bulb 9W 5 Star Cool White B22
		₹ 120	₹ 1600
		Usha Racer 1200MM Ultra High Speed 400RPM Ceiling Fan	Atomberg Ozeo 1200mm BLDC 5 Star Rated Ceiling fan
		₹ 4,260	₹ 5,790
		₹ 4,380	₹ 7,390
	For total fixtures	₹ 9,63,600	₹ 16,25,800
Cost of water fixtures	1 faucet, 1 WC [33]	Stainless Steel Bib Tap	Hindware Contessa Pillar Cock body
		₹ 425	₹ 975
		P Closed front Hindware flora wall mounted WC	Hindware Mario Starwhite WC
		₹ 3,800	₹ 10,700
		₹ 4,225	₹ 11,675
	For total fixtures	₹ 9,29,500	₹ 25,68,500
	Total cost	₹ 12,36,88,100	₹ 4,49,03,100

Table 12.8 Material cost calculation

Inference:

- Total savings - ₹ 7,87,85,000
- The proposed case is **63.69% more efficient** than the base case.

Criteria	Specification	Base case	Proposed case
Light	Fixture selected	PHILIPS B22 GLS Incandescent Bulb (60 W)	Orient Eternal Shine LED Bulb 9W 5 Star Cool White B22
	Wattage	60W/fixture	9W/fixture
	Annual electricity consumption	2,31,264 kWh	34,688 kWh
	Cost per annum	₹ 12,67,200	₹ 1,93,600
	Electricity consumption for 30 years	69,37,920 kWh	10,40,640 kWh
	Cost spent for 30 years	₹ 3,80,16,000	₹ 58,08,000
Fan	Savings per annum	Usha Racer 1200MM Ultra High Speed 400RPM Ceiling Fan	Atomberg Ozeo 1200mm BLDC 5 Star Rated Ceiling fan
	Wattage	78W/fixture	28W/fixture
	Annual electricity consumption	1,00,214 kWh	35,974 kWh
	Cost per annum	₹ 5,50,000	₹ 1,98,000

Electricity consumption for 30 years	30,06,420 kWh	10,79,220 kWh
Cost spent for 30 years	₹ 1,65,00,000	₹ 59,40,000
Total cost for 30 years	₹ 5,45,16,000	₹ 1,17,48,000

Table 12.9 Electricity cost calculation

Inference:

- Total savings for 30 years - ₹ 4,27,68,000
- The proposed case is 78.45% more efficient than the base case.

Criteria	Specification	Base case	Proposed case
Construction cost	Cost of painting (for 1 time)	Brick wall	Shipping container wall
		₹ 65/m ² (for plastering)	₹ 40/m ² (for applying ceramic paint)
		₹ 5,460	₹ 3,360
	Total painting cost for every 5 years in 30 year period	₹ 12,01,200	₹ 7,39,200
Replacement cost of light fixtures	Fixture	PHILIPS B22 GLS Incandescent Bulb (60 W)	Orient Eternal Shine LED Bulb 9W 5 Star Cool White B22
	Total no. of fixtures	1,760	1,760
	Replacement period	1 years	5 years
	Replacement cost (1 time)	₹ 26,400	₹ 3,52,000
	Total painting cost for 30 year period	₹ 7,92,000	₹ 21,12,000
Replacement cost of ceiling fans	Fixture	Usha Racer 1200MM Ultra High Speed 400RPM Ceiling Fan	Atomberg Ozeo 1200mm BLDC 5 Star Rated Ceiling fan
	Total no. of fixtures	440	440
	Replacement period	2 years	5 years
	Replacement cost (1 time)	₹ 9,37,200	₹ 12,73,800
	Total painting cost for 30 year period	₹ 1,40,58,000	₹ 76,42,800
Total cost		₹ 1,60,51,200	₹ 1,04,94,000

Table 12.10 Maintenance cost calculation

Inference:

- Total savings for 30 years - ₹ 55,57,200
- The proposed case is **34.62% more efficient** than the base case.

12.9.1 INFERENCE

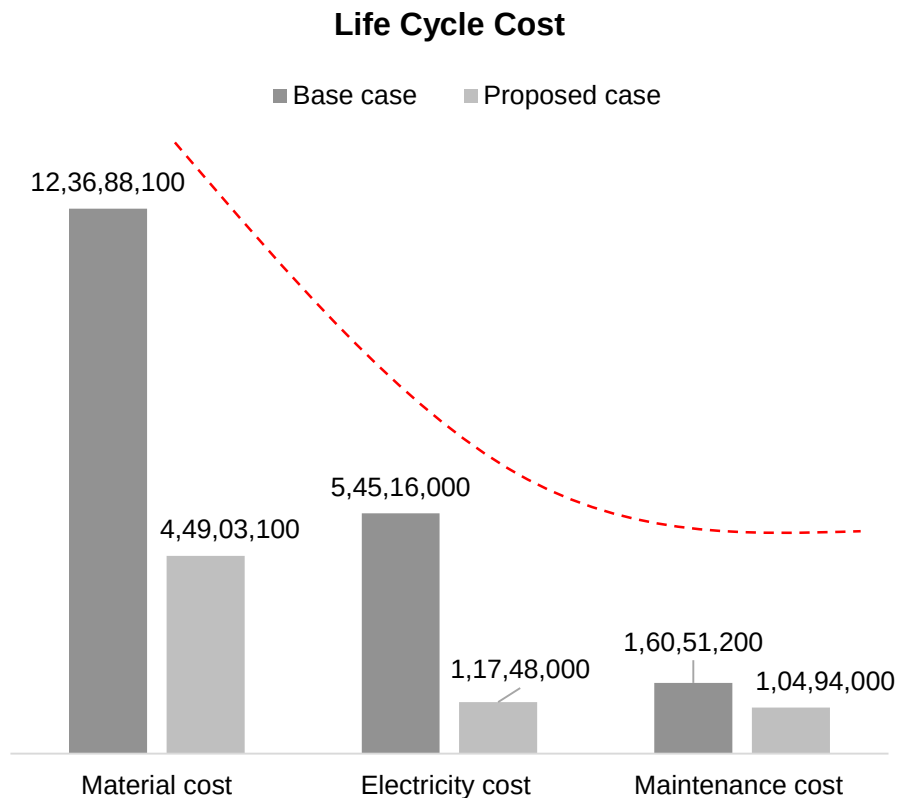


Fig 12.15 LCC Comparison

- Total savings from materials and construction is ₹ 7,87,85,000
- The proposed case is 63.69% more efficient than the base case.
- Total savings from electricity usage over 30 years - ₹ 4,27,68,000
- The proposed case is 78.45% more efficient than the base case.
- Total savings from maintenance over 30 years - ₹ 55,57,200
- The proposed case is 34.62% more efficient than the base case.

Category	Percentage savings
Material (including construction) cost	63.69%
Electricity cost	78.45%
Maintenance cost	34.62%

Table 12.11 LCC savings

12.10 ENERGY GENERATION - SOLAR POWER GENERATION

- Throughout the year, Madhavaram receives around 3800 hours of sunlight.
- Average daily sunshine hours is 7.5 hours.

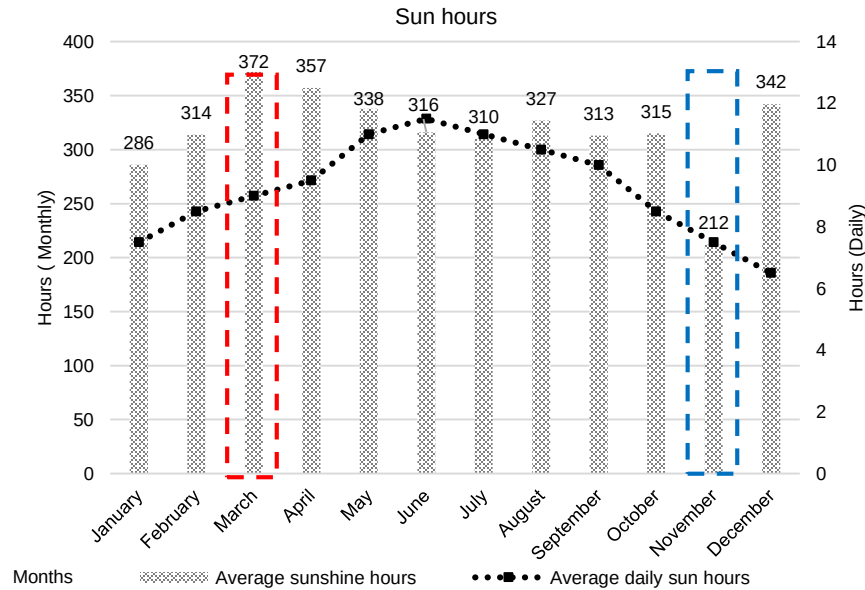


Fig 12.16 Daylight and sun shine hours

Energy consumption for lights

Annual electricity consumption = 34,688 kWh

Annual monthly consumption = 2890 kWh

Energy consumption for fans

Annual electricity consumption = 35,974 kWh

Annual monthly consumption = 2998 kWh

Total monthly average electricity consumption = **5888 kWh**

Solar Panel Calculation [34]

kWh per Month / (Daily Sunlight Average in Your State x 30) = kW Solar System Needed

$$\text{kW solar panels needed} = 5887 / (7.5 \times 30) = 26.17 \text{ kW}$$

$$26.17 \times 1000 = 26,170 \text{ W}$$

$$\text{No. of panels required} = \text{kilowatt solar requirement} / \text{wattage of one solar panel}$$

$$= 26,170 / 380 = \mathbf{68 \text{ panels}}$$

Most Efficient Solar Panels [35]	Efficiency Rating	Power
Panasonic EverVolt	21.7%	380 W

Cost = ₹ 9,500/ Piece

Cost for 68 panels = ₹ 6,46,000

Panel size – 1 x 2m

20% subsidy from the authorities

Over-all cost = ₹ 5,16,800

12.11 ENERGY PERFORMANCE THROUGH SIMULATION

Parameter	Base case	Proposed case
Wall	Brick – U-value - 3.637 W/m ² .k	Ceramic paint + container wall + cork insulation + gypsum dry wall – U-value - 0.34 W/m ² .k
Floor	Concrete – U-value - 1.13W/m ² .k	Reclaimed wood – U-value - 0.252 W/m ² .k
Roof	RCC– U-value - 2.553 W/m ² .k	Ceramic paint + container wall + cork insulation + gypsum dry wall – U-value - 0.293 W/m ² .k
Glass	3mm Single pane clear – U-value - 4.8 W/m ² .k, SHGC - 0.7	3mm double pane low-E– U-value - 0.29 W/m ² .k, SHGC - 0.39
Light	PHILIPS B22 GLS Incandescent Bulb (60 W)	Orient Eternal Shine LED Bulb 9W 5 Star Cool White B22

Energy usage

Site and Source Energy

	Total Energy [kWh]	Energy Per Total Building Area [kWh/m ²]
Total Site Energy	9845.12	55.70
Net Site Energy	9845.12	55.70
Total Source Energy	31179.48	176.40
Net Source Energy	31179.48	176.40

Site and Source Energy

	Total Energy [kWh]	Energy Per Total Building Area [kWh/m ²]
Total Site Energy	3196.16	17.66
Net Site Energy	3196.16	17.66
Total Source Energy	10122.24	55.91
Net Source Energy	10122.24	55.91

9845.12 kWh

3196.16 kWh

Electricity intensity

EAp2-6. Energy Use Summary

	Process Subtotal [kWh]	Total Energy Use [kWh]
Electricity	1135.48	9845.12
Natural Gas	0.00	0.00
Additional	0.00	0.00
Total	1135.48	9845.12

Utility Use Per Total Floor Area

	Electricity Intensity [kWh/m ²]
Lighting	49.28
HVAC	0.00
Other	6.42
Total	55.70

EAp2-6. Energy Use Summary

	Process Subtotal [kWh]	Total Energy Use [kWh]
Electricity	1162.94	3196.16
Natural Gas	0.00	0.00
Additional	0.00	0.00
Total	1162.94	3196.16

Utility Use Per Total Floor Area

	Electricity Intensity [kWh/m ²]
Lighting	11.23
HVAC	0.00
Other	6.42
Total	17.66

55 kWh/m²

17.66 kWh/m²

Table 12.12 Energy performance through design builder

CHAPTER 13 CONCLUSION AND GUIDELINES

13.1 INFERENCE

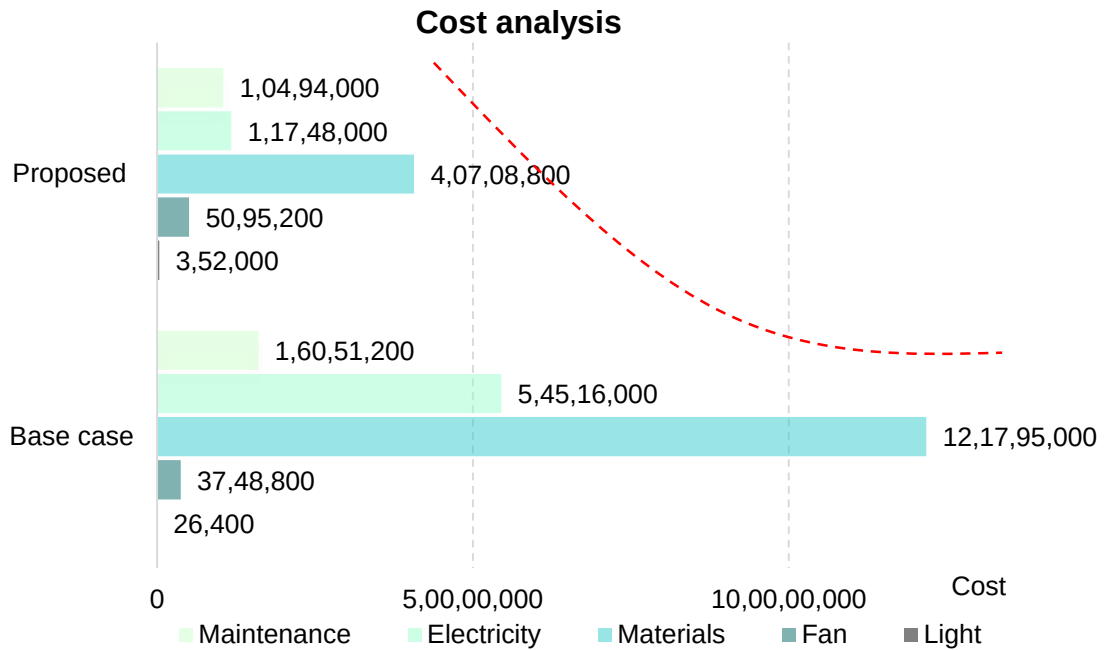


Fig 13.1 Cost Analysis

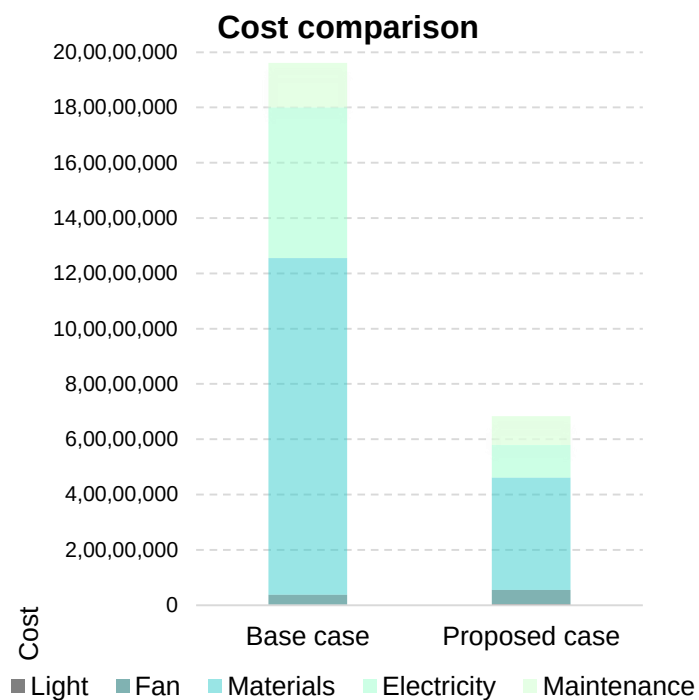


Fig 13.2 Cost comparison

- Initial Fixture cost of **proposed case is 30.69% higher than base case.**
- But maintenance and material cost of **proposed case is 68.48% more efficient than the base case.**

13.2 GUIDELINES FOR CONTAINER BUILDINGS

1. Inspect the Shipping Container before Buying It

- Consider getting high-cube containers, which are a foot taller than standard containers and will aid to insulate the container building.

2. Picking the Right Insulation Choice

- Consider insulating panels, which consume less the same amount of inside space.

3. Understand the Container's Structure

- The two long walls are both load-bearing and bracing, so if we cut a hole in one, it must be compensated.

4. Plan for Simplicity

- Planning and construction techniques should be simple

5. Cut as Little as Possible

- Try to keep to a design that necessitates the minimum amount of cuts.

6. Finalize a Design and Stick to it

- Each cut has a cost, but when we take away a piece of a shipping container, it includes a significant cost and time to rebuild it, so avoid swinging back on a choice.

7. Choose Low-Maintenance

- Choose materials that are low-maintenance and easy to clean.

8. Minimize the Welding Required

- Welding is costly in both money and time, therefore design the construction to minimize the amount of welding needed.

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